Bristol City Council
South Gloucestershire Council
Lower Severn Drainage Board

Strategic Flood Risk Assessment Avonmouth / Severnside

TECHNICAL REPORT FINAL

February 2011

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Figures

List of digital data CDs

CS002563_DD_01 – Site Visits GIS Data
CS043163_DVD_01 –Project Digital Data

About this document

This document contains the detailed technical information that describes a Level 2 Strategic Flood Risk Assessment of the Avonmouth / Severnside area. This document was originally produced during Phase 3 of the study (prepared from the two detailed technical reports, Phase 1 and Phase 2, prepared for the initial study) and has been updated during Phase 4.

The Strategic Flood Risk Assessment is prepared to support decision making on land use planning and development control. It is therefore necessary that it be up dated from time to time so that it can be used to provide competent, strategic evidence on flood risk at the time that decisions need to be made.

As new information and concepts become available, the technical sections within this document will be updated as necessary so that decisions are made using the "best available" data.

Following each technical section is a "Revision Status and Schedule of Changes" summary. This provides guidance on segments of the technical section that have either been updated for the current release, or are no longer compliant to current government policy or guidelines (and should be addressed in future releases). The schedule of changes audit trail presents a comprehensive list of amendments to the SFRA to date.

All revisions to this technical document to date are listed in Table D1.

Table D1 Document register

Version	Issue Date	Issued by	Issued to	Amendments from previous version
Draftv1	04/05/2007	Capita Symonds Ltd	Management Group	N/A
Draft Final v2	30/11/2010	Capita Symonds Ltd	BCC, SGC, LSDB, EA	Updates to hydraulic modelling (chapters 3 & 5); update to defence assessment (chapter 4); inclusion of strategic flood mitigation measures assessment (chapter 8); update to strategic assessment (chapter 7); removal of Flood Risk Matrix to Summary Report.
Final v4	February 2011	Capita Symonds Ltd	BCC, SGC, LSDB, EA	Minor amendments to address comments from steering group

Glossary and notation

Actual risk	The risk that has been estimated based on a qualitative assessment of the performance capability of the existing flood defences.
ABPmer	Associated British Ports Marine Environmental Research.
AEP	Annual probability of exceedance. The annual chance of experiencing a flood with the corresponding flood magnitude, i.e. a 1% AEP flood is a flood with a flow magnitude that has a 1% chance of occurring in each and every year.
AONB	Areas of Outstanding Natural Beauty.
BAP	Biodiversity Action Plan.
BCC	Bristol City Council.
BPC	Bristol Port Company.
Breach or failure hazard	Hazards attributed to flooding caused by a breach or failure of flood defences or other infrastructure which is acting as a flood defence.
BTP	Bettridge Turner and Partners.
CFMP	Catchment Flood Management Plan.
ChaMP	Coastal Habitat Management Plan.
Climate Change	The global climate is changing and likely impacts include sea level rise and the potential increase in intensity, severity and frequency of coastal storms, and rainfall events affecting flooding in fluvial catchments and urban surface water systems. Current DEFRA guidance are outlined in Table B.1 of PPS 25.
COMAH	Control of Major Hazards.`
cSACs	Special Areas of Conservation.
DCLG	Department for Communities and Local Government.
DEM	Digital Elevation Model.
DTLR	Department of Transport, Local Government and the Regions.
DTM	Digital Terrain Models.
EA	Environment Agency.
ESAs	Environmentally Sensitive Areas.
FEH	Flood Estimation Handbook.
Flood defence	Natural or man-made infrastructure used to prevent flooding.

Flood risk	*Flood risk is a combination of two components: the chance (or probability) of a particular flood event and the impact (or consequence) that the event would cause if it occurred* (EA 2003).
FRA	Flood risk assessment.
FRM	Flood Risk Matrix.
Flood risk management	*Flood risk management can reduce the probability of occurrence through the management of land, river systems and flood defences, and reduce the impact through influencing development in flood risk areas, flood warning and emergency response* (EA 2003).
Flood Zones	This refers to the Flood Zones in accordance with Table D1 of PPS 25.
IPC	Integrated Pollution Control.
JBA	Jeremy Benn Associates.
JPA	Joint Probability Analysis of extreme water levels and wave heights.
LBAPS	Local Biodiversity Action Plans.
LDD	Local development documents.
LDF	Local development framework.
LEAP	Local Environment Agency Plan.
LNRs	Local Nature Reserves.
LSDB	Lower Severn Drainage Board.
M	metres (measure of distance)
m/s	metres per second (measure of velocity)
MHWS	Mean High Water Spring Tide Level.
MIPs	Major Incident Plans.
MLWS	Mean Low Water Spring Tide Level.
NFCDD	National Flood and Coastal Defence Database.
NGR	National grid reference.
NNR	National Nature Reserve.
ODPM	Office of the Deputy Prime Minister (ODPM). Former government body responsible for PPG25 and PPS25. DCLG is now the responsible Government body.
OS	Ordnance survey.
PPG	Planning Policy Guidance.
PPG25	Policy Planning Guidance Note 25: Development and Flood Risk – Previous Guidance explaining how flood risk should be considered at all stages of the planning and development process in order to reduce future damage to property and loss of life.
PPS25	Planning Policy Statement Note 25: Development and Flood Risk. Current Government

	Guidance on Flood Risk.
pSAC	Possible Special Area of Conservation.
Precautionary principle	*''Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost effective measures to prevent environmental degradation*''. The precautionary principle was stated in the Rio Declaration in 1992. Its application in dealing with the hazard of flooding acknowledges the uncertainty inherent in flood estimation.
PUA	Principal Urban Areas.
QMED	Median Annual Flow Rate.
RBMP	River Basin Management Plan.
Residual risk	Flood risks resulting from an event more severe than for which particular flood defences have been designed to provide protection.
RFRA	Regional Flood Risk Assessment.
RPG 10	Regional Planning Guidelines 10.
RQOs	River Quality Objectives.
RSS	Regional Spatial Strategy.
SAC	Special Area of Conservation.
SAM	Scheduled Ancient Monuments.
SAR	Synthetic Aperture Radar.
Sequential risk-based approach	Priority in allocating or permitting sites for development, in descending order to the flood zones set out in Table D1 of PPS25, including the sub divisions in Zone 3. Those responsible for land development plans or deciding applications for development would be expected to demonstrate that there are no reasonable options available in a lower-risk category subject to satisfying other sustainability objectives.
SEFRMS	Severn Estuary Flood Risk Management Strategy
SFRA	Strategic Flood Risk Assessment
SFRM	Strategic Flood Risk Management. Current Environment Agency framework for commissioning flood mapping products (2003 - 2012).
SGC	South Gloucestershire Council.
SLAs	Special Landscape Areas.
SMP	Shoreline Management Plan.
SMs	Scheduled Monuments.
SNCIs	Sites of Nature Conservation Interest.
SPAs	Special Protection Areas.
SREP	Strategic Risk Evaluation Procedure.
SSSI	Site of Special Scientific Interest.

SuDS	Sustainable Drainage Systems.
SWRDA	South West Regional Development Agency.
S105	National Section 105 Framework Agreement (NATCON 257) (1998 to 2003). Previous Environment Agency framework for commissioning flood mapping products under Section 105 of the Water Resources Act (1991).
TSS	Tidal Severn Flood Risk Management Strategy.
TUFLOW	A two-dimensional fully hydrodynamic modelling package developed by WBM Oceanics Australia. The TUFLOW model differs from the ISIS model in that it models the whole floodplain as 2D domains, providing a more complete description of flood behaviour where complex overland flows and backwater filling occur.
1D	1 Dimensional.
2D	2 Dimensional.
1 in 100 year return period flood event	A flood with an average return period of 100 years. This term is not used in the SFRA as it can be misleading, in that it is possible that this size flood will not occur once in a 100 year period and likewise it is possible that it will occur more than once. It is a flood with a 1 in a hundred chance (or 1% chance) of happening in each and every year. Thus if no floods are experienced for a number of years the chance of experiencing a big flood will increase. The flood is also known as 1 per cent annual probability of exceedence (1% AEP) flood.

Section 1. Introduction

1.1. Background

1.1.1.1 Capita Symonds Ltd are commissioned by Bristol City Council (BCC), the Lower Severn Drainage Board (LSDB) and South Gloucestershire Council (SGC) to undertake a "strategic level" Flood Risk Assessment (SFRA) of the Avonmouth / Severnside area. The main purpose of which is to provide a local assessment of the flood risk in the study area, (see Figure 1.1 Study Area). This assessment is intended to assist the strategic and local planning authorities to make informed decisions through the development planning and development control processes relating to land in Avonmouth / Severnside. This SFRA must be defendable under examination at inquiry.

1.1.1.2 Avonmouth / Severnside is a low lying area adjacent to the Severn Estuary, extending northwards from the mouth of the River Avon, and includes both the Port of Bristol, Avonmouth Village, the existing industrial area immediately to the north of the village, and an extensive area of undeveloped land to the east of Severn Beach.

1.1.1.3 The SFRA so far been carried out in four phases. This document contains technical information that describes the SFRA. The SFRA was last updated in 2010 (Phase 4), which included:

- A review of the hydrological assessment (Section 3) and derivation of flows for additional flood events;
- A review and update to the defence assessment (Section 4) in accordance with latest tide and defence levels, including an assessment of potential for developer contributions to improvements and other funding sources;
- An update to the hydraulic assessment & model (Section 5), incorporating new survey data, latest tide level estimates, model improvements and modelling additional scenarios;
- An update to the Strategic Assessment (Section 7), based on latest guidance and the latest model results;
- An appraisal of strategic flood mitigation options for the Avonmouth / Severnside area (Section 8); and
- A revision to the guidance contained in the Summary Report to take account of latest national guidance, specifically related to Level 2 SFRAs, and a revision to the Flood Risk Matrix (included in the Summary Report).

1.2. Scope of Work

1.2.1.1 This document will seek to provide a single source of information, which draws together a number of data sets relating to flood issues, for example, Flood Zone Maps (EA), Section 105/25(4) Maps (EA), EA Extreme Tide Analyses, Avonmouth / Severnside Asset Survey (EA).

1.2.1.2 The Key Objectives are set out in Section 3 of the Specification issued with the tender invitation (See Appendix A1.1). These objectives can briefly be summarised as to:

- Inform the preparation of Regional & Local Planning Policy;
- Assist in assessing the longer term development potential in the Study Area;
- Enable Policies to be developed to minimise and manage flood risk;
- Produce a Flood Risk Matrix/Initial Planning Response Table;
- Advise on Probability of Defending Avonmouth / Severnside against flood risk;
- Be inclusive of the relevant economic, social and environmental sustainability policies.

1.3. Overall Methodology

1.3.1.1 This document presents the detailed technical sections prepared for the SFRA. The individual sections are:

Section 2 – Data Collection

1.3.1.2 This section outlines the information and data collected during the preparation of the SFRA and subsequent revisions. The section includes summaries of key documents relevant to the preparation of the SFRA.

Section 3 – Hydrology, Drainage and Groundwater

1.3.1.3 This section focuses on assessing the water quantity inputs for the hydraulic modelling, and involved an assessment of the following three principal components:

- Severn Estuary boundary to hydraulic model;
- Surface water flows landward of the Severn Estuary tidal defences and main storm sewer outfalls within the study area;
- The influence of groundwater on flood risk in the study area.

Section 4 – Flood Defence Assessment

1.3.1.4 This section has been undertaken in two parts:

1.3.1.5 The first, an initial flood defence assessment involved determining the base case scenario for use in the hydraulic modelling and required a review of both current levels of protection and condition assessments of Flood Defences. This included the identification of potential breach locations for inclusion in the hydraulic modelling.

1.3.1.6 The second part involved a broad base flood defence review, focusing on the following:

- Reviewing physical and other data relating to existing defences;
- Assessment of the requirements to enhance the defences to defend the area to the industry accepted minimum standard of 1 in 200 year return period tidal flood event with an allowance for climate change ;
- Prepare broadly based cost estimates for defending Avonmouth / Severnside as a whole, or for parts only, against tidal flood risk;
- Undertake broadly based assessment of environmental impacts;
- Undertake broadly based assessment of funding for defence improvements and potential for Developer contributions; and
- Identification of any factors which make it impossible to provide flood defences.

Section 5 – Hydraulic Modelling

1.3.1.7 This section describes the development of a hydraulic flood model for the Avonmouth / Severnside area using TUFLOW, a 2D hydrodynamic software package. Inputs to this model include a Digital Elevation Model of the study area, flood defence details, major road and rail embankments, major watercourses and other elements deemed to influence flows within the study area. Model outputs are produced in standard GIS format providing flood outlines, flow routes, velocities, levels, depths and storage volumes. The model is used to represent several flooding mechanisms that affect the study area, including:

- Local catchment fluvial flooding from the rhine network;
- Defence overflowing from extreme tide levels in the Severn Estuary;
- Defence overflowing from wave action in the Severn Estuary;
- Breach of the tidal defence; and
- Blockage of key rhine network structures.

Section 6 – Planning, Socio-Economic and Environmental Appraisal

1.3.1.8 This section presents the review that was undertaken to establish the economic, social and environmental impacts of proposals. The economic impacts of proposed options focused on an estimation of the damage due to flooding, based on the number of properties affected, and depth and duration of flooding. The social impact will identify the area of flooding, number of people affected and their 'social vulnerability'. The environmental sustainability looked at existing environmental policies within the study area, with more detailed analysis at key locations.

Section 7 – Strategic Flood Risk Assessment

1.3.1.9 This section describes the SFRA prepared for the Avonmouth / Severnside study area, comprising the following components:

- Integration of Flood Zone data using results from hydraulic modelling;
- Preparation of mapping showing the Flood Zones in accordance with Table D1 in PPS25;
- Preparation of plans showing existing flood defences and their standard of protection;
- Preparation of mapping showing physical features that convey flood flows;
- Review of flood mechanisms for the study areas;
- Preparation of mapping showing the actual flood risk;
- Preparation of mapping showing residual flood risk.

Section 8 – Strategic Mitigation Assessment

1.3.1.10 This section provides an assessment of strategic mitigation measures that could be employed to manage flooding in the study area. Mitigation measures have been assessed for each of the strategic development zones identified for the SFRA, based on likely future development and flood mechanisms.

1.3.1.11 This assessment has been split into an intial assessment and a more detailed multi criteria assessment of the preferable options.

1.3.1.12 The strategic flood risk management options were identified using existing documentation, eg. CFMP, SMP and TSS, and technically feasible options provided in Defra's FCDPAG. An initial screening study was used to identify potentially feasible options, followed by a broad based multi-criteria assessment (technical feasibility, environmental / social factors, cost and deliverability) for each of the strategic zones. Recommendations for future studies have been included.

Section 9 – Management of the SFRA

1.3.1.13 This section provides recommendations for the future management and update of the SFRA.

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Mapping and Figures

Figure 1.1 Study Area

Section 1 Appendices

A1.1 Specification

SFRA Specification Oct 04 final1.doc

SFRA Specification July 06 Phase 3 final1.doc

ASSFS.Ph4.Specification.Feb.2010.Final.doc

Section 2. Data Collection, Site Visits and Review

2.1. Revision Status

2.1.1.1 This chapter has been updated during Phase 4 (2010) to include the most recent data collected for the SFRA. A site visit to assist in the hydraulic modelling was completed during Phase 4 however this phase did not include a site review of the defence assessment or a formal update to the literature review. The draft revision to the SMP (SMP2) was referred to for this update to the SFRA.

2.2. Data Collection

2.2.1.1 Data collection was primarily undertaken in the initial stage of the commission during November and December 2004. However, additional reference items were collected throughout the initial study and further fundamental datasets generated since were acquired in July 2006 and 2010.

2.2.1.2 Appendix A2.1 contains a descriptive list of reference documents and digital data, as well as a data collection register noting source, dates, and distribution. This Appendix also contains important documents received by the EA relating to the removal of various sections of flood defence.

2.2.1.3 Of particular interest, the following data is presented graphically:

Environment Agency National Flood and Coastal Defence Database (NFCDD) – Figure 2.1 – Environment Agency National Flood and Coastal Defence Database Information. This information is shown in tabular format in Appendix A2.1 as part of the digital submission; (Appendix A2.1.xls

NFCDD_Defences.xls

, NFCDD_Defences.xls

NFCDD_Structures.xls

)

- Digital Aerial Photography – Figure 2.2 Aerial Photography;
- Environment Agency Flood Survey 1997 – Figure 2.4 – Environment Agency 1997 Flood Survey.

2.3. Site Visits

2.3.1.1 During the course of the initial study the site was visited four times. Table 2.1 summarises the visits and specific purposes.

Table 2.1 – Site Visits

Date	Names / Organisation	Purpose
25/11/2004	Jacob Franklin, Greg Rogencamp, Sally Benham, Megan Gould, Saber Razmjooei / Capita Symonds Ltd Niall Hall / Environment Agency Nikki Broomfield / Bristol City Council	Initial site visit - study area appraisal
06/12/2004 09/12/2004	David Clinton, Stuart Whiteford / Capita Symonds Ltd Niall Hall / Environment Agency	Initial Flood Defence Assessment
07/01/2005	Jacob Franklin Capita Symonds Ltd	Inspection of Structure Openings (under and over passes)

2.3.1.2 Figure 2.3 – Site Visit 1, 25 November 2004 shows the points of interest from the first site visit.

2.4. Literature Review

2.4.1.1 A comprehensive literature review was undertaken to gain an understanding and appreciation of the various high level Environment Agency plans and strategies. The following key documents were reviewed, with summaries of the specific documents reviewed being provided in Appendix A2.2:

1) The Local Environment Agency Plan (LEAP) for Severn Vale (1999).
2) Tidal Severn Strategy (TSS), Draft Report (December 2004).
3) Severn Estuary Shoreline Management Plan (SMP) (2000).
4) Bristol Avon Catchment Flood Management Plan (CFMP) Draft Inception Report (March 2003).
5) North Wessex Local Contribution (2002).

2.4.1.2 The SFRA must ensure compatibility with these documents and cross referencing to future flood mitigation and management strategies (for example the Flood Defence Review outlined in Section 4). It should be noted that the Shoreline Management Plan is currently being revised, and that the Severn Estuary Flood Risk Management Strategy (SEFRMS) will in time replace the Tidal Severn Strategy.

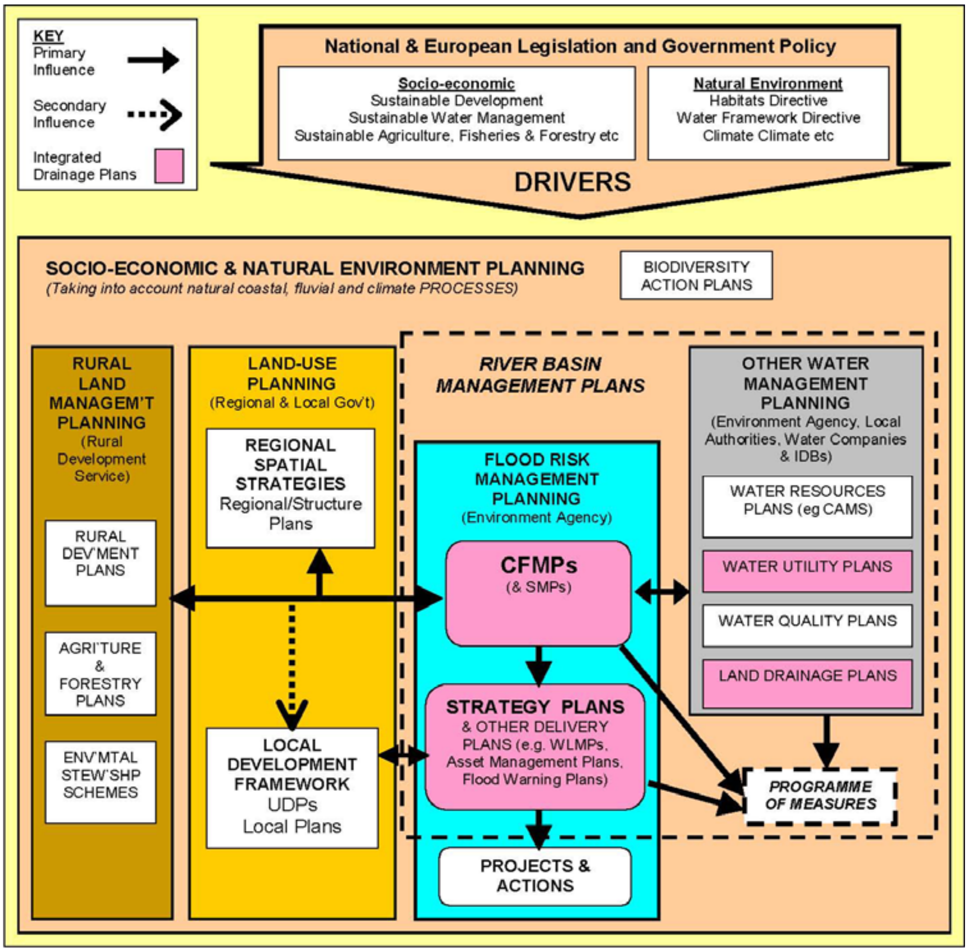
2.4.1.3 Other relevant documents reviewed as part of this study include the Avon Biodiversity Action Plan (http://www.avon-biodiversity.org.uk/), 'Reasons for notification' for the ecological various designations', the 1994 Habitat Regulations, the Wildlife & Countryside Act 1981 (as amended), the CROW Act 2000.

2.4.1.4 The key issues with respect to data reviewed are:

- This study has made use of the best data available. It should be recognised that subsequent studies and more detailed assessments undertaken in the future may modify the SFRA outputs and conclusions;
- The most relevant document reviewed and of particular significance for the Flood Defence Review outlined in Section 4 is the TSS. This document identified flood defence options for four (4) Management Units (MU's) covering the extents of the SFRA study area, which are summarised in Table A2.3, and shown graphically in Figure 2.5 – TSS Management Units;
- The CFMPs, LEAP, and North Wessex Local Contributions documents provided very little information relating to detailed flood risk, social-economic and environmental constraints in the Avonmouth Severnside SFRA study area.

2.4.1.5 The context for the SFRA in relation to planning and Flood Risk Management is shown below (adopted from Figure 1 of EA CFMP Guidelines Volume 1).

Links between Flood Risk Management Plans and the wider planning framework



Mapping and Figures

Section 2 Appendices

A2.1 Data Collection

A2.1.1 List of Data Collection

Initial Study Data Collection

- All required digital OS Mapping has been obtained through the Environment Agency, which includes 50k and 10k raster, Landline 2500, and MasterMap.
- Digital Elevation Model (DEM) data has been obtained from the Environment Agency, which includes LiDAR and SAR.
- 1976 Digitised Photogrammetry Contours has been obtained from the Environment Agency.
- Digital Aerial Photography has been obtained from the Environment Agency.
- Six Redrow Homes documents submitted to SGC have been received.
- Three BTP Drainage Modelling Reports received from LSDB, as well as interim modelling files.
    - Bettridge Turner and Partners (2003). Redrow Homes (SW) Ltd Severnside Development. Land east of M49 Drainage Feasibility Report.
    - Bettridge Turner and Partners (2003). Cabot Park – Avonmouth, Flood Risk Assessment
    - Bettridge Turner and Partners (2003). Cabot Park – Avonmouth, Merebank Drainage Study and Flood Risk Assessment
- Bristol Avon CFMP Draft 2003 Inception Report received from the Environment Agency
- Avonmouth COMAH Sites FRA received from the Environment Agency.
- EA South West Extreme Tidal Levels Report, February 2003, received from the Environment Agency.
- EA South West North Coast Tidal Mapping Inception Report, October 2003, received from the Environment Agency.
- Various additional information regarding Avonmouth / Severnside received from the Environment Agency.
- Walker Ladd 1997 Avonmouth Topographic Survey received from BCC.
- Draft Tidal Severn Strategy 2004 received from the Environment Agency.
- JBA Tidal Severn Model Report 2001 received from the Environment Agency.
- JBA Tidal Severn Model Addendum Report 2003 received from the Environment Agency.

- Regional Planning Documents received from Joint Strategic Planning and Transport Unit.
- Drainage information relating to the Bristol Port Company.
- EA Midlands NFCDD Information (which includes general South West Information at the southern extremity of the Study Area).
- Severn Shoreline Management Plan (SMP).
- 2000 Flood Photos – Jamie Clayton (Capita Symonds) relating to work done as part of EA Historic Flood Photos commission.
- Severn Tidal Strategy ISIS Models (Babties / JBA):

  1) 100 year Fluvial + 2 year tide

  2) 100 year Fluvial + 2 year tide (climate change)

  3) 5 year Fluvial + 200 year tide

  4) 5 year Fluvial + 200 year tide (climate change)
- EA North Wessex Local Contributions Document 2002.
- Severn Vale Local Environment Agency Plan (LEAP) 1999.
- EA Southern Region Sussex Tidal Mapping.
- Tidal Severn Flood Management Strategy Consultation Draft 2004.
- Esso Flood Defences Assessment, Avonmouth.
- EA Midlands (paper) and South West (GIS Digital) Flood Survey 1997.
- EA South West and Midlands hydrometric data.
- EA South West GIS IFM and Flood Zones.
- EA Report on the February 1995 flood event.
- Environmental Designations GIS layers.
- BTP Drainage Modelling.
- Boston Borough Council Strategic Flood Risk Assessment.
- Bristol Local Plan Written Statement Adopted 1997, and accompanying Proposals Map.
- Proposed Alterations to the Bristol Local Plan Proposals Map, First Deposit Draft for Consultation, February 2003. Proposed Alterations Written Statement available via Bristol City Council website at www.bristol-city.gov.uk).
- Joint Replacement Structure Plan, Adopted September 2002, Bath & North East Somerset, Bristol, North Somerset, South Gloucestershire.
- Various documents relating to Flood Zones, Surge Levels, and 1607 flood from the Environment Agency.

Data Collection Post July 2006

- ABPmer (Associated British Ports Marine Environmental Research) Avonmouth to Aust Tidal Defence Scheme: Joint Probability Analysis of Waves and Water Levels Report, October 2005, obtained from the Environment Agency.
- Infomap Surveys and Mapping Limited, Sea Defence Topographic Survey 30 August 2005, Avonmouth to Aust tidal defence scheme. Including longitudinal sections along the crest of the defence and 118 cross sections between Avonmouth and Aust, obtained from the Environment Agency.
- LSDB rhine network review.
- Marsh Common Ground Survey, 2005, obtained from the Lower Severn Drainage Board.
- LiDAR Digital Elevation Model (DEM) data flown 2006, obtained from the Environment Agency.

Data Collection Post January 2007

- Royal Haskoning Report on Extreme Tide Levels, February 2008, containing updated extreme tide level estimates for Avonmouth, obtained from the Environment Agency.
- Defence crest level survey (2009) received from the Environment Agency
- Updated LiDAR data obtained from the Environemnt Agency
- Updated NFCDD and asset condition data provided by the Environment Agency.
- Various information relating to future development in Avonmouth / Severnside obtained from BCC, SGC and the LSDB.
- National Surface Water Flood Maps & DG5 information obtained from BCC.
- Bristol Avon and Severn Tidal Tribuatries CFMP Summary Reports obtained from the Environment Agency.
- Draft Severn Estuary Shoreline Management Plan 2, obtained from BCC.
- 2000 Event Aerial Photos

A2.1.2 Digital Data Collection Register

Appendix A2.1.xls

NFCDD_Defences.xls

NFCDD_Structures.xls

EA Flood Defence Correspondence

BRI_ID_029.pdf

AvonmouthTides2.doc

(NB: Revised tide levels have since been obtained)

Flood_Zones_Engineers_brief.doc

REthemeseverntsunami.doc

2000FloodPhotos.doc

A2.2 Literature Review

A2.2.1 The Local Environment Agency Plan (LEAP) for Severn Vale (1999)

Industry and Commerce

A2.2.1.1 The majority of industry is concentrated in the Avonmouth area, ranging from pharmaceuticals to zinc smelting. Under Bristol City Council's provision, the docks and industrial complex at Avonmouth are scheduled for continued development and rehabilitation.

Infrastructure

A2.2.1.2 Five motorways cross the Severn Vale. The principal motorway is the M5, which conveys traffic between Bristol and Birmingham. Four motorway arteries radiate from the M5; the M50 joins north of Tewkesbury taking traffic west towards Wales, the M48 directs traffic across the first Severn Bridge into Wales, the M4 joins north of Bristol and the M49 takes traffic from Avonmouth to the second Severn Bridge. An extensive network of A and B class roads serve these motorways.

A2.2.1.3 Rail transport is concentrated on the lines to Bristol and Birmingham, Gloucester to Swindon via Stroud, Gloucester to South Wales either via the Severn tunnel or Chepstow, Filton to Avonmouth and Bristol to Severn Beach.

Power Generation

A2.2.1.4 Seabank operates a gas-fired power station at Hallen, near Bristol. Seabank are also proposing two further gas-fired power stations at Avonmouth to meet peak electricity demands in the southwest.

A2.2.1.5 Within the study area there are two nuclear power stations in the process of being decommissioned. These are located at Oldbury and Berkeley on the banks of the Severn estuary.

Water Resources

A2.2.1.6 There are a number of licensed groundwater abstractions within the study area for industrial process use.

A2.2.1.7 The Severn Vale Local EA Plan (1999) indicates that the sewage treatment works at Avonmouth treats a volume of sewage (dry weather flow) of greater than 50,000m^3/day. This STW treats sewage and effluent from a large area to the north of Bristol.

Flood Defence

A2.2.1.8 The vast majority of the Severn coastline within the study area has had tidal defence improvements.

Nature Conservation Designations

A2.2.1.9 The Severn Estuary is a proposed Special Protection Area. The boundary of the estuary contains Atlantic salt marshes, a variety of mudflats and has been subject to geomorphological processes.

Archaeology and Cultural Heritage

A2.2.1.10 The Severn Vale represents a unique historic and prehistoric landscape, rich in archaeological remains. Throughout history the Severn has been a principal arterial route into the heart of Britain. There are no Scheduled Ancient Monuments (SAM) within the study area.

Recreation

A2.2.1.11 Within the study area there is a boat club located at Severn Beach and a focal access point to the south of this.

Boating and Navigation

A2.2.1.12 The River Severn navigation falls under the jurisdiction of the Bristol Port. Contact - Bristol Port Company: (0117) 9820000

A2.2.1.13 Details of established boat clubs and marinas can be obtained from British Waterways: (01923) 201115

Integrated Pollution Control (IPC)

A2.2.1.14 Table A2.2 outlines the processes regulated under the IPC in the study area:

Table A2.2 – Processes regulated under IPC in the Severn Area

Site	Location	Type of Process
Albright & Wilson Ltd	Avonmouth, Bristol	Inorganic chemical processes
BG Plc	Avonmouth, Bristol	Gasification and associated processes
Blagden Packaging	Avonmouth, Bristol	Incineration
Bristol City Council	Avonmouth, Bristol	Incineration
Britannia Zinc	Avonmouth, Bristol	Non-ferrous Metals
Chemical Recoveries	Avonmouth, Bristol	Recovery Process
Rhodia Organique fine Ltd	Avonmouth, Bristol	Manufacture and use of organic chemicals
Rhodia Organique Fine Ltd	Avonmouth, Bristol	Process involving halogens

Site	Location	Type of Process
Seabank Power Bristol	Avonmouth, Bristol	Combustion Processes
Sevalco Ltd, Bristol	Avonmouth, Bristol	Carbonisation and associated processes
Zeneca Ltd	Avonmouth, Bristol	Manufacture and use of organic chemicals

A2.2.1.15 There are significant discharges of SO_2 and NOx from the industrial complex at Avonmouth.

Urban Waste Water Directive

A2.2.1.16 This directive resulted in the improvement of the sewage treatment works at Avonmouth whereby fine screening and tertiary treatment was introduced.

Watercourses

A2.2.1.17 There are no canals within the study areas and most watercourses comprise field drains and are defined by the Agency as ordinary watercourses. The River Severn borders the study area along the northwest perimeter.

A2.2.2 Environment Agency – Tidal Severn Flood Risk Management Strategy, Draft Report December 2004

Background

A2.2.2.1 The Severn area is characterised by flat, open floodplain areas with localised pockets of high ground. The predominant superficial geology is estuarine alluvium, underlain by Permo-Triassic mudstones and clays. Harder geological formations of the Devonian and Triassic periods exist at Sharpness and Aust, forming higher ground. Terrace deposits exist at Sharpness and Frampton on Severn. The east bank is characterised by clayey, silty soils which are seasonally wet. The west bank comprises similar soils, but with more loamy and calcareous series. These support agricultural and arable uses as well as the more widespread permanent grassland.

A2.2.2.2 Within the Tidal Severn Strategy (TSS) study area there are limited sources of groundwater. A sandstone aquifer exists between Northington and Sedbury on the west bank. Although some minor aquifers exist, for example, Sharpness, the major limestone aquifer of the Cotswolds lies further to the east.

A2.2.2.3 Numerous licensed surface and groundwater abstractions exist within the TSS area, for agricultural, horticultural and industrial purposes. Water is abstracted from Gloucester to Sharpness Canal at Purton by Bristol Water plc for public water supply and from the River Lyd at Lydney for industrial use. The latter has a license to discharge into the Severn just downstream of Lydney Harbour. The 1995 National Water Classification for estuaries indicates that water quality is generally good to fair. Lower quality water exists near population centres such as Avonmouth and Sharpness, where discharges from sewage treatment works and industrial premises are more frequent.

A2.2.2.4 Channel geomorphology changes significantly downstream, from a fluvially dominated narrow channel (<50m wide) to a tidally dominated estuary at Avonmouth around 8000m wide. The estuary experiences the second largest tidal range in the world – 14.5m at Avonmouth on a spring tide. Sediment movement is dynamic due to the high tidal range and the channel shape. In the upstream section erosion and transportation occur, whereas in the downstream section, around Avonmouth, erosion and deposition are broadly in equilibrium. Large meanders exist around areas or harder geology and the large tidal range and sediment dynamics have led to the formation of wide mudflats and in-channel bars.

A2.2.2.5 The climate consists of warm summers and mild winters. Average temperatures range from 2°C - 22°C with a standard average annual rainfall around 700mm. The predominant wind direction is south-westerly and can cause wave heights of up to 1.5m at Avonmouth.

A2.2.2.6 The TSS study area lies within the Severn and Avon Vales Character Area. The landscape is typical of a lowland river; the channel meanders through an expansive floodplain becoming more estuarine. Wide views exist across open farmland with isolated vale hillocks. The predominant landscapes are drained floodplain farmland and grazed salt marsh. Limited woodland exists, although some pollards and alder exist along some of the channel. Orchards, some of which have historical interest, exist in much of the upstream floodplain, particularly between Noard's Point and Rodley (west bank) and Elmore Back and Longney (east bank). Industrial premises at Avonmouth, the canal and docks at Gloucester and high ground towards the Forest of Dean dominate the longer views. Landscape Conservation Areas exist at Arlingham, Saul and Hempsted.

A2.2.2.7 Dating back to the Palaeolithic period, the estuary and surrounding floodplain attracted settlers. The Romans constructed rhines and sea walls as flood defences and land reclamation measures, providing opportunities for permanent settlement. The long history of settlement and navigation provides a diverse and rich archaeological heritage. Some of the heritage assets are protected, but English Heritage advises that the majority of sites have not yet been discovered or recorded and it is considered that the entire estuary may be archeologically sensitive.

Review of the Tidal Severn Strategy

A2.2.2.8 As a result of the winter 2000 fluvial flooding and tidal flooding caused by high tides throughout the 1990s, the Environment Agency (EA) commissioned a strategic study into flooding on the tidal reaches of the River Severn: the Tidal Severn Strategy (TSS). The area encompassed by this study extends from the weirs at Gloucester to Avonmouth (east bank), beyond which the tidal influence is less significant, to Beachley Point (west bank).

A2.2.2.9 The aim of the TSS is to provide a long-term (50 year) framework to manage flood risk and provide a short-term plan for investment into flood risk management schemes. The objectives are to:

- Identify areas at risk of flooding;
- Identify potential flood risk management options;
- Appraise options against technical, economic and environmental criteria;
- Identify preferred flood risk management options and any environmental enhancements;
- Provide an action plan for implementation and further work.

A2.2.2.10 The TSS identifies flood risk management options to implement the policies outlined in the Severn Estuary Shoreline Management Plan (SMP). It also aims to inform development decisions taken by local planning authorities. It supports the targets outlined in the Local Biodiversity Action Plan and will inform the forthcoming Coastal Habitat Management Plan (ChaMP) for the internationally designated habitats of the Severn Estuary.

A2.2.2.11 Flooding in the TSS area is caused predominantly by overtopping or breach of flood defences caused by high tides and river levels resulting from flows from the upper catchment. Flooding has historically occurred on the Severn Estuary and defences were constructed as early as Roman times; newspaper reports from the 1700s onwards document severe flood events. Severe flooding occurred in 1981 when elevated river levels coinciding with high tides resulted in inundation of large swathes of land. Less severe flooding occurred in 1990, 1995, 1999 and 2000. As the majority of the floodplain area is flat, the extent of flooding can be significant once defences are overtopped.

A2.2.2.12 In 1981 the Worcester to Avonmouth Improvements Scheme was commissioned to manage flooding and build new defences in the worst affected areas. By the mid 1990s most of the economically justifiable work, had been undertaken. Flooding has continued to occur where defences were not constructed or where a currently viewed low standard of protection is afforded. The TSS considers whether there is a case to raise, maintain, lower or remove the existing defences or whether there are other, alternative ways of managing flood risk.

A2.2.2.13 Flood defences maintained by the EA exist throughout the study area, comprising floodwalls and earth embankments. Additionally infrastructure, such as railway embankments or canal banks, provide some protection for residents and property. Other parties such as the Ports Authority, British Waterways and Network Rail maintain these as their own assets.

A2.2.2.14 The Severn Estuary and the TSS study area contain many environmentally sensitive areas. The entire Estuary downstream of Slimbridge New Grounds (east bank) is internationally designated for intertidal features such as mudflats and salt marsh. These provide habitats for bird, plant and invertebrate species, protected under UK and EU legislation. There are opportunities to enhance much of this habitat through realigning or removing existing flood defences, which prevent the natural evolution of the habitat. The quality and extent of internationally and nationally designated sites must be considered when choosing a flood management option. Adverse impacts must be avoided or mitigated. Other environmental features exist in and around the TSS study area, such as archaeology, landscape and fisheries. These have to be considered when choosing and implementing a flood management option.

A2.2.2.15 Early in the development of the TSS a range of 23 possible flood risk management options was identified, which offered some benefit in reducing flood risk to people and property, ranging from maintaining existing defences at their current level, building new defences, to removing existing defences. Using economic, technical and environmental criteria, this list was reduced to 17 options, listed below:

- Do nothing
- Do minimum: flood warning only
- Do minimum: flood warning and maintenance of defence
- Improve flood warning and forecasting
- Maintain current line of defence to existing standard of protection
- Raise defences to optimum standard based on current guidance
- Construct new line of defence
- Managed retreat – to high ground
- Managed retreat – with new defences
- Breach existing defence to create flood flow route

- Construct formal flood flow route
- Raise highway level
- Improve outfall by replacing flap gate
- Reduce ground levels to improve conveyance
- Reinstate abandoned flood defences
- Development control
- Flood proofing of property and improved awareness of flood risk

A2.2.2.16 The TSS was then divided into management units, with broadly similar physical characteristics in terms of topography, drainage and channel processes. These were based on the SMP's management units. There are 39 units in total, split between the east and west bank. For each unit the 17 options were appraised with regard to the aforementioned criteria. For the purpose of this review a synoptic overview of 4 of these appraisals has been undertaken for the study area at Severnside.

A2.2.2.17 For each management unit the options were considered for their practicality and possible benefit to flood management, using the following criteria:

- Is the option likely to reduce flood risk in situ and/or upstream
- Are there properties needing protection – and how many?
- What are the physical constraints for example, space, topography, infrastructure?
- What are the broad environmental impacts of such an option based on the strategic baseline review?
- Are there likely to be sufficient benefits compared with the potential costs to justify a scheme?

A2.2.2.18 When combined, these assessments led to the identification of one preferred flood risk management option for each management unit, ranging from 'do minimum – provide flood warning only' to 'construct a new defence'. The full list of preferred options for the 4 areas assessed in this review are contained in Table A2.3. These were ranked according to the DEFRA priority score, which is based on economic, people and environmental issues, and is used by DEFRA to justify its allocation of funding across the country.

A2.2.2.19 The TSS identifies a programme for further work, in the short term (<5 years) and medium to long term (>10 years). This 'Strategic Action Plan' helps the EA make decisions about where and when to focus its resources to implement new flood defence projects.

Table A2.3 – TSS Preferred Options for Flood Defence

MU Ref	MU Name	Settlement	Preferred Option	Rank
7/B East	Old Passage to New Passage	Northwick	Maintain current line of defence to existing standard of protection	4
15/A East	New Passage to New Pill	Severn Beach	Raise defence to optimum standard based in current guidance	1[#]
15/B East	New Pill to Mitchell's Salt Rhine	Severnside Works	Maintain current line of defence to existing standard of protection	
15/C East	Mitchell's Salt Rhine to Customs House	Avonmouth	Construct new line of defence	

7B East: Old Passage To New Passage

A2.2.2.20 The line of defence commences south of Old Passage and extends beyond the B4055 to Cake Pill outfall and beyond to New Passage and Chestle Pill outfall. These were constructed in the last 10 years to protect the village of Northwich and surrounding agricultural land from 100 year floods and are set back to avoid damage to a large tract of salt marsh (part of the Ramsar SPA) which extends along Northwick Warth. The defences were built low, but still protect to this standard due to the wide foreshore and are considered to be in a fair condition. As they are set behind the B4055, the road is still subject to tidal flooding. Various assets such as the A4033 main road, pig farm and Northwick waste-processing site would be at risk if these defences did not exist.

A2.2.2.21 The **SMP** identified the preferred policy of:

- Hold the line (short term)
- Hold or retreat the line (long term)

A2.2.2.22 **Technical Appraisal** identified that any of these options could be applied within this management unit

[#] These management units are lumped together as they act as one flood cell

- Do nothing
- Do minimum – provide flood warning only
- Do minimum – maintain existing defence to current levels and provide flood warning
- Improve flood warning and forecasting
- Maintain current line of defence to existing standard of protection

A2.2.2.23 **Environmental Appraisal** identified that the most favoured option would be:

- Do minimum – maintain existing defence to current level and provide flood warning.

A2.2.2.24 **Economic Appraisal** identified that damages associated with the 'do nothing' option were medium to high. It identified that there was sufficient benefit to maintain the current defence.

A2.2.2.25 **Preferred Option**

- **Maintain current line of defence to existing standard of protection**

A2.2.2.26 This was preferred because:

- An economic case exists for this option as the benefit/cost ratio exceeds unity
- Flooding of this management unit may increase flood risk downstream
- Maintaining the existing defence to the current level would provide ongoing protection to assets and structures within the floodplain

A2.2.2.27 **Uncertainties, Issues and Opportunities** The Severn Estuary ChaMP should be completed to confirm the need for compensatory habitat to be provided elsewhere to offset losses from coastal squeeze and maintenance of this defence.

15A East: New Passage To New Pill

A2.2.2.28 The line of defence continues under the M4 to Severn Beach, and is known as the "Bin Wall". This was constructed in the 1990s and comprises a sheet piled toe with a sloping wall and wave return at the crest. Block stone has been placed at the front of the wall. The wall design has reduced overtopping. Before defence construction approximately 40 properties were at risk. The Binn Wall is considered to be in good condition. The village of Severn Beach is located immediately to the south of Binn Wall. 1500 properties are potentially at risk. Defences were designed to a 100-year standard, and are at risk of overtopping during high tides. Severn Beach is located below the estuary bank level and in the event of overtopping, floodwater could take time to evacuate. High waves can occur around this area due to the long fetch of the Bristol Channel. Defences downstream of the Binn Wall are in a poor condition.

A2.2.2.29 The **SMP** identified the preferred policy of:

- Hold the line (short and long term) with local Retreat the Line

A2.2.2.30 **Technical Appraisal** identified that any of these options could be applied within this management unit

- Do nothing
- Do minimum – provide flood warning only
- Do minimum – maintain existing defence to current level and provide flood warning
- Improve flood warning and forecasting
- Maintain current line of defence to existing standard of protection
- Raise defences to optimum standard based on current guidance

A2.2.2.31 **Environmental Appraisal** identified that the most favoured option would be:

- Raise defences to optimum standard based on current guidance

A2.2.2.32 **Economic Appraisal** identified that damages associated with the 'do nothing' option were high. It was noted that there was significant economic benefit in undertaking a scheme.

A2.2.2.33 **Preferred Option**

- **Raise the defences to optimum standard based on current guidance**

A2.2.2.34 This was preferred because:

- There was a robust economic case
- Flood risk would be reduced at residential, industrial and commercial properties at Severn Beach and Pilning

A2.2.2.35 **Uncertainties, Issues and Opportunities** Modelled water levels suggest the existing defence provides a standard of protection greater than 100-year, assuming no breach occurred. Further modelling should be undertaken to confirm the current standard of protection using combined probability analysis. If the standard of protection is shown to be at optimum levels, the preferred option would be 'maintain to current SoP'. It was recommended that modelling be undertaken as part of an assessment of the flood cell from New Passage to Avonmouth (15A East to 15C East). Ultimately, there should be a consistent standard of protection provided for the whole flood cell to avoid breach. The Severn Estuary ChaMP should be completed to confirm the need for compensatory habitat to be provided elsewhere to offset losses caused by coastal squeeze and raising this defence.

15B East: New Pill To Mitchell's Salt Rhine

A2.2.2.36 The floodplain is developed with industrial works, including fuel depots, Seabank power station, gas works, warehouses and car depots. The wide intertidal zone of Chittening Warth comprises salt marsh and mudflats. At New Pill the railway line forms the defence, but may be breached during high tides and waves. A short line of EA owned defence exists between here and Mitchell's Salt Rhine, providing a 100-200 year indicative standard of protection. About 70 properties are at risk in the Severnside area; many of which are non-residential.

A2.2.2.37 The **SMP** identified the preferred policy of:

- Hold the line (short term)
- Hold or Retreat the Line (long term)

A2.2.2.38 **Technical Appraisal** identified that any of these options could be applied within this management unit.

- Do nothing
- Do minimum – provide flood warning only
- Do minimum – maintain existing defence to current level and provide flood warning
- Improve flood warning and forecasting
- Maintain current line of defence to existing standard of protection
- Raise defences to optimum standard based on current guidance

A2.2.2.39 **Environmental Appraisal** identified that the most favoured option would be:

- Do minimum – maintain existing defence to current defence level and provide flood warning

A2.2.2.40 **Economic Appraisal** identified that damages associated with the 'do nothing' option were high. There was economic benefit in undertaking a scheme.

A2.2.2.41 **Preferred Option**

- **Maintain current line of defence to existing standard of protection**

A2.2.2.42 This was preferred because:

- There was a robust economic case to maintain the existing defence
- Maintaining the standard of protection would continue to manage flood risk to industrial assets such as Seabank Power Station and Chittening Warth Industrial Estate
- Potential contamination of the Natura 2000 site by flooding of industrial premises would be avoided

A2.2.2.43 **Uncertainties, Issues and Opportunities** Given the robust economic case for this management unit, it is recommended that further study be undertaken of the flood cell from New Passage to Avonmouth (15A East to 15C East). There should be a consistent standard of protection provided for the whole flood cell to avoid breach. The Severn Estuary ChaMP should be completed to confirm the need for compensatory habitat to be provided elsewhere to offset losses caused by coastal squeeze and raising this defence. It was assumed that the railway line, which acts as the main line of defence in this management unit, would be maintained to avoid a breach.

15C East Mitchell's Salt Rhine To Customs House (Avonmouth)

A2.2.2.44 Downstream of Mitchell's Pill Salt Rhine, defences are privately owned and maintained by various landowners, for example, Bristol Port Authority. Defences comprise steep sided embankments with informal rip-rap placed at the toe to dissipate wave energy and reduce the likelihood of overtopping. Fuel depot tanks, located immediately behind the defence, are at risk of flooding if the defences were to breach or overtop. Downstream of Holes Mouth Pill the banks provide protection to the industrial premises immediately behind. Further downstream informal defences (walls with blocks on top) have been constructed. These are at high risk of breach / failure. A breach to any of the defences could result in flooding of the low-lying land around Avonmouth and Severnside works, where numerous industrial premises exist.

A2.2.2.45 Downstream to Avonmouth Docks the ground is higher (made ground) and provides protection from flooding. The Docks present a potential breach point as the entrance lock gates are lower than both the surrounding banks and/or between the lock and the River Avon embankment. This embankment extends along the mouth of the River Avon to the lock entrance, but does not tie into high ground or the lock itself. There are around 1700 properties, mostly industrial, potentially at risk of flooding.

A2.2.2.46 The **SMP** identified the preferred policy of:

- Hold the Line (short term)
- Hold or Retreat the Line (long term)

A2.2.2.47 **Technical Appraisal** identified that any of these options could be applied within this management unit.

- Do nothing
- Do minimum – provide flood warning only
- Improve flood warning and forecasting
- Construct new line of defence

A2.2.2.48 **Environmental Appraisal** identified that the most favoured option would be to:

- Construct new line of defence

A2.2.2.49 **Economic Appraisal** identified that damages associated with the 'do nothing' option were very high. There was a robust economic case for undertaking a scheme.

A2.2.2.50 **Preferred Option**

- **Construct a new line of defence**

A2.2.2.51 This was preferred because:

- There was a robust economic case to construct a new line of defence
- Providing a new line of defence would reduce flood risk to industrial assets such as the Esso petrochemical depot and Avonmouth Docks
- Potential contamination of the Natura 2000 site by flooding of industrial premises would be avoided

A2.2.2.52 **Uncertainties, Issues and Opportunities** There may be economic benefit to provide a high standard of protection for this management unit. It is recommended that further study be undertaken of the flood cell from New Passage to Avonmouth (15A East to 15C East). Ultimately, there should be a consistent standard of protection provided for the whole flood cell to avoid breach. If defences were to be built, the height of the Dock gates would need to be increased to the same level and standard of protection, to avoid breach. The Severn Estuary ChaMP should be completed to confirm the need for compensatory habitat to be provided elsewhere to offset losses caused by coastal squeeze and construction of this defence.

Recommendations for Further Work

A2.2.2.53 Recommendations outlined in the TSS for further work are listed below:

- Feasibility studies for the preferred options within the capital programme
- Environmental Impact Assessments at those locations, to include local issues and environmental constraints
- Level 3 / 4 EIA where necessary for maintenance works identified in the TSS
- Undertake the Severn Estuary ChaMP
- Complete the Gloucester feasibility study
- Review contiguous flood cells around Aust and Severn Beach to confirm the economic analysis and interaction of flooding between management cells
- Incorporate flood cells into downstream sections of the tidal model using the improved topographic data
- More detailed appraisal of environmental benefits into the economic analysis (benefit: cost) for locations where there is a possible scheme

A2.2.2.54 The TSS is a live document and as such it is recommended that it be reviewed every five years to ensure that recommendations remain appropriate and are being correctly implemented.

A2.2.3 Severn Estuary Shoreline Management Plan (SMP) 2000

A2.2.3.1 The aim of the Severn Estuary Shoreline Management Plan (SMP) is to provide the basis for sustainable coastal defence policies within the Severn Estuary. It also aims to develop objectives for the future management of the shoreline. The report states "sustainable coastal defence policies need to take account of the inter-relationships between defences and development processes within the Estuary".

A2.2.3.2 The SMP provides a framework for shoreline management decisions. It identifies management objectives and preferred strategic shoreline management options for coastal defence, which will enable studies to be undertaken for the development of site-specific schemes. The SMP takes the following issues into account:

- The protection of urban areas, industry, commercial activity and agricultural land;
- The conservation of the natural environment;
- Conservation of our heritage and archaeology;
- Access, recreation and enjoyment of the estuary.

A2.2.3.3 Volume 1 of the SMP outlines Data, Issues and Objectives. Chapter 5 considers the Human and Built Environment in terms of Land Use (land use categorisation, tourism and recreation, water and shoreline recreation, fisheries, agriculture and drainage, ports and navigation, dredging/mineral extraction and waste disposal and ownership), Landscape (landscape character, landscape conservation and policy implications) and Heritage (archaeological resources, protection and policy framework). Chapter 6 refers to Land Use and Development Planning. It describes the context provided by government policies, statutory development plans and non-statutory guidance produced by Local Authorities. It also refers to planning constraints and interactions with Shoreline Management Plans.

A2.2.3.4 Volume 2 refers to Strategic Shoreline Management Options for the following three areas:

- Lavernock Point to the Wye;
- The Wye and the Avon to Haw Bridge; and
- The Avon to Brean Down.

A2.2.3.5 The three individual areas have been subdivided into twenty-two process units. The study area for this report is located within the area 'Avon to Brean Down', and Process Unit 7 'The Severn Crossings'.

A2.2.3.6 The Severn Crossings process unit encompasses both banks of the Severn Estuary. The unit has international and national statutory conservation designations and is within the Severn Estuary candidate SAC. Both shorelines contain extensive areas of low-lying land. Land use is mainly agricultural with small settlements. The report states the following with regards to the left bank (looking downstream):

"Littleton Warth to Aust Warth including Aust Cliff is located on higher ground. Aust Cliff is the location for the foundation structures of the Severn Road Bridge."

"The land between Aust Warth to New Passage is low-lying and is therefore dependent on a series of embankments and sluices for flood defence. Saltmarsh has colonised the foreshore and intertidal zone. Lower saltmarsh provides a

shallow sloping foreshore. Higher saltmarsh is backed by an embankment, which protects sheep-grazed pastureland behind. A road runs behind the marsh. Landward of the road is a secondary bund around Cake Gout Pill and sluice where accretion of saltmarsh has buried former bank protection works. The saltmarsh in this area clearly shows former surfaces of the Northwick and Rumney formations."

A2.2.3.7 Each Strategic Shoreline Management Option is assessed under Do Nothing scenario (carry out no coastal defence activity), Hold the Line scenario (maintain the defence in its current position), Advance the Line (by intervention, move the defence seawards) and Retreat the Line scenario (by intervention, move the defence landwards).

A2.2.3.8 The preferred strategic shoreline management options are summarised in Table A2.4.

Table A2.4 – Management Units for the Study Area

Unit	Location	Description	Existing	Shorter term	Longer term
MU 7/4	Aust Cliff to Old Passage	This unit comprises the Jurassic cliffs of Aust Cliff upon which the western approach to the Severn Road Bridge has been built. The unit includes a saltmarsh and rock outcrop foreshore and intertidal zone.	Do Nothing locally (preferred overall strategy), Hold the Line (preferred strategy at Severn Road Bridge	Do Nothing, Locally. Hold the Line (as previous)	Do Nothing, locally Hold the Line (as for existing)
MU 7/5	Old Passage to New Passage	This unit comprises the low-lying area of Aust Warth. The unit is bounded by offshore rock outcrops of Aust Cliff at the north and English Stones at the south of the unit. The land use is primarily agricultural.	Hold the Line (to defend the existing low-lying agricultural land including residential areas and infrastructure)	Hold the Line	Hold the Line or Retreat the Line (the foreshore has been stable or accreting. If erosional trend were to develop, then it may become appropriate to consider set back of the defences. This would maintain adequate width of the foreshore, to achieve an economically and environmentally sustainable defence).

A2.2.4 Bristol Avon Catchment Flood Management Plan (CFMP) Draft Inception 2003

A2.2.4.1 The purpose of the Bristol Avon CFMP is to reduce flood risk within the catchment by:

- Encouraging the provision of adequate and cost-effective flood warning systems;
- Encouraging the provision of technically, environmentally and economically sound flood defence measures; and
- Discouraging inappropriate development in areas at risk from flooding.

A2.2.4.2 Following the production of the Bristol Avon CFMP, a number of Strategy Plans will be developed to look in more detail at flood risk management for smaller parts of the catchment. These will provide solutions to specific flood risk problems.

A2.2.4.3 Chapter 3 of the CFMP gives an overview of the Bristol Avon Catchment, which includes the whole of Bristol Avon, to its confluence with the Severn Estuary. It covers an area of 2,221km² and encompasses the major cities of Bristol and Bath. The tidal range at Avonmouth is the second largest in the world. Major tributaries to the main river include the River Marden, Semington Brook, River Biss, Somerset Frome, Midford Brook, By Brook, River Chew and Bristol Frome.

A2.2.4.4 The River Avon is affected by tides from the Avon Gorge to Keynsham. The geology of the upper catchment is principally Oxford Clay, which is relatively impermeable and geo-morphologically stable. The low catchment consists mainly of limestones, sandstones and shales that have been extensively folded and faulted. Soil erosion, sediment runoff and channel siltation are not considered to be major issues for flood risk management. However, due to the steepness of the land and instability of the rocks, extensive areas of land-slippage have occurred in the upper part of the catchment.

A2.2.4.5 Rainfall quantities vary from 700mm to the north west of Bristol, to 900mm over the Cotswolds and 1200mm on the Mendip Hills. Peak flood flows in the area at a central location in the Bristol Avon catchment have reached 320m³/s and 270m³/s.

A2.2.4.6 In its upper reaches, the Bristol Avon drains a rural landscape with gently undulating topography. Quarrying has a significant hydrological and hydrogeological impact, as removal of rocks result in flashier, higher magnitude responses within the local rivers during extended periods of rainfall.

A2.2.4.7 Flooding in July 1968 and Autumn 2000 had a severe impact within the Tidal Avon sub-catchment. The Environment Agency provides a flood warning service for eleven of the main river watercourses and a number of associated tributaries within the area.

A2.2.4.8 Major Incident Plans (MIPs) have been prepared for the area, with additional being prepared for Malmesbury, Chippenham, Melksham, Bradford-on-Avon, Bath and Pill. The Bristol MIP covers parts of the city, namely Broadmead, Ashton Vale and Brislington Brook.

A2.2.4.9 Section 3.1.7 of the report outlines the environmental opportunities and constraints within the area. There are five candidate Special Areas of Conservation (cSACs), three Special Protection Areas (SPAs) and one Ramsar site within the Bristol Avon catchment. In addition there are over 100 Sites of Special Scientific Interest (SSSIs) within the area, none of which are riverine SSSIs. However, many of them are water-dependent. SSSIs are nationally important and those that are water-dependent or affected by flooding within the Bristol Avon catchment will have higher implications in terms of constraints and opportunities for flood risk management.

A2.2.4.10 The area contains one National Nature Reserve (NNR), Leigh Woods, an area of predominantly mixed broadleaved woodland, which may present some constraint to flood risk management. Other nature conservation designations of regional or county level importance include Local Nature Reserves (LNRs) and Sites of Nature Conservation Interest (SNCIs).

A2.2.4.11 Within the Bristol Avon catchment, the city of Bath is a designated World Heritage Site. This designation offers both a high level of potential constraint and opportunity (in terms of reducing flooding in the city) with respect to flood risk management. There are approximately 300 Scheduled Monuments (SMs) within the Bristol Avon catchment. The current legislation supports a formal system of Scheduled Monument Consent for any work affecting an SM and, therefore, they may offer some constraint to flood risk management. The implications are likely to be greater if any of the Bristol Avon SMs are dependent on the water environment (such as bridges, water mills, etc.) or within the floodplain and/or preserving organic matter.

A2.2.4.12 There are four Areas of Outstanding Natural Beauty (AONB):

- Cotswold Hills;
- Cranborne Chase and West Wiltshire Downs;
- Mendip Hills; and
- North Wessex Downs.

A2.2.4.13 There are seven Natural Areas, which include The Cotswold Hills; Severn and Avon Vales; Bristol, Avon Valleys and Ridges; Thames and Avon Vales; South Wessex Downs; Wessex Vales; and Mendip Hills.

A2.2.4.14 The Bristol Avon catchment has two Environmentally Sensitive Areas (ESAs): the Cotswold Hills and South Wessex Downs. As only small areas of the catchment are covered by these ESAs, they are likely to have no/very few implications in terms of constraints or opportunities for flood risk management.

A2.2.4.15 Other designations/features of national, regional or local importance include Special Landscape Areas (SLAs), Stewardship Schemes, Forestry/Woodland Trust and Tree Preservation Orders. These may have some implications for flood risk management particularly if they cover areas within the floodplain.

A2.2.4.16 There are four Local Biodiversity Action Plans (LBAPS) covering the Bristol Avon catchment. These are:

- Wiltshire Biodiversity Action Plan;
- Bristol Biodiversity Action Plan;
- Wild Things – A Biodiversity Action Plan for Bath and North East Somerset; and
- South Gloucestershire Local Biodiversity Action Plan.

A2.2.4.17 Under the River Ecosystem (RE) Classification System, the majority of watercourses have River Quality Objectives (RQOs) of RE1 (very good) to RE3 (fairly good), with only twenty rivers classified as RE4 (fair quality) and one classified as RE5 (poor quality). In terms of the implications of this for flood risk management, the higher quality watercourses (with lower RE values) will offer greater potential constraints, and watercourses with RE values from 2 to 5 will offer the greatest potential for opportunity.

A2.2.4.18 Under the EC Freshwater Fisheries Directive (78/659/EEC), approximately 60% of the designated river reaches in the Bristol Avon catchment are suitable for salmonids.

A2.2.4.19 As a result, all of these sites may present a high level of constraint to flood risk management within the Bristol Avon catchment. This would imply that opportunities for flood risk management are likely to be minimal due to the nature of the designated features of interest associated with these sites.

Major Flood Risk Management Issues within the Bristol Avon Catchment

A2.2.4.20 The major issues for flood risk management in the Bristol Avon catchment relate to potential flooding of the urban areas, notably Bristol and Bath but also smaller settlements such as those indicated in the description of key flood risk problem areas below (4.22).

A2.2.4.21 In addition, the potential impact of climate change on flood frequency within the area would have an impact on flood management. At this stage in the Bristol Avon CFMP process, it is estimated that a fluvial flood that currently has a 1% risk of occurrence in any given year (for instance, occurs, on average, once every 100 years) could, as a consequence of climate change, have a 2% risk of occurrence in any given year (for instance, occurs, on average, once every 50 years) at some point in the future.

Key Flood Risk Problem Areas

A2.2.4.22 The following areas are sites for preliminary hydrological analysis and flood peak sensitivity tests under current and potential future urban development scenarios. These include:

- Malmesbury;
- Lacock and Reybridge;
- Melksham;
- Bradford-on-Avon;
- Hallatrow;
- Bath;
- Swinford;
- Chew Magna;
- Keynsham;
- Winterbourne Down;
- Siston and Warmley;
- Bristol; and
- Ashton Vale (Bristol).

Changes within the Bristol Avon Catchment

A2.2.4.23 The CFMP states that three key factors could affect future flood risk within the area over the next 50 years, as follows:

- Urban development;
- Agricultural land use change; and
- Climate change.

A2.2.4.24 The CFMP suggests that urban development would be most likely to affect the hydrological response and flood generating mechanisms within the area. It states the following, with regards to urban development:

"To assist in flood risk management within the Bristol Avon catchment it is important to identify current and future development pressures that may affect the Bristol Avon catchment and try to address uncertainties in the locations of potential future urban development. The current local plans for relevant district councils were consulted to understand the urban developments likely to take place in the catchment during the next 10 to 15 years. This exercise indicated that the following existing urban areas may undergo greenfield development in the range of 1 to 3km²:

- Melksham (Bowerhill);
- Westbury Leigh/Eden Vale;
- Trowbridge;
- Radstock/Midsomer Norton;
- Keynsham, Harry Stoke, Emerson's Green and Filton.

Such development could have knock-on effects for the exacerbation of existing flood risk both locally and further downstream; or it could trigger the onset of increased flood risk (implied by increased peak flows) at locations that are not currently thought to experience major problems for example, Trowbridge. Beyond the short-term planning horizon used by the district councils, an extrapolation of urban development trends in the Bristol Avon catchment of 20-30 year and 50-year planning horizons was undertaken on the assumption that the larger existing urban areas would continue to expand to satisfy housing, amenity and employment needs. It is unlikely that the Bristol Avon catchment will undergo any large-scale 'one-off' developments, such as a new town, in the foreseeable future, although there is the possibility of a new 'regional airport' being located within the vicinity. At this time it is not known where in the catchment this would be located, but a more specific future scenario may be developed during Phase 2 of the Bristol Avon CFMP process if further details of the plan are identified.

Comparative % increases in peak flood flows (against existing catchment conditions) at key flood risk problem areas and sub-catchment outlets were investigated for the following future urban development scenarios:

- ***Scenario A***: 10 – 15 year planning horizon (2012 to 2017) – utilising information on planned urban expansion from current local authority development plans;
- ***Scenario B***: 20 – 30 year planning horizon (2022 to 2032) – extrapolating urban development trends identified for Scenario A by doubling the planned increases in urban area; and

- ***Scenario C***: 50 year planning horizon (2052) – uniform application of the FEH13 generalised urban expansion factor (linked to a UK national average model of urban growth). ”

A2.2.4.25 Each of the above scenarios assumed that the forecast urban development would occur on greenfield sites within the Bristol Avon catchment and that no runoff mitigation measures would be put in place. Of the three scenarios, Scenario A was considered to be the most robust (being based on catchment-specific development proposals), whilst Scenario C was the least certain.

A2.2.5 North Wessex Area Local Contributions 2002

A2.2.5.1 This report aims to identify the means by which North Wessex will achieve environmental improvements within its local area. It states “its vision is for a healthy rich and diverse environment in England and Wales, for present and future generations”. It outlines its priorities as follows:

- A better quality of life;
- An enhanced environment for wildlife;
- Cleaner air for everyone;
- Improved and protected inland and coastal water;
- Restored, protected land and healthier soils;
- A ‘greener’ business world;
- Wiser, sustainable use of natural resources;
- Limiting and adapting to climate change; and
- Reducing flood risk

A2.2.5.2 The report outlines a range of targets for the area. Table A2.5 outlines the targets and actions for delivery with regards to flood defence.

Table A2.5 – Targets and actions for delivery for flood defence

North Wessex Target for 2007	Actions to deliver the target	Indicator of progress
Ensure that 75% of residents in flood risk areas will take effective action	- Support the Flood Advisory Service - Deliver an effective public awareness campaign targeting major areas of risk. The 24 areas identified will receive a locally targeted information /advice leaflet by 2005. - Work with the local media to disseminate and promote an 'effective action' message - Send out appropriate literature	- Reduction in the impact of major flooding incidents - Number of 'at risk' properties within flood risk areas not increased - No loss of life attributable to flooding in areas receiving a full flood warning service
Improve the coverage of flood warning services to 77.5% of properties in flood risk areas	- Increase the number of local communities with active flood warden schemes - Increase the public take-up of the Direct Warning Service using targeted education. - Work in partnership with Local Authorities, emergency services and others to ensure flood response aspects of Major Incident Plans are comprehensive and robust - Undertake a programme of flood incident exercises and participate in any national exercise	- Customer surveys show 75% response to flood warnings
Achieve a reduction in the proportion of 'at risk' properties exposed to high risk flooding	- Develop Catchment Flood Management Plans to ensure a holistic approach to flood management - Promote the use of SUDS - Investigate and report on flood problems at 33 identified locations in Bristol Avon and 44 locations in Somerset.	-Increased numbers of farms taking up best soil management practices - Capital programme delivered

North Wessex Target for 2007	Actions to deliver the target	Indicator of progress
By 2005 ensure 50% of key flood defence systems in urban areas are in good condition or better (70% by 2008) no more than 5% (3% by 2008) are in poor condition or worse	-Continue to implement an effective risk-based maintenance programme for flood defence assets and incorporate into National Flood and Coastal Defence Database - Carry out strategy studies investigating the sustainability of existing defences at 5 locations, and investigate defences at a further 3 sites - Incorporate the impact of climate change into existing flood defences in defended areas and new schemes. Take account of managed realignment along the Severn Estuary	- Flood defence systems meet good condition targets
Prevent 100% of inappropriate development inside floodplain	- Work with developers and local authorities to seek improvements to existing and proposed development in accordance with the aims of PPG25 - Build partnerships and involve local communities in developing solutions to flooding problems - Influence local authorities and others to take up the policies and measures identified within Catchment Flood Management Plans - Ensure good flood risk policies are in Development Plans - Provide timely, clear and informative replies to planning consultations	- Reduction in the number of new properties/developments that are built in flood risk areas

Revision Status and Schedule of Changes

Section Revision Status

All technical revisions of the SFRA November 2010 release for Section 2 – Data Collection, Site Visits and Review are outlined below:

- Royal Haskoning Report on Extreme Tide Levels, February 2008, containing updated extreme tide level estimates for Avonmouth, obtained from the Environment Agency.
- Defence crest level survey (2009) received from the Environment Agency
- Updated LiDAR data obtained from the Environemnt Agency
- Updated NFCDD and asset condition data provided by the Environment Agency.
- Various information relating to future development in Avonmouth / Severnside obtained from BCC, SGC and the LSDB.
- National Surface Water Flood Maps & DG5 information obtained from BCC.
- Bristol Avon and Severn Tidal Tribuatries CFMP Summary Reports obtained from the Environment Agency.
- Draft Severn Estuary Shoreline Management Plan 2, obtained from BCC.
- The Literature Review presented in this section has **not** been updated as part of the SFRA November 2010 release. The status and findings of key documents reviewed may not reflect the most recent versions.

All technical revisions of the SFRA January 2007 release for Section 2 – Data Collection, Site Visits and Review are outlined below:

- ABPmer (Associated British Ports Marine Environmental Research) Avonmouth to Aust Tidal Defence Scheme: Joint Probability Analysis of Waves and Water Levels Report, October 2005, from the Environment Agency.
- Infomap Surveys and Mapping Limited, Sea Defence Topographic Survey 30 August 2005, Avonmouth to Aust tidal defence scheme. Including longitudinal sections along the crest of the defence and 118 cross sections between Avonmouth and Aust, from the Environment Agency.
- LSDB rhine network review.
- Marsh Common Ground Survey, 2005, from the Lower Severn Drainage Board.

- LiDAR, flown 2006, from the Environment Agency.

- The Literature Review presented in this section has **not** been updated as part of the SFRA January 2007 release. The status and findings of key documents reviewed may not reflect the most recent versions.

Schedule of Changes – Latest release only

Section 2.1 – revision status added, following sections renumbered accordingly

Section A2.1.1

Data Collection Post January 2007 included (see above).

Section 3. Hydrology, Drainage and Groundwater

3.1. Revision Status

3.1.1.1 No technical revisions were made to section 3 during the Phase 4 (November 2010) update of the SFRA. Additional hydrometric data and information relating to groundwater levels was sought, but none was available. It is recommended that additional hydrometric installtions to improve the flow estimates used in the study are considered for future updates to the SFRA.

3.2. Hydrological Assessment

3.2.1 Introduction

3.2.1.1 The Avonmouth / Severnside Strategic Flood Risk Assessment uses a hydrological assessment of the study area to ascertain peak flood flows for a range of flood events. The results are compared with the InfoWorks CS drainage model prepared by Bettridge Turner and Partners (BTP), which is referred to in Section 3.3.

3.2.1.2 The flows derived from the hydrological assessment were generally not used in the hydraulic modelling analyses (i.e. in the TUFLOW 2D/1D - ESTRY model). For purposes of consistency, the inflows from the BTP InfoWorks CS models (described in Section 5) were used in the hydraulic modelling assessments for the SFRA in the area south of the London – Cardiff railway line.

3.2.2 Catchment Boundaries and Flow Nodes

3.2.2.1 The SFRA study area is approximately bordered by the River Avon to the south, the Severn Estuary to the west and the M48 to the north. The east boundary is situated between the M5 and the M49, approximately that of the LSDB management boundary. The area is low-lying ground containing the Avonmouth port area, industrial estates and residential settlements. The site contains a network of natural waterways and man-made drainage paths. The study catchment extends slightly further to the east and north-east than the study area.

The Flood Estimation Handbook (FEH) CD-ROM[1] divides the total catchment draining to the study area into six sub-catchments based on the 1:50,000 scale mapping topography of the study catchment. The

[1] FEH CD-ROM, Version 1.0, 1999, CEH Institute of Hydrology. The FEH Hydrological assessment was completed in 2004 / 2005 prior to release of the latest FEH CD-Rom and updates to the FEH methodologies. The updates are not considered to significantly affect the outcomes of the assessment.

hydrological assessment provides flow estimates at the outfall location of these six sub-catchments. Table 3.1 describes these flow node locations and the FEH catchments are shown in Figure 3.1 – FEH Catchment

3.2.2.2 . The FEH catchments are of a macro-rural scale compared to the BTP InfoWorks CS catchments, which are predominately of a micro-urban scale.

Table 3.1 – FEH Flow Node Locations

Flow Nodes	NGR Grid Reference	Area (km^2)	Location
Cake Pill	356000 188300	15.53	Northern most outfall. Catchment includes areas such as Aust and Ingst.
Chestle Pill	354600 186300	34.58	Outfall located north of M4. Catchment includes Severn Beach, Compton Greenfield and north to Alveston.
New Pill	353500 183110	6.68	Catchment is situated north-west of Cribbs Causeway.
Mitchells Outfall	352500 181600	2.18	Local drainage catchment west of Cribbs Causeway and the M49.
Holesmouth Outfall	351900 180700	8.31	Local drainage catchment including Hallen.
Kings Weston Outfall	351500 179300	1.02	Port drainage catchment including Kings Weston.

3.2.3 Catchment Description

3.2.3.1 The FEH CD-ROM provides catchment descriptors for each of the six sub-catchments. These are provided in Table 3.2.

Table 3.2 – Catchment Descriptors

Catchment Descriptor	Cake Pill	Chestle Pill	New Pill	Mitchells Outfall	Holesmouth Outfall	Kings Weston Outfall
AREA	15.53	34.58	6.68	2.18	8.31	1.02
BFIHOST	0.616	0.569	0.658	0.734	0.615	0.734
SPRHOST	28.7	32.1	29.5	25.3	30.5	25.3
PROPWET	0.35	0.35	0.35	0.35	0.35	0.35
FARL	1.000	1.000	1.000	1.000	1.000	1.000
URBEXT 1990	0.021	0.033	0.040	0.124	0.157	0.397
SAAR	764	768	777	787	790	792
DPSBAR	25.6	36.2	24.2	3.5	42.4	22.7

3.2.3.2 The Proportion of Time Soils are Wet (PROPWET) statistic is constant throughout the catchment. This reflects the relatively small size of the total catchment area and the general undulating nature of the area.

3.2.3.3 The Flow Attenuation due to Reservoirs and Lakes (FARL) values are also identical throughout the catchment. A FARL of 1.0 implies no lakes or reservoirs in the catchment.

3.2.3.4 The Standard Average Annual Rainfall (SAAR) differs by 28mm between the northern most and southern most sub-catchments. The SAAR increases in a northerly direction (the more northerly sub-catchments have higher SAAR).

3.2.3.5 A catchment with an Urban Extent (URBEXT1990) above 0.025 is classed as 'urban' in the FEH procedure. As the descriptors show, the southern area of the study catchment is highly urbanised. The values given on the FEH CD-ROM are static as at 1990.

3.2.3.6 The Standard Percentage Runoff (SPRHOST) and The Baseflow Index (BFIHOST) are based on geology and soil types in the catchment. A catchment with an SPRHOST less than 20% is classed as 'permeable' under FEH procedures. The values shown are slightly above this limit and similar across each sub-catchment, indicating relatively constant geology of a permeable nature. Baseflow represents the normal flow in the watercourse (without accounting for flow from a flood event) and includes seepage from the bed and banks. The baseflows shown are quite high, again reflecting the permeable nature of the catchment.

3.2.3.7 The Drainage Path Slope (DPSBAR) value varies between subcatchments. The study area itself is relatively flat however, east of the study extent, the land rises. The DPSBAR figures reflect this. Mitchells Outfall value is low because the catchment is contained within the SFRA study area.

3.2.4 Hydrometric Monitoring

3.2.4.1 At the time of this study no FEH flow gauges were located within the study area.

3.2.4.2 Where a subject site is un-gauged, the FEH recommends the use of data transfer. This process involves adjusting a generalised estimate at the subject site by reference to how the generalised procedure performs at a nearby, gauged site, or a more distant gauged catchment that is thought to be hydrologically similar. A 'donor' catchment is a local catchment offering gauged data that are particularly relevant to flood estimation at the subject site. Ideally it is sited just upstream or downstream of the subject site, or more typically some distance upstream or downstream but with a similar catchment area. An 'analogue' catchment is a more distant gauged catchment that is sufficiently similar to the subject catchment to make a transfer of information worthwhile (FEH Volume I S2.3).

3.2.4.3 Due to the absence of flow gauging in the study catchment, it has been necessary to select analogue sites for use in the FEH flood procedures, based on their hydrological similarities to the study catchment. Table 3.3 shows the sites used.

Table 3.3 – Analogue Sites

Analogue Sites	Maintained by	No. of years of data	Measurement Method	Rating Description
54034 Dowles Brook @ Dowles	EA	30	Stage	Rating range 1.5m. Reliable up to QMED.
52016 Currypool Stream @ Currypool Farm	EA	28	Stage from stilling well	Theoretical and velocity area rating, reliable to 0.4m.
68015 Gowy @ Huxley	EA	26	Not in Hi-Flows	
44006 Sydling Water @ Sydling St Nicholas	EA	25	Stage from stilling well	Theoretical original rating, applicable to bankfull but probably not above.
25019 Leven @ Easby	EA	27	Stage from stilling well and floats	Theoretical rating in accordance with Hydraulics Research work

3.2.4.4 There are two local analogue sites – 53006 Frome @ Frenchay and 52015 Land Yeo @ Wraxall Bridge. The Frome site has no catchment descriptor data in the WINFAP-FEH dataset. The Land Yeo site has a much larger catchment area than the study catchments. Thus, these sites were not considered suitable for data transfer.

3.2.5 Description of the Hydrological Model

3.2.5.1 The FEH Statistical Method has been used to produce flood frequency curves for each flow node. From these, peak flood flows for return periods of 2, 5, 10, 25, 50, 100, 200, 500 and 1,000 years were extracted.

3.2.5.2 For a target return period (T) greater than 27 years (in this case T = 1,000), and a gauging station record of between 14 and T years, the FEH Statistical Method requires a dataset covering five times the return period, in this case 5000 years of data, in order to reasonably estimate future floods based on past data. This 5000 years of data is not feasible and would require the use of many analogue sites. A more reasonable and accurate method is to produce a flood frequency curve assuming a period of interest of 100 years and then to derive it for the 1,000-year event. This does however create further uncertainty in these high-end results.

3.2.5.3 As the study catchment is un-gauged, the use of analogue sites is required. Such data is sourced from other hydrometrically similar gauged sites. To achieve 500 years of data, information from a series of sites has been used. This process of combining records is known as 'pooling'.

3.2.6 QMED Derivation

3.2.6.1 The FEH Statistical Method requires an estimate of the median annual flow (QMED), at each of the six flow nodes. At un-gauged sites the standard method of QMED estimation is to use data transfer from a hydrologically similar site to scale the QMED from catchment descriptors to real data.

3.2.6.2 Using basic FEH catchment descriptors and the equation given in the FEH Volume III S3.3, initial QMED values were obtained for each of the nodes within the study catchment. These QMED values were then adjusted using data from the chosen analogue sites. The ratio between the QMED data obtained using AMAX data and the QMED obtained from catchment descriptors for the analogue sites has been calculated and applied to the QMED obtained from catchment descriptors for the flow node in question. This allowed the initial catchment descriptor estimates to be altered to take account of real data, thus reducing the error associated with the estimation of QMED from catchment descriptors alone.

3.2.6.3 The WINFAP-FEH software was used to generate the pooling groups. It prioritises analogue sites according to their hydrologic similarity to the subject site, with reference to the catchment descriptors. Examination of the catchment characteristics for the top 4 sites of each pooling group allowed the selection of 1 analogue site per study sub-catchment. This analysis of the catchment descriptors is shown in the spreadsheet (AvonmouthCALCSHEET.xls) – Digital Submission only. Note that a site may be rejected for pooling but still be suitable for QMED derivation. Table 3.4 outlines the analogue sites chosen for data transfer. Table 3.5 outlines the adjustment ratios applied.

Table 3.4 – Ratio of Adjustment for QMED

Analogue Sites	Method (AM or POT)	QMED from flow data (A) (m^3/s)	QMED from catchment descriptors (B) (m^3/s)	Adjustment ratio (A/B)
54034 Dowles Brook @ Dowles	AM	9.97	4.66	2.14
52016 Currypool Stream @ Currypool Farm	AM	2.86	3.52	0.81
68015 Gowy @ Huxley	AM	8.37	8.07	1.04
44006 Sydling Water @ Sydling St Nicholas	AM	0.85	0.82	1.03
25019 Leven @ Easby	AM	4.99	3.10	1.61

3.2.6.4 Due to the study catchments being classed as 'urban', an urban adjustment had to be made to the QMED estimates before the data transfer adjustment ratio was applied. The process is described in the FEH Volume III S9.2.

3.2.6.5 In the case of Cake Pill, a joint analysis was used whereby an average adjustment ratio was applied. Both sites were considered hydrometrically similar, yet produced very different adjustment ratios. This reduced confidence in using one site alone. The same reasoning applies at Holesmouth Outfall.

3.2.6.6 The original and final QMED values for the nodes within the study catchment, as well as information concerning the analogue sites used for each node, are included in Table 3.5.

Table 3.5 – Original and Adjusted QMED Values

Flow Node	Original $QMED_{rural}$ (m^3/s) From Catchment Descriptors	Adjusted $QMED_{urban}$ (m^3/s)	Adjusted $QMED_{urban}$ (m^3/s) Using Analogue Site	Adjust-ment ratio	Analogue Site(s)
Cake Pill	2.27	2.35	3.48	1.48	54034 Dowles Brk @ Dowles; 52016 C'pool Stm @ C'pool Farm

Flow Node	Original $QMED_{rural}$ (m^3/s) From Catchment Descriptors	Adjusted $QMED_{urban}$ (m^3/s)	Adjusted $QMED_{urban}$ (m^3/s) Using Analogue Site	Adjust-ment ratio	Analogue Site(s)
Chestle Pill	5.43	5.71	5.92	1.04	68015 Gowy @ Huxley
New Pill	0.90	0.96	0.78	0.81	52016 C'pool Stm @ C'pool Farm
Mitchells Outfall	0.24	0.30	0.31	1.03	44006 Sydling Water @ Sydling St Nicholas
Holesmouth Outfall	1.33	1.69	2.04	1.21	52016 C'pool Stm @ C'pool Farm; 25019 Leven @ Easby
Kings Weston Outfall	0.12	0.22	0.23	1.03	44006 Sydling Water @ Sydling St Nicholas

3.2.7 Pooling Group Analysis and Growth Curve Derivation

3.2.7.1 The FEH Statistical Method uses flow records from a number of similar catchments to produce a record at the subject site long enough to forecast floods at the site and return periods of interest. The flood growth curve produced by pooling is used in conjunction with an estimate of the median annual maximum flood (QMED) to produce an estimate of the flood frequency curve for the study site. This methodology is described in the FEH Volume III. The WINFAP-FEH software is used to generate the pooling groups and fit growth curves to the data.

3.2.7.2 Individual pooling groups have been created for the six representative flow nodes. Details of the sites contained in each pooling group are contained in supplementary files (Cake_Chestle_Pill.xls and Kings_Holes_Mitchells_New.xls) – Digital Submission only. The distribution adopted was the Generalised Logistic Distribution.

3.2.7.3 The initial pooling groups were classed as strongly heterogeneous with a review noted as essential. A closer inspection of the pooling groups resulted in the removal of sites as detailed in the files referred to in the previous paragraph.

These sites were designated as unfit for pooling by information gathered from the Environment Agency, the WINFAP-FEH data and the HiFlows-UK website. No sites were required to be added. Some of the resulting pooling groups were still classed as strongly heterogeneous with a review noted as essential, however, the removal or addition of extra sites was not justifiable and no further changes have been made.

3.2.7.4 A number of sites contained in the pooling group were classed as permeable. However, these sites had already been updated as per FEH procedure and so no further adjustments to the data were required.

3.2.7.5 The final pooling groups have been used to generate flood growth curves and flood frequency curves for each of the flow nodes. These flood frequency curves were used to estimate flows at each node for different return periods. The growth curves and flood frequency curves produced for each flow node are contained in the supplementary file (Growth Curves and Flood Frequency Curves) – Digital Submission only.

3.2.8 Final Statistical Method Flows

3.2.8.1 The estimated peak flows for different return period events at each flow node in the model are summarised in Table 3.6. These figures are the peak flows at the outfall locations.

Table 3.6 – Present Day FEH Statistically Derived Flows (m^3/s)

Flow Node	Return Period (Years)								
	2	5	10	25	50	100	200	500	1000
Cake Pill	3.48	5.34	6.74	8.83	10.69	12.85	15.37	19.39	23.05
Chestle Pill	5.92	9.09	11.43	14.86	17.84	21.27	25.22	31.41	36.96
New Pill	0.78	1.15	1.43	1.83	2.17	2.56	3.02	3.72	4.35
Mitchells Outfall	0.31	0.44	0.53	0.65	0.75	0.87	0.99	1.19	1.35
Holesmouth Outfall	2.04	3.10	3.90	5.08	6.12	7.32	8.72	10.93	12.94
Kings Weston Outfall	0.23	0.31	0.36	0.41	0.46	0.51	0.56	0.63	0.69

3.2.9 Limitations

3.2.9.1 A primary limitation results from the lack of hydrometric gauging stations within the study catchment. This has led to data transfer from analogue sites in the development of QMED (Median Annual Flow Rate). The analysis of QMED relies heavily upon inferred flows from the comparison of a hydrometrically similar analogue site. Whilst every effort has been made to produce realistic flows, it must be recognised that these are not produced from data specific to this catchment and are likely to contain inherent differences as a result.

3.2.9.2 The same is true regarding the use of pooling groups to derive a flood growth curve. In an ideal situation, in order to provide a reliable estimation of the 1 in 1,000 year flood event flood flows, data for the study catchment for a period of 5,000 years would be required for such an analysis. However, as no sites have records spanning greater time periods than approximately 50 years (of reliable data), pooling is the best option for such analyses. For this study, extrapolation of the flood frequency curves created for a period of interest of 100 years to produce 1 in 1,000 year return period flood estimates creates further uncertainty.

3.2.9.3 The use of stage-discharge relationships in the prediction of flows adds to overall uncertainty. Rating curves used to calculate flows from a measured level for each site in the pooling group are assumed to be accurate. The updating of a number of rating curves under recent initiatives within the Environment Agency, including HiFlows-UK, and separate studies carried out for individual sites means that this is largely true. However, there remain some sites whose ratings have not been verified with gaugings (real data) above a certain stage, or which have not been included within such reviews. While every effort has been made to remove unsuitable sites, some remain which may carry uncertainty with their ratings.

3.2.10 The Effects of Climate Change

3.2.10.1 Numerous publications over recent years, including the FEH, have addressed the issue of climate change. Evidence suggests that human activity is influencing the world’s climate. In particular, an increase in greenhouse gas emissions is leading to an accumulation in the atmosphere that is irreversibly affecting the climatic system.

3.2.10.2 Volume I, chapter 7 of the FEH discusses the likely effects of climate change over time. Numerous models exist for modelling climate change but these are variable and contradictory. Whilst observations of global sea levels are tending to support climatic models, the effects on fluvial flooding are much more speculative. Natural variability in rainfall regimes and non-uniform flooding factors across catchments further complicate any predictions. Hulme and Jenkins (1998) suggested that UK mean annual rainfall will be about 5% higher by the 2050s. It is generally accepted that winter rainfalls will increase and summer rainfalls will decrease in southern Britain. The FEH recommends that estimates of QMED derived from short records should be adjusted for climatic variation by reference to long–term records from nearby catchments that are hydrologically similar, thus continuing the theme of data transfer.

3.2.10.3 In October 2006, DEFRA released a supplementary note to operating authorities on the impacts of climate change. The note outlined indicative sensitivity ranges for fluvial peak rainfall intensities and peak river flow, as shown in Table 3.7. For small catchments and urban/local drainage sites, DEFRA indicate that the peak rainfall intensity ranges should be used. For river and stream catchments over 5km^2, the peak flow ranges should be applied.

Table 3.7 – Fluvial Climate Change Indicative Sensitivity Ranges (DEFRA, Oct 2006)

Parameter	1990 - 2025	2025 - 2055	2055 - 2085	2085 - 2115
Peak rainfall intensity	+5%	+10%	+20%	+30%
Peak river flow	+10%		+20%	

3.2.10.4 Based on the BTP InfoWorks CS catchments, which are predominately of a micro-urban scale, the fluvial peak rainfall intensity ranges have been adopted. Subsequently, a 30% increase in flows has been applied to allow for future climate change over the 100 year planning horizon. The FEH flows factored by 1.30 are shown in Table 3.8.

Table 3.8 – Flow (m^3/s) with 30% Increase for Effects of Climate Change

Flow Node	Return Period (Years)								
	2	5	10	25	50	100	200	500	1000
Cake Pill	4.52	6.94	8.76	11.48	13.90	16.71	19.98	25.21	29.97
Chestle Pill	7.70	11.82	14.86	19.32	23.19	27.65	32.79	40.83	48.05
New Pill	1.01	1.50	1.86	2.38	2.82	3.33	3.93	4.84	5.66
Mitchells Outfall	0.40	0.57	0.69	0.85	0.98	1.13	1.29	1.55	1.76
Holesmouth Outfall	2.65	4.03	5.07	6.60	7.96	9.52	11.34	14.21	16.82
Kings Weston Outfall	0.30	0.40	0.47	0.53	0.60	0.66	0.73	0.82	0.90

3.2.11 Comparison with BTP Flows Routed Through Hydraulic Model

3.2.11.1 The peak flows derived by the above process were compared with the peak flows resulting from the hydraulic model assessments (described in Section 5) using the TUFLOW 2D /1D model during the initial study, in order to provide an indication of the uncertainties within the FEH flow estimation method.

3.2.11.2 It needs to be recognised that the FEH flow estimation method is a necessarily less accurate method in this catchment due to the complex role of flood storage and drainage interaction. This drainage system is made more complex by the role of the tidal variations at the outfalls. At high tides, the outfalls become tide-locked and runoff stores in the drains and on the floodplains until lower tide levels allow outflow. Neither of these complexities is accounted for by the FEH method.

3.2.11.3 In order to highlight these differences, Table 3.9 shows a comparison between peak flows derived by the FEH process and peak flows from the TUFLOW 2D/1D hydraulic model (using a 1 in 2 year tidal surge event and mean spring tide) undertaken in the initial study.

Table 3.9 – Comparison of 1 in 1,000 year return period FEH Flows versus Hydraulically Routed Flows (m^3/s)

Flow Node	Hydraulically Routed Flows	FEH Statistical Flows
Cake Pill	1.55	23.05
Chestle Pill	3.60	36.96
New Pill	5.10	4.35
Mitchells Outfall	3.20	1.35
Holesmouth Outfall	8.40	12.94
Kings Weston Outfall	8.00	0.69

3.2.11.4 The comparison shows that there are substantial differences in the peak flows from the two approaches. For example, the Cake Pill catchment peak flows from the FEH process resulted in 23.05 m^3/s. This is compared with 1.55 m^3/s flow through the outfall structure in the hydraulic model simulation. The primary reasons for these differences are:

- No allowance for the attenuation of the flood peak due to the considerable storage volume in the rhine system in the FEH approach;
- No allowance for the effect of tidal back-up and tide-locking of the outfall in the FEH approach.

3.2.11.5 In conclusion, it is considered that the FEH approach to estimating peak flows at the outfalls has considerable deficiencies. However, the derivation of inflows for individual sub-catchments for use in a complex hydraulic model is a valid approach (assuming the delineation of the sub-areas is of a sufficiently high resolution).

3.2.11.6 The fluvial inflows for the hydraulic model described in Chapter 5 were therefore derived directly from the inflows used by BTP in the InfoWorks CS models. For further details see section 5.10 of this report.

3.2.11.7 The qualitative FEH statistical flows probably do indicate the susceptibility of the respective catchments to inundation during high depth rainfall events. Accordingly it is likely that the catchment contributing to Cake Pill and Chestle Pill will be vulnerable to fluvial flooding.

3.3. Drainage Assessment

3.3.1 Introduction

3.3.1.1 The primary source of drainage information and data used for the SFRA is from studies completed by Bettridge, Turner and Partners, namely:

1) BTP (2003). Redrow Homes (SW) Ltd Severnside Development. Land east of M49 Drainage Feasibility Report
2) BTP (2003). Cabot Park – Avonmouth, Flood Risk Assessment
3) BTP (2003). Cabot Park – Avonmouth, Merebank Drainage Study and Flood Risk Assessment

3.3.1.2 Summaries of the BTP drainage reports are given in Appendix A3.1.

3.3.1.3 This section summaries how the BTP InforWorks Drainage Model data was used for the construction of the SFRA TUFLOW 2D/1D - ESTRY model described in Section 5.

3.3.2 BTP InfoWorks Drainage Model Data Transfer for TUFLOW

3.3.2.1 As discussed in more detail in Section 5, the geometry and inflows of the InfoWorks CS models were provided to Capita Symonds Ltd in order to create the 2D/1D model using TUFLOW. Table 3.10 summaries the data provided by BTP.

Table 3.10 – BTP InfoWorks Drainage Model Data Transfer Specification

Item	Method of Transfer	Deliverables
1D Model Geometry	Export InfoWorks CS Model Geometry in MIF Format.	MIF and MID files for entire InfoWorks CS model. This comprises about 25 MIF and 25 MID files.

Item	Method of Transfer	Deliverables
1D Model Cross-Sections	Manual export of about 80 irregular shaped cross-sections for Mitchell Pill to a single csv file.	A csv file with tables of Offset .vs. Elevation .vs. Manning's n.
Runoff Hydrographs	Export of the runoff results using the 'Export Results' / 'Other Format' / CSV Format option.	All runoff hydrographs generated for the following events were provided for. 1,000y, 100y, 10y and 2y return period flood events for durations of 3.5h, 7h, 12h and 24h.
Effective Rainfall	Export from InfoWorks CS Model	All rainfall .vs. time curves for the following events were provided for. 1,000y, 100y, 10y and 2y return period flood events for durations of 3.5h, 7h, 12h and 24h.

3.3.2.2 The transferred data is contained on Project Digital Data DVD.

3.4. Groundwater Assessment

3.4.1.1 There is little data to assist in quantifying the influence of groundwater contributions to surface flooding. However, the computational analyses undertaken for the SFRA did indicate that the extent of predicted flooding from surface fluvial events was not as great as has been witnessed historically (most notably in Autumn and Winter 2000). On this basis it can be deduced that groundwater may influence the severity and frequency of flooding in the study area. When data is collected and comes available in the future, quantitative assessments of the influence of groundwater levels can be performed.

3.4.1.2 Subsequent investigations during the 2010 update of the SFRA did not identify any groundwater data or that groundwater flooding was a key factor for assessment. It is recommended that groundwater contributions to flooding are reviewed if new data becomes available which suggests it is important in the study area and allows a quantitative assessment.

Mapping and Figures

Figure 3.1 – FEH Catchment

Section 3 Appendices

A3.1 Hydrology Study

AvonmouthCALCSHEET.xls

Cake_Chestle_Pill.xls

Kings_Holes_Mitchells_New.xls

Growth Curves and Flood Frequency Curves

A3.2 Review of Bettridge Turner and Partners (BTP) Modelling Reports

A3.2.1 Bettridge Turner and Partners (2003). Redrow Homes (SW) Ltd Severnside Development. Land East of M49 Drainage Feasibility Report.

A3.2.1.1 This report notes improvements to the drainage networks in the area between the M49 motorway and the sea wall, specifically comprising widening of the rhines and the construction of storage ponds, to allow redevelopment of the industrial area. These were designed to cater for 1 in 100 year return period fluvial event. This and the raising of levels to approximately 7.0-7.2m AOD have proven to be effective in minimising flooding.

A3.2.1.2 The Lower Severn Drainage Board (LSDB) is the main land drainage regulator for the area. LSDB requires developers to submit details of proposed land drainage network improvements to demonstrate adequate protection from flooding caused by exceptional rainfall. The LSDB maintains a hydraulic model of the drainage networks, which is available for developers to demonstrate the suitability of their proposals. The developer must show that:

- Flooding would not occur in a 1 in 100 year return period rainfall event;
- Buildings are constructed with ground floor levels at least 600mm above the 1 in 100 year return period flood level;
- Any external areas for example, car parks, have positive drainage and outfall to the drainage network at a level which will not flood in the 1 in 5 year return period rainfall event.

A3.2.1.3 The BTP (2003) report notes that previous studies carried out by the LSDB in Severnside were undertaken prior to the introduction of PPG25[2] (2001) and the FEH Handbook (1999), and the changes to the rhine network. These studies (1999) concluded that an upland carrier rhine would be required to accommodate additional flows generated by the proposed development and to alleviate the risk of flooding in the upper reaches of the New Pill network. The proposed system was modelled in the Hydroworks[3] hydraulic network model, using rainfall-runoff methods as set out in the Flood Studies Report.

A3.2.1.4 Redrow Homes commissioned the update of the hydraulic model for the New Pill catchment, to account for the PPG25 requirements. The modelling software used was migrated to InfoWorks, incorporating the SCS runoff model, assuming soil

[2] Planning Policy and Guidance Note 25 – Development and flood risk. Department of Transport, Local government and the Regions (DTLR), July 2001

[3] Hydroworks hydraulic network modelling software written and supported by Wallingford Software

type C – soils with a fine texture, slow water transmission and a slow infiltration rate. Calibration of the modelling to the October 2000 event was undertaken.

A3.2.1.5 The model used two boundary conditions 1) New Pill outfall into the Severn Estuary, 2) Culvert under the Severn railway crossing, and sinusoidal tidal stage hydrographs to simulate the estuary's tidal cycle. The stage hydrograph at Chestle Pill was taken as 80% of the full tidal range assuming some damping of flows.

A3.2.1.6 Design rainfall inputs to the model were:

- 1 in 140 year (+20%) 3 hour FEH event rainfall;
- 1 in 140 year (+20%) 6 hour FEH event rainfall;
- 1 in 140 year (+20%) 12 hour FEH event rainfall;
- 1 in 140 year (+20%) 24 hour FEH event rainfall;
- 1 in 140 year (+20%) 48 hour FEH event rainfall.

A3.2.1.7 The upland carrier rhine was modelled as suggested in earlier studies (LSDB). This included the widening of the existing rhine along the B4055 and arterial rhines to a 3.0m base and the enlarging of the culvert under the B4055 to 2.0mx1.8m. Several large pond areas were provided for offline storage.

A3.2.1.8 The model results showed the following maximum water levels for the critical storm duration at the following locations:

Table A3.11 – BTP Worst Case 1 in 100 year flood water level

Description	**Node**	**5 Year Level**	**140 Year Rainfall**	**100 Year Level**
Existing Western Approach Stage 1	40073	5.86	6 hour (+20%)	6.72
Existing undeveloped land south of proposed storage area	3112	5.61	48 hour (+20%)	6.14
Proposed Western Approach Stage 2	40113	5.84	6 hour (+20%)	6.69
Proposed residential (east of M49)	7003	5.84	6 hour (+20%)	6.65
Proposed commercial (east of M49)	4117	5.78	6 hour (+20%)	6.53
Proposed football stadium (east of M49)	40191	5.77	3 hour (+20%)	6.51
Existing Easter Compton Village	94444	5.56	3 hour (+20%)	6.25

Description	Node	5 Year Level	140 Year Rainfall	100 Year Level
Houses east of B4055 Main Road	6001	5.11	48 hour (+20%)	5.71
Culvert crossing under B4055 Main Road	6003	4.78	48 hour (+20%)	5.68

A3.2.1.9 The report recommended that to prevent flooding five storage ponds should be built measuring between 1-12Ha in size. These were included within the modelling, which noted that in all cases the residual risk of flooding was below the required 1% threshold stipulated in PPG25. For the 6hr, 12hr 24hr, 48hr rainfall events no parts of the rhine network were predicted to experience flooding. For the 3hr rainfall event the model showed spikes at three nodes where it was noted that water levels appeared to indicate out of bank flows for very brief spells. The report attributed this to intense runoff arriving instantaneously at a node, and was deemed unrepresentative of the physical processes, and the residual risk deemed to be below the prescribed 1% threshold (PPG25).

A3.2.1.10 The report suggested that the proposed alterations to the drainage network would result in an overall reduction in flooding in the New Pill catchment for all modelled rainfall events. Incorporation of the 2000 rainfall profile into the model also showed no flooding of the network. In particular, the areas of Easter Compton and Washingpool, currently subject to flooding, were predicted to be better protected for the 1 in 100 year return period fluvial event following the implementation of the drainage network improvements, associated with the proposed development. Maximum discharge rates from the site were predicted to remain 'virtually unchanged' as a result of the planned incorporation of storage ponds and increased cross sectional area of a number of the channels.

A3.2.2 Bettridge Turner and Partners (2003). Cabot Park – Avonmouth, Flood Risk Assessment

A3.2.2.1 In September 2003 BTP were commissioned by Burford Holdings Ltd, to undertake a flood risk assessment of Cabot Park; located within the Mitchells Pill catchment on low lying land behind the sea defences at the Avonmouth docks, with the section of the estuary immediately to their north. Land in this area below 10m AOD is considered by the LSDB to be at risk from tidal flooding. The general ground levels of the Cabot Park area are approximately 6.0m AOD.

A3.2.2.2 This study assessed the risk from tidal (1 in 200 year) and fluvial (1 in 100 year) flooding, including climate change, according to current PPG25 guidelines. The scenario of possible sea defence failure was also considered. The fluvial study assessed the effects of the development on the rhine system using the InfoWorks drainage model held by the LSDB.

A3.2.2.3 The report outlines a number of remedial and maintenance works to the current rhine system, including the construction of storage ponds. These were modelled using the InfoWorks hydraulic modelling package. Specifically the modelling included:

- Modification of the existing rhine to the new profile and alignment
- Raising of ground levels
- Alteration of land use
- Insertion of offline storage for extreme fluvial events
- Inclusion of the TTE reservoir into the rhine network following remediation and decontamination works

A3.2.2.4 Rhine cross sections were modelled as trapezoidal with side slopes of 1 in 1.5 and a base width of at least 1.5m.

A3.2.2.5 140 year rainfall was modelled for the following storm durations:

- 3.5 hours
- 7 hours
- 12 hours
- 24 hours

A3.2.2.6 For events up to and including 12 hours a 20% increase was modelled to account for climate change. Tidal locking of the Mitchell's Pill outfall was also included.

A3.2.2.7 The SCS runoff model was selected, assuming soil type C – fine texture, slow infiltration. Three main runoff surfaces modelled include roofed areas, paved areas and natural ground.

A3.2.2.8 Worst-case 1 in 100 year flood water levels including climate change at all nodes were estimated at a level of 6.5m AOD. Tidal water levels were taken from the Environment Agency ISIS model (JBA, 2001/2003) of the Severn Estuary, between Avonmouth and Haw Bridge. Five possible tidal flooding scenarios were modelled, the results of which are contained in Table A3.12.

Table A3.12 – BTP Summary of Tidal Flood Water Levels

Possible Sea Defence Failure	Average Depth of Flooding (mm)	1 in 200 year Flood Level (m AOD)
Overtopping of the Royal Edward Dock entrance lock	None	N/A

Possible Sea Defence Failure	Average Depth of Flooding (mm)	1 in 200 year Flood Level (m AOD)
Overtopping of informal defences south of Mitchell's Pill	None	N/A
Breach of informal defences south of Mitchell's Pill	125	6.3
Overtopping of formal defences north of Mitchell's Pill	17	6.22
Breach of formal defences north of Mitchell's Pill	350	6.55
Worst Case 1:200 year tidal event	**350**	**6.55**

A3.2.2.9 The results predicted no post-development flooding of raised ground levels, car parks, external areas or buildings for either the 100 year fluvial or 200 year tidal events. The residual risk of tidal flooding on site was predicted to be less than 0.5% provided that rhine maintenance, enlargement and pond storage were constructed in accordance to the schedule of works outlined in the report.

A3.2.3 Bettridge Turner and Partners (2003). Cabot Park – Avonmouth, Merebank Drainage Study and Flood Risk Assessment

A3.2.3.1 In September 2003 BTP were commissioned by Burford Group Plc, to undertake a flood risk assessment according to PPG25 guidelines, for a development under the Cabot Park project. The site occupies an area of 24 Ha and is located in the Mitchell's Pill catchment, off of Kings Weston Lane in Avonmouth. The land had been used prior to this and levels were between 7.2-7.5m AOD. The 1 in 100 year fluvial flood level was predicted to be 6.60m AOD, therefore the site was considered to be outside of the fluvial floodplain. However, the site was deemed to be within the 1 in 200 year tidal floodplain. An assessment of the 1 in 200 year tidal event was carried out to the following specification:

- To review early work on drainage at Merebank
- To re-establish allowable discharge through Rhone Poulenc
- To model the undeveloped and developed areas to establish suitable drainage facilities including ponds / storage tanks to protect development under the 1 in 100 year event
- To make recommendations for approval by the client, architect and LSDB
- To contribute to a park wide Flood Risk Assessment

A3.2.3.2 The report assessed the risk of tidal (1 in 200 year) flooding, combined with the effects of climate change over the next 50 years and included the possibility of failure of the formal sea defences.

A3.2.3.3 The site had existing discharges to the Severn Estuary via two pipes (600mm and 900mm in diameter), the former discharging through the north west corner of Merebank and the latter through the Kings Weston Rhine. The allowable discharge for future flows from the developed site is based on assumptions of the capacity of the both of these outfalls and the receiving sewer drainage system.

A3.2.3.4 The site was modelled using Microdrainage[4] software (WINDES Version 8.1), which set up notional drainage systems serving both the northern (13.2 ha) and southern (10.8 ha) parts of the site. Capacities of 285l/s and 450l/s were assumed for the northern and southern outfalls respectively. Microdrainage software (WINDES version 8.1) showed the storage volumes required to attenuate the discharges to these levels, were 4550.5m^3 for the northern system and 3056.7m^3 (maximum) and 2551.9m^3 (minimum) for the southern system.

A3.2.3.5 A previous report by BTP – 'Development on Land at Merebank/Lakeside – Drainage Report' July 1997 – and subsequent site survey had established the flood level for the 1 in 100 year event as 6.60m AOD and 6.00m AOD at the two outfalls both of which have an outfall level of 5.50m AOD. The surface level to satisfy storage volume requirements for the site were stated as 6.70m AOD.

A3.2.3.6 Storm water storage on the site will involve excavation through the contaminated material overlaying the site. It was proposed to raise development slab levels to 7.70m AOD to cap the contaminated layer with a minimum of 0.5m of inert material.

A3.2.3.7 The existing sea defences along the Severn Estuary consisted of:

- Avonmouth to Severn Beach: 1 in 100 year protection to 9.0-10.0m AOD;
- South of Mitchell's Pill outfall (Avonmouth Docks): not to an approved standard and not owned by the EA. Bristol Port Company state a level of defence to 10.0m AOD excepting a 1600m section south of the Esso terminal (9.82m AOD), and the entrance to the Royal Edward Dock (9.26m AOD) for 110m. The former is to be raised to 10.0m AOD in the near future;
- North of Mitchell's Pill. EA mixed earth embankments 9.5-10.0m AOD. Railway embankments form part of the defence – lowest section at 9.06m AOD;
- Tide flapped outfalls not operated by the Environment Agency prevent tidal flooding of the rhine network.

A3.2.3.8 Properties of the main flood cells in the area as shown on Drawing 1 of the BTP report and summarised in Table A3.13:

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[4] Micro Drainage Limited, Jacobs Well, West Street, Newbury, Berkshire RG14 1BD

Table A3.13 – BTP Main Flood Cells

Cell Number	Location/Name	Area (m^2)	Mean Ground Level (m AOD)	Comments
1	Dock/industrial Area	6,520,000	7.5	Largely developed
2	Mitchell's Pill (west)	1,606,000	6.2	50% developed
3	Mitchell's Pill (east)	1,440,000	6.0	Largely undeveloped
4	Stup Pill (west)	3,850,000	6.2	Partially developed
5	Stup Pill (east)	1,790,000	6.0	Undeveloped
6	New Pill (west)	3,940,000	6.0	Partially Undeveloped
7	New Pill (east)	6,390,000	5.8	Undeveloped

A3.2.3.9 Tide water levels were taken from the iSIS model of the Severn Estuary between Avonmouth and Haw Bridge held by the EA (JBA, 2001/2003), using the water levels developed for the 1 in 200 year tidal event in combination with the 1 in 100 year fluvial event for flows in the River Severn, incorporating an allowance of 250mm for sea level rise at 5mm per year over the next 50 years.

A3.2.3.10 The iSIS model did not allow for decay in the storm surge and assumed that the maximum tidal range repeats indefinitely. However, the BTP report assumed that the surge would reduce by 600mm for the second tidal cycle and by a similar amount for the third cycle, returning to the predicted astronomical tide levels by the fourth cycle.

A3.2.3.11 Although the EA advise that a further 600mm be added to the still water levels to allow for wind and wave effects this was not considered appropriate for calculating volumes of water breaking over the sea wall and was not included within the BTP study. Information on ground levels was obtained using LiDAR survey supplied by the EA (2002).

A3.2.3.12 Possible flooding scenarios considered within the BTP report were:

- Overtopping of the entrance lock of the Royal Edward Dock;
- Overtopping of informal sea defences;
- Breach of informal sea defences south of Mitchell's Pill;
- Overtopping of informal sea defences north of Mitchell's Pill;
- Breach of formal sea defences north of Mitchell's Pill.

A3.2.3.13 A summary of the flood water levels predicted for a 1 in 200 year tidal event for the tested sea defence failure modes are contained in Table A3.14.

Table A3.14 – BTP Summary of 200 year tidal Flood Water Levels

Possible model of Sea Defence Failure	Predicted 1 in 200 Year Floodwater Level (m AOD) + Sea Level Rise	Average Depth of Flooding (mm)
Overtopping of Royal Edward Dock entrance lock	Nil	N/A
Overtopping of informal sea defences south of Mitchell's Pill	Nil	N/A
Breach of informal sea defences south of Mitchell's Pill	6.33	127
Overtopping of formal defences north of Mitchell's Pill	6.22	17
Breach of formal sea defences north of Mitchell's Pill	6.55	350

A3.2.3.14 An assessment of the increased runoff attributable to the development has been accounted for through onsite storage. The options for this are as follows:

- **Scheme 1** – Widening of northern rhine to 9m over a length of 350m. Construction of new rhine 12m wide over a distance of 300m and of an outfall structure at the existing discharge point;
- Widening of southern rhine to 8m over a length of 480m and construction of an outfall at the discharge point. Should the widening not be possible an overflow pond would be constructed to accommodate storm water storage;
- **Scheme 2** – Linkage of the north and south rhines to a new storage pond ($7200m^2$) located on the south western site boundary, discharging to both outfalls. Construction of a 120m rhine, culverted under the railway, to connect the northern rhine to the pond. Outfall construction at the discharge points. Both rhines to be cleared and reconstructed as necessary;
- **Scheme 3** – North and south rhines to be cleared and culverted over a distance of 350m and 480m respectively, to link to underground storage ($4400m^3$ and $2740m^3$) located under the proposed car parking areas. Construction of outfalls at discharge points and at car park discharge points;
- **Scheme 4** – North and south rhines to be cleared, reconstructed as necessary and linked to underground storage ($3135m^3$ and $2569m^3$), located under the proposed car parking areas. Construction of outfalls at existing discharge points and at car park discharge points;
- **Scheme 5** – Reconstruction of the two rhines as necessary and linking these to a storage pond in a similar position as in Scheme 2. The pond

would be deeper and of smaller surface area. Location of two pumping stations with twin submersible pumps at the northern and southern ends to discharge to the existing outfalls at the required rate. Construction of a 120m rhine to connect the north rhine to the pond. Construction of a pond (4900m^2);

- **Scheme 6** – Linkage of existing rhines to underground storage (3135m^3 and 2569m^3) located under the proposed car parking area. Construction of outfalls at existing discharge points and at car park discharge points;

Conclusions

A3.2.3.15 The BTP report concluded that the site was within the EA 1 in 200 year tidal indicative floodplain. The worst case scenario was expected to be a breach in the sea defences north of Mitchell's Pill outfall. The flood level in the event of a 1 in 100 year fluvial flood event was predicted to be 6.6m AOD including a 20% increase for climate change. This level was below the existing site levels therefore placing Merebank outside of the fluvial floodplain.

A3.2.3.16 It was proposed to raise site, road and building levels to place the development outside of the 1 in 200 year tidal floodplain. Minimum floor levels were set at 7.7m, placing them above the nominal 600mm freeboard required to be added to the 1 in 100 year flood level according to guidance from the Internal Drainage Board.

A3.2.3.17 It was noted that a short term risk of flooding would exist for the undeveloped low-lying area of the Mitchell's Pill catchment, although this was deemed to be immeasurably small, as was the rate of flooding of these areas. It was concluded that the residual risk of flooding on site post-development would be less than 0.5%.

A3.2.3.18 Recommendations made within the report suggest Scheme 2 to be the preferred option for flood attenuation as the retention of the existing rhines would enable the construction of the surface water storage facility to be commenced at an early stage with no effect on the site development. The report noted that should land values appreciate significantly then scheme 5 or 6 maybe more appropriate. It was also noted that an increase in allowable discharge to 900l/s at the southern outfall would reduce the storage construction costs.

Revision Status and Schedule of Changes

Section Revision Status

No technical revisions were made for the November 2010 SFRA release for Section 3 – Hydrology, Drainage and Groundwater.

All technical revisions of the SFRA January 2007 release for Section 3 – Hydrology, Drainage and Groundwater are outlined below:

- Hydrology updated based on DEFRA Oct 2006 climate change (flood flows) predictions.
- Comparisons with BTP flows routed through hydraulic model **not** remodelled following improvements to hydraulic model outlined in Section 5.

Commentary on Revision

Phase 3 – January 2007:

DEFRA 2006 Climate Change Guidance

The update to the DEFRA (2006) climate change guidance had the following implications on the outputs of the SFRA:

- For the initial study, climate change in terms of fluvial flooding was based on a conservative increase in flows of 33%. The DEFRA (2006) guidance suggests that sensitivity testing of an increase in flivual flooding of 30% (rainfall intensity) should be used over the next 100 years. This presents a slight reduction in fluvial flood flows for the year 2105, however, flooding is dominated by the tidal component and the change to flooding risk is minimal.

Schedule of Changes – Latest release only

Section 3.1 – Revision status added, following sections renumbered accordingly

Paragraph 3.4.1.2 included.

Section 4. Flood Defence Assessment

4.1. Revision Status

4.1.1.1 The defence breach assessment was revisited during phase 4 to take account of revised tide level estimates and condition information. A detailed site inspection of defences was not completed therefore the findings of the Phase 2 study site visits remain current. The appropriateness of the conceptual design and cost estimates were reviewed based on the revised target crest level (using the most recent tide level estimates and Defra 2006 climate change guidance). The conceptual designs themselves have not been amended.

4.1.1.2 During Phase 4 further assessment was undertaken to identify potential funding regimes and the potential for developer contributions to defence improvements. Recommendations for future flood defence improvement studies are provided.

4.2. Introduction to Flood Defence Assessment

4.2.1.1 As a result of the fluvial flooding and tidal flooding caused by high surge tides experienced during the 1990s and winter of 2000, the Environment Agency (EA) commissioned a strategic study into flooding along the tidal reaches of the River Severn Estuary. This study, the Tidal Severn Strategy (TSS), was released for public consultation in December 2004 and is discussed in Section A2.2.2. WS Atkins were subsequently commissioned by the EA National Capital Programme Management Services (NCPMS) to undertake an options study to identify an optimum flood defence scheme. The project appraisal taking account of engineering costs, flood damages saved, social vulnerability and environmental impact was based on the Department for Environment, Food and Rural Affairs (Defra) Flood & Coastal Defence Project Appraisal Guidance (FCDPAG). The previous studies are in the process of being replaced by the Severn Estuary Flood Risk Management Startegy (SEFRMS), which is currently in development and was not available for the SFRA.

4.2.1.2 Future development potential within the flood zones is dependant upon the area being defended to the 1 in 200 year return period (plus allowance for climate change) in accordance with current best practice.

4.2.1.3 For phase 2 of the SFRA a detailed defence assessment was undertaken, taking into consideration the visual condition of the existing flood defences and assessing the likelihood and consequence of failure of sections of the defences. Furthermore, in broad terms to provide advice on the realistic probability of defending the area to the industry accepted minimum standard for the duration of the planning horizon. The defence assessment has been updated for phase 4 to account for the latest information on defence levels, defence condition and predicted water levels. Further information is also provided on potential funding of defence improvement works and developer contributions. This section of the report describes the outcome of this element of the study.

4.2.1.4 The study area comprises a flood-prone zone along the eastern bank of the Severn Estuary, the area is largely uninhabited and consists of salt marshes and wide foreshores, and this provides a natural protective barrier along much of this stretch of coast, however, due to existing / expanding development this has been augmented through the installation of artificial flood defences. This assessment is to assess the integrity and suitability of the existing structures. The integrity/condition scores are based on visual inspections only as no ground investigation work has been included within this study.

4.2.1.5 The study area is an Environment Agency designated flood-warning zone and identified on the Flood Map of the area. The flooding is classified as coastal / tidal flooding due to the tidal nature of the Severn in this area. Assessment of the flood defences bordering the estuary was carried out by visual inspection of the structures and their surroundings, aided by topographical data accessed through a GIS system. The inspection was carried out by a chartered geotechnical engineer accompanied by a representative of the Environment Agency familiar with this section of the coastal defences in December 2004.

4.2.1.6 This section of the report presents the results of the site inspection and comments on the apparent risk posed by a breach of the defences, in terms of both the likelihood of a failure and the possible consequences. Recommendations are made for breach scenarios that may merit hydrodynamic modelling and assessment. The section goes on to outline in broad terms the cost to ensuring the flood defence provides the 1 in 200 year standard of protection for the duration of the planning period, the next 100 years.

4.3. Site Description in regard to Flood Defence Assessment

4.3.1.1 The area of the flood risk assessment is the low-lying ground between the River Avon in the south and Aust to the north. The tidal defences along the River Avon sited between the M5 Avonmouth Bridge and the mouth of the Avon were also assessed. The assessment continued, following the existing defence structures along the coast and eventually tying in to the higher ground at the village of Aust.

4.3.1.2 The area has been subject to flooding and at certain places along the site, is known to flood at least five times in a 10-year period.

4.3.2 Geology & Hydrogeology

4.3.2.1 The soils within the study area are classified as Calcareous Clays and as such likely to be of low permeability. The local drift comprises of Estuarine Alluvium.

The solid geology comprises Mercia Mudstone (Keuper Marl) overlying Upper Coal Series and Pennant Sandstone (a water bearing formation). Abstraction takes place from the sandstone formation, which lies within the Avonmouth Basin. The area is not designated as a source protection zone; probably due to the presence of the Mercia Mudstone formation, which represents a significant aquiclude.

Flood Defence Inspections

4.3.2.2 A walk over survey was undertaken to assess the condition and effectiveness of the existing tidal flood defence installations. This was carried out on 6th and 9th December, 2004. The inspection paid particular attention to defects or aspects that may contribute to failure of the infrastructure, and was undertaken in accordance with the EA's National Sea and River Defence Surveys "*A Guide to the Visual Condition Assessment of Sea and River Defences*". Site photography is shown in Appendix A4.1.

4.3.2.3 The Environment Agency supplied defence condition data from their National Flood and Coastal Defence Database (NFCDD). This was supplied on 19/05/2010 and included data from visual inspections carried out between November 2007 and March 2010. This information has been used to determine the current condition of defences.

4.3.2.4 Defence crest levels used in this study have been obtained from a 2009 crest level survey supplied to Capita Symonds by the Environment Agency. It should be noted that this survey data does not cover the entire study area and as such defence sections I-P have not been updated during the Phase 4 (2010) revision of the SFRA.

4.3.2.5 The Agency had previously commissioned a "Study of the Esso Oil Plant Flood Defences" (April 2003) along the foreshore area in front of the Esso Oil Plant located at Avonmouth. These are private defences and these are constructed in what could be described as an improvised and ad-hoc manner.

4.3.2.6 This study highlighted concerns about the stability of the defences at this location and concluded that although "the rate of failure cannot be accurately estimated and under or immediately following a flood event, the possibility of a breach cannot be discounted". Although the report is dated April 2003, the findings and conclusions were confirmed in the current study and thus the conditions of the defences here are significant.

4.3.2.7 The main part of the coastal defences consists of a raised earth embankment, which in some areas is faced either by rock revetments or engineered structures such as reinforced concrete walls. Other parts of the defences consist entirely of masonry walls.

4.3.2.8 Currently the assumption is that a failure of the embankment would be due to erosion of the toe, however, other failure mechanisms due to increased pore water pressures, internal failure and weathering should not be overlooked.

4.4. Summary of Tidal Defence Structures

4.4.1.1 The NFCDD data outlined in 4.3 enabled identification of various categories of defences with regard to type and condition of the structures. These are summarised in Table 4.1 and shown in Figure 4.0 – Tidal Defence Assessment. The defences extend from Aust (A) to Avonmouth Docks (J) to M5 Avonmouth Bridge on the River Avon (P). Defences along the Avonmouth / Severnside frontage consist of a combination of formal defences and also natural landforms and 3rd party infrastructure which were not built as a defence. Currently the EA classes these as “de-facto” defences, which do provide a certain degree of protection and will act as a barrier to flood water. However as their construction is known to be poor, and are often made from non-cohesive material, the EA would not formally class them as a flood defence. De-facto defences are very much an unknown quantity and a visual inspection will not necessarily provide information about the integrity of a landform or 3rd party structure. The De Facto defences are highlighted in Table 4.1.

Table 4.1 – Tidal Flood Defence sections

Section	Type of Structure	Status	Condition
A – B	Raised Earth Embankment	Formal EA defence	Good-Fair
B – C	Rock Armour and Sea Wall	Formal EA defence	Very Good-Fair
C – D	Faced Earth Embankment	Formal EA defence	Good-Fair
D – E	Raised Foreshore	Private / De Facto	Good
E – F	Raised Railway Embankment	Private / De Facto	Good
F – G	Raised Earth Embankment	Formal EA defence	Good
G – H	Rock Armour and Raised Earth Embankment	Private / De Facto	Good-Fair
H – I	Rock Armour, Pipework and Block Wall	Private / De Facto	Fair
I – J	Rock Armour and Small Ballast Bund	Private / De Facto	Fair
J – K	Lock/ Dock Gates	Private / De Facto	Fair
K – L	Rock Armour, Sea Wall and Earth Embankment	Private / De Facto	Poor
L – M	Rock Armour (Rubble) and Earth Embankment	Private / De Facto	Poor
M – N	Raised Earth Embankment	Private / De Facto	Fair
N – O	Brick Wall	Private / De Facto	Fair
O – P	Raised Earth Embankment	Private / De Facto	Fair

4.4.2 Types of Structure

Embankments

4.4.2.1 The composition of the embankments has been assessed through a visual inspection, as this will also provide information for possible breach locations. It is apparent through visual inspection of the eroded exposures that most of the earth embankments appear to be constructed of various materials ranging from gravels, sands and clays to general rubble, including brick, concrete and glass. The most common material is a reddish brown clay, probably locally derived Mercia Mudstone clay. Due to the 'de facto' status of many of the embankments, and as only a visual inspection has been completed it was not possible for the SFRA to determine the composition of the defences with accuracy.

4.4.2.2 The embankments can generally be expected to be impermeable, preventing significant water flow. However, some penetration of water could be expected during high tide, enabling pore pressures to become established within the embankment thus reducing its strength. In some places water is able to collect in a ditch on the landward side of the embankment, which will also eventually penetrate the embankment, raising pore pressures and which could result in slumping and / or eventual integral failure and collapse.

4.4.2.3 It was not possible to determine the composition of the railway embankment that forms part of the defence for a significant length. Such embankments were frequently formed of ash, which would be more permeable than clay. Ballast is used in the top section of the embankment to support the track. In this area, significant settlement of the embankment could have occurred since its initial construction. This would have occurred gradually, and the alignment of the track would have been maintained by continual placement of ballast. It is therefore likely that at least the upper section of the railway embankment is very permeable.

Concrete / Masonry Structures

4.4.2.4 A reinforced concrete sea wall and promenade (Section B-C) has been constructed along the foreshore of part of the site. It is protected by rock abutments and its condition varies from very good to fair along its length. The Binn Wall, as this stretch of defence is known, is approximately 300m in length and consists of two tiers of defence, stepped and curved-face sea wall. To landward of this structure is a residential estate.

4.4.2.5 The wall at Avonmouth docks (Section H-I), consists of a single width of blockwork mortared on top of a reinforced concrete vehicle barrier kerb and is ranging between 0.5m and 1.0m high. This is entirely fronted by a network of pipes, which runs the length of the foreshore. Rock revetments constructed from demolition materials in turn front this and appear to be in fair condition. Drainage holes exist at regular intervals, however, the wall has been knocked over at one point as the result of a vehicle collision. (Grid ref. x: 351400 y: 179900)

4.4.2.6 Another short section of brick wall exists at (Section N-O) (Grid ref. x: 351800 y: 177400) this comprises a 300mm width brick & blockwork wall.

Grouted Stone Revetment

4.4.2.7 South of Binn Wall (Section C-D), the tidal defence is an earth embankment, faced with a grouted stone revetment.

4.5. Flood Defence Assessment Results

4.5.1 Proposed Approach to Flood Defence Assessment

4.5.1.1 Both visual inspection and cross section interpretation were used during the initial assessment, in order to effectively locate and analyse potential breach locations. The data collected would assist in the implementation of a 'Breach Method' model and was intended to assess the integrity and inherent capabilities of the existing defences.

4.5.1.2 The findings of the survey are presented in the form of a semi-quantitative risk assessment, which is indicative of the likelihood of a breach and the consequence of that event. The resultant risk is characterised by the effect of the event.

4.5.1.3 By providing values for both the severity and the likelihood of a possible breach location a quantified risk value can be expressed. In this case both the severity and probability are defined by the following values:

Table 4.2 – Risk Assessment Classification

Probability	Value	Severity	Value
Inevitable	5	Catastrophic	5
	4		4
	3		3
	2		2
Unlikely to occur	1	No impact	1

4.5.1.4 By multiplying the two values a subsequent risk value can be determined.

for instance, Probability x Severity = Risk

Table 4.3 – Risk Assessment Definition

Value	Defined Risk
15 – 25	HIGH
5 – 14	INTERMEDIATE
1 – 4	LOW

4.5.1.5 The probability or likelihood of a breach event can be attained through assessment of the condition of the existing defences and implementation of a worst-case scenario such as an extreme tide event. The severity is identified by the consequence or impact of a breach, which in this case is reliant on its location including the topography behind the defence and the properties likely to be affected.

4.5.1.6 By allocating risk values through the entirety of the study area, a hazard map can be devised, representative of those areas which may require a form / degree of remediation and management.

4.5.2 Breach Assessments

4.5.2.1 The assessments have been carried out in accordance with the Environment Agency's "Tidal Flood Risk Areas – Simple Credible", which describes the 'Breach Method'. Two breaching cases are considered, namely undefended, those, which are likely to fail, and defended, those not expected to fail. Both are determined through assessing the type, size, condition of the defence and its ability to withstand water level, wave action and overtopping. The majority of the coastal tidal defences included in this study and the protected areas can be considered 'defended' through formal and defacto defences.

4.5.2.2 In order to specifically assess the severity of these events cross sections have been taken at intervals along stretches of the coastal defences. These provide an indication as to the height and size of the defence structure and the level of the adjacent land. Cross section locations are listed in Table 4.4, and shown in Figure 4.1a – Flood Defence Assessment Cross Sections Locations (XS1, XS2, XS3, XS4, XS5)a to Figure 4.1h – Flood Defence Assessment Cross Sections Locations (XS27, XS28, XS29, XS30, XS31)h. Cross sections are presented in tabular and graphical format in Appendix A4.2.

4.5.2.3 The Steering Group instructed that breach assessments be carried out along areas of the coastal defences which protect urban areas or built infrastructure, with the aim of identifying the locations where the potential consequence of a flood event would be most severe. The Steering Group further requested that detailed breach modelling be conducted at six locations and that other sections of defences are partially or completely removed (Bristol Port, Avonmouth Docks) for the analysis. Details are shown in Figure 4.2a – Defence Locations and Breach Locationsa to Figure 4.2f – Defence Locations and Breach Locationsf.

4.5.2.4 Levels were initially established by reference to a combination of Environment Agency LiDAR and NextMap SAR (Synthetic Aperture Radar) Digital Terrain Models (DTM), resulting in an amalgamation of 1m, 2m and 5m grids with vertical accuracies varying from 0.25m to 0.8m. Crest level information has subsequently been updated with defence crest topographic survey from 2009.

Table 4.4 – Flood Defence Assessment Cross Sections

XS	Breach		Defended/ Undefended	Type of Structure
	No	Type		
1	**1**	Partial Removal	Defended	Raised Earth Embankment
2	**1**	Partial Removal	Defended	Raised Earth Embankment
3	**5**	Partial Removal	Defended	Raised Earth Embankment
4	**6**	Partial Removal	Defended	Sea Wall & Promenade
5	**6**	Partial Removal	Defended	Sea Wall & Promenade
6	**4**	Partial Removal	Defended	Sea Wall & Promenade
7	**4**	Partial Removal	Defended	Sea Wall & Promenade
8	**3**	Partial Removal	Defended	Sea Wall & Promenade
9	**3**	Partial Removal	Defended	Sea Wall & Promenade
10	**2**	Partial Removal	Defended	Sea Wall & Promenade
10a	**2**	Partial Removal	Defended	Sea Wall & Promenade
10b	**2**	Partial Removal	Defended	Sea Wall & Promenade
11	**2**	Partial Removal	Defended	Sea Wall & Promenade
12	**1**	Partial Removal	Defended	Faced Earth Embankment
13	**1**	Partial Removal	Defended	Faced Earth Embankment
14	**1**	Partial Removal	Defended	Faced Earth Embankment
15	**7**	Partial Removal	Defended	Railway Embankment
16	**7**	Partial Removal	Defended	Railway Embankment
17	**7**	Partial Removal	Defended	Railway Embankment
18	**8**	Complete Removal	Undefended	Raised Earth Embankment
19	**8**	Complete Removal	Undefended	Raised Earth Embankment
20	**8**	Complete Removal	Undefended	Raised Earth Embankment
21	**9**	Complete Removal	Defended	Raised Earth Embankment
22	**9**	Complete Removal	Defended	Raised Earth Embankment
23	**9**	Complete Removal	Defended	Raised Earth Embankment
24	**10**	Complete Removal	Undefended	Raised Block Wall
25	**10**	Complete Removal	Undefended	Raised Block Wall
26	**10**	Complete Removal	Undefended	Raised Block Wall
27	**11**	Complete Removal	Defended	Small Ballast Bund
28	**11**	Complete Removal	Defended	Small Ballast Bund
29	**12**	Complete Removal	Undefended	Raised Earth Embankment
30	**12**	Complete Removal	Undefended	Raised Earth Embankment
31	**12**	Complete Removal	Undefended	Raised Earth Embankment

4.5.2.5 Twelve breach location assessments were carried out as listed in Table 4.55.4.5. These were for structures defending infrastructure and residential development where any failure would potentially have severe consequences.

4.5.2.6 The Steering Group requested that the existing defences at Avonmouth Docks be removed for the purposes of the breach assessment. The justification being that the condition, construction and maintenance of these defences mean that their integrity can not be relied upon.

Table 4.55.4.5 – Conditions of Existing Defences for Breach Assessments

Breach No.	Condition of Structure / Failure Mechanism	Failure Mode
1	No significant defect or damage, minor cracks, Good Condition.	Undermining, possible structural failure
2	No significant defect or damage, minor cracks, Good Condition. Some settlement of structure.	Weathering, surface erosion, hollowing due to settlement, failure of facing leading to erosion.
3	No significant defect or damage, minor cracks, Good Condition.	Undermining, possible structural failure
4	No significant defect or damage, minor cracks, Good Condition.	Undermining, possible structural failure
5	No significant defect or damage, minor cracks, Good Condition.	Undermining, possible structural failure
6	No signs of active erosive processes, Very Good Condition.	Very gradual erosion resulting in local slump; rapid erosion of breach
7	No signs of active erosive processes, Very Good Condition. (Raised Railway Embankment)	Scouring of seaward face. Internal erosion due to seepage.
8	Active erosion occurring, over-steepening and undermining of embankment, erosion of foreshore, and makeshift rock armour, Poor Condition.	Loss of stability and integral strength. Slumping, rotational failure.
9	Active erosion occurring, over-steepening and undermining of embankment, erosion of foreshore, and rock armour, Poor Condition.	Loss of stability and integral strength. Slumping, rotational failure.
10	Active erosion occurring, over-steepening and undermining of embankment, erosion of foreshore, and rock armour, Poor Condition. Block wall – Good Condition, has been knocked over at one point.	Loss of stability and integral strength. Slumping, rotational failure. Failure due to collision or loss of grout. Structural failure under water pressure and wave action.
11	No signs of active erosive processes, Very Good Condition.	Weathering, wave erosion.
12	Erosion occurring at seaward base, some slippage at surface, reduced width of structure, over-steepening and undermining occurring. Poor Condition	Complete rotational failure, slumping and loss of internal strength.

4.5.3 Summary of Findings of Flood Defence Assessment

4.5.3.1 The breach assessments and subsequent cross sections identified those areas of land most severely affected in the event of a failure of the defence structures. The aim being to assess what the likely effects would be in the event of failure.

4.5.3.2 The breach assessment scores have been revisited during phase 4 although the original data used for the defence breach assessment was not available for a thorough comparison. Probability scores have therefore been adjusted where the change in 200 year + climate change water levels from phase 2 to phase 4 leads to a change in the state of the defence at the peak water level, i.e. where defences are within their freeboard or are overtopping in the phase 4 assessment and were not in the phase 2 assessment. The breach assessment risk scores are considered appropriate indicative measures, however as the assessment is largely based on information that is several years old, and is based solely on visual defence condition it is recommended that more detailed assessments are completed to inform future site specific studies.

Breach Assessment 1

4.5.3.3 The earth embankment, which lies to the north of New Passage (Grid ref. NGR 355000, 186700) appears to be in its entirety in very good condition. The ground adjacent to this structure is mostly level or in some places actually higher and is generally used for grazing. This area has a wide foreshore and thus little or no current erosive processes are occurring. Failure/ breach of this structure would only result if a prolonged extreme tide was experienced (see Section 5 for more detail on tidal/surge levels and durations). The result would be continuous scouring of the structure by wave action and eventual failure. Once a breach occurred further erosion and expansion of the breach may be rapid. These structures may also be susceptible to overtopping and subsequent erosion if extreme water levels exceed predicted figures. Risk 1 ~ LOW.

Breach Assessments 2 to 5

4.5.3.4 Breach assessments 2 to 5 are four assessments, which have been carried out along Binn Wall, a combined stepped and curved-face sea wall and promenade, fronted by rock armour. The area adjacent to this structure is low lying and contains residential dwellings and other infrastructure (XS 4 –11). The sea wall is in good condition although wave action is inevitable. Undermining and subsequent collapse of the structure is a potential failure mode, however, the provision of rock armour would reduce the likelihood of this occurrence. Internal structural weaknesses, sand abrasion, saline corrosion and hydrostatic pressure cannot be overlooked as failure mechanisms.

4.5.3.5 Failure of this structure could either be gradual over a period of years, or a sudden event such as a prolonged winter storm, depending on which failure mechanisms are active. Due to construction practices and build quality, it is unlikely that the structure will fail completely and therefore the likelihood of a catastrophic event is low. Risk 10 ~ INTERMEDIATE.

Breach Assessment 6

4.5.3.6 To the south of Binn Wall (Grid ref. NGR 353840, 184060) the defence is earth embankment reinforced with a grouted stone revetment facing, represented by cross sections 12-14 (Breach no.6). This part of the defence has a wide foreshore, and with the exception of the railway line, shields little infrastructure immediately behind the defence. The structure appears to be in good condition, however, analysis of cross sectional data indicates that slight settlement of part of the structure may have occurred. Accordingly, this may lead to structural instabilities of the embankment and could cause hollowing and weakening of the concrete matrix making it vulnerable to wave action and leading to washout of the mortar. This would occur over a protracted period of time and remediation measures could be implemented prior to any failure. Any failure of this structure however, would be potentially severe due to the proximity of residential areas and the A403. Risk 4 ~ LOW.

Breach Assessment 7

4.5.3.7 Cross sections 15-17 (Breach no.7) are taken through a raised railway embankment. The embankment is in good condition although its composition is undetermined. In the event of an extreme water level the structure would be exposed to wave action and depending on the composition and build quality of the embankment this may result in a degree of erosion and steepening of the seaward face. This is a cause for concern due to the nature of the structure and frequent loading of the structure by rail carriages, a combination of which may lead to complete rotational failure. The embankment may be relatively permeable, and seepage through it could cause internal erosion possible resulting in a breach.

4.5.3.8 A sudden failure along this part of the defence would be potentially catastrophic due to the proximity of chemical works adjacent to the A403, although at this point the A403 is raised and provides an additional barrier albeit with openings.

4.5.3.9 This structure would only fail if a continued extreme tide level was reached and wave action was severe and sustained. Rotational failure would only occur at low tide once the tide had receded. Risk 8 ~ INTERMEDIATE.

Breach Assessment 8 and 9

4.5.3.10 Breach location assessments numbers 8 and 9 are on the foreshore within the northern region of the Avonmouth docks. The foreshore includes armouring constructed from demolition materials. This is in poor condition and the seaward side of the engineered earth embankment, is heavily eroded due to both wave action and wind abrasion. Part of this defence is being undermined and a small degree of slumping has occurred at several points. In places, severe wave action could form a sudden breach by erosion and undermining the embankment. Failure could also occur through gradual erosion, over-steepening of the seaward slope which would result in rotational failure. Due to the degree of erosion that has already occurred this is a major cause for concern as any breach would have a catastrophic impact on adjacent docks area.

4.5.3.11 A breach by severe wave action would occur around high tide. It is most likely that any rotational failure would occur at low tide once the water had receded. However, at this location it is probable that such a breach would not be noticed until the following high tide.

4.5.3.12 Given sufficient time remediation measures could be implemented prior to a subsequent high tide. Given the width of this defence structure it is likely that any failure would be partial with a low likelihood of a full breach occurring. However, access for repair or reconstruction is poor. Risk15 ~ HIGH.

Breach Assessment 10

4.5.3.13 Breach assessment no.10 represented by cross sections 24 –26, consists of two elements of defence structures. The foreshore is a steep narrow stretch of rock armour constructed from demolition materials such as reinforced concrete and this is backed by a steep embankment. Defences at this location are in poor condition and the embankment, which is capped by concrete, is heavily eroded. On top of the embankment there is a series of pipes of the order of 500mm diameter, presumably carrying oil, supported slightly above ground level and running parallel to the foreshore. Behind this, and bordering the perimeter road, is a single width block wall built on top of a reinforced concrete vehicle barrier kerb, maximum height of approximately 1m, with drainage holes through it at regular intervals. Although the actual structure is in good order its stability under water pressure and effectiveness is questionable. The structure had been knocked over presumably by a vehicle, and needs replacing. The pipework, effectively provides some protection for the wall against wave attack at this location but was not intended to serve this purpose. However, continuous undermining via wave action at lower tides would eventually lead to loss of support for the pipework foundations.

4.5.3.14 Continuous erosion of the foreshore and toe, through wave activity could undermine the embankment causing collapse of the embankment and piping supports. Initial displacement would be gradual, however, a failure of the pipework, could occur, without further monitoring and management. The blockwork wall may collapse under water pressure and wave action at an extreme high tide.

4.5.3.15 The docks at this location are situated on relatively high ground, however, overtopping and / or breaching of the existing defences would have a significant impact on operations. Risk 16 ~ HIGH.

Breach Assessment 11

4.5.3.16 A small ballast bund forms the tidal defence structure around the area of the locks/ port entrance. It is in reasonable condition, however, its effectiveness is debatable because the top of the lock gates are below base level of the defence structure. Risk 4 ~ LOW. A low risk has been derived from a high likelihood of failure but an insignificant severity estimated by quick response to structure replacement.

Breach Assessment 12

4.5.3.17 Although for the purpose of this assessment the existing tidal defences around the Avonmouth dock have been removed. Breach assessment (no.12) has been undertaken to the east of the lock gates along the Avon Estuary and boundary of Avonmouth Docks to assess the current situation. The defence structure at this location is an earth embankment fronted by demolition rubble 'rock armour'. Drainage outfalls cross the embankment and at the crossing the defence is reinforced by gabions. Due to its location this stretch of the defence is highly susceptible to wave attack and is currently in a poor condition due to the erosive processes, and lack of foreshore. Although rock armour has been placed it appears to be diminishing rapidly. A continuation of these processes would result in undermining of the embankment and sudden failure. Risk 15 ~ HIGH. A high risk has been derived from a high likelihood of failure.

4.6. Flood Defence Engineering Assessment

4.6.1 Scope and Objectives

4.6.1.1 Areas with insufficient protection and inherent structural instability, as well as the likelihood of potential failure or breach, are summarised in Section 4.5. Figure 4.3 – Flood Defence Review: Assessment and Current / Future Levels of Protection shows the assessment area, sections, defence breach locations and the current and future standards of protection offered by the defence system.

4.6.1.2 Although structural failure is currently occurring along sections of the defences, the day to day functional efficiency is considered to be adequate, hence the option of taking no action is applicable. However, a breach of any part of the defence structure would result in the loss of both structural and functional capability, the effects of which are described in Section 4.5.3.

4.6.1.3 The implementation of revised and upgraded coastal tidal defence structures can be justified based on the flood defence assessment, and the strategic flood risk assessment outlined in Section 7. However, the study area has economic potential that needs to be very carefully balanced with the protection and enhancement of the fragile and important ecological environment of the Severn Estuary.

4.6.1.4 A comprehensive planning, environmental and socio-economic appraisal is presented in Section 6. A preliminary cost estimate for upgrading the existing structures is included in this section and is based on guidance provided by EA and Government Documentation[5]. The cost estimate was originally derived during the 2004 study and briefly reviewed for the Phase 4 (2010) release of the SFRA.

4.6.1.5 A 1 in 200 year return period still water tidal surge level (Climate Change Year 2110) of 10.24 mAOD was established, based on the Royal Haskoning Report on Extreme Tide Levels (2008). Typical freeboard allowances tend to be 300mm (hard) and 600mm (soft) for defence structures. For the purposes of this assessment an ‘average’ standard design freeboard of 500mm has been assumed and will result in a minimum design crest level of 10.74 mAOD. Distinguishing between different types of defence for freeboard allowances would have added complexity beyond the scope of this study. **Note:** the above mentioned design crest levels have been based on the Avonmouth extreme water levels and scaled along the entire Severn Estuarine frontage. Climate change has been accounted for in accordance with DEFRA guidance (October 2006) and is suitable for the indicative defence assessment.

4.6.2 Hydraulic Modelling

4.6.2.1 The hydraulic model developed for phase 2 of this SFRA was used to investigate areas benefitting from improvements to coastal defences. The model helped to determine the benefits of a financial commitment to provide a coastal defence that met both the minimum standard level of protection (crest level of 9.59 mAOD for phase 2) and a freeboard of 500mm added (crest level of 10.09 mAOD for phase

[5] MAFF, Flood and Coastal Defence Project Appraisal Guidance. (FCDPAG 1-4)

2). The specific defences associated with Bristol Port and the Severnside railway were included in the model.

4.6.2.2 The model was run for both target crest levels using 1 in 200 and 1 in 1,000 year return period tidal surge boundaries with 1 in 2 year return period fluvial inflows, and wave overtopping volumes calculated. Figure 4.4 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 9.59mAOD Peak Flood Depths, With Defences, Future Case 200 Year Tide, 2 Year Fluvial to Figure 4.11 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 10.09mAOD Peak Flood V x D Products, With Defences, Future Case 1000 Year Tide, 2 Year Fluvial show the maximum flood depths, maximum flood hazard (velocity-depth products), and flooding extents for the extreme tidal surge events. The model results showed that only a very small area would benefit from the newly constructed defences at the minimum design level of 9.59 mAOD. Significant areas are shown to benefit from defences with a crest level of 10.09 mAOD, but these are generally confined to the back of the floodplain, and not in areas which are already developed.

4.6.2.3 It should be noted that while the still water levels, and therefore the design crest levels have increased by 0.65m from phase 2 to phase 4, the total wave overtopping volumes have not changed significantly and as such, the assessment described in paragraph 4.6.2.2 is assumed to remain unchanged. The relative benefits provided by defences at the minimum standard level of protection will therefore be the same.

4.6.3 Conceptual Engineering Design Options and Cost Estimates

Conceptual Design Options

4.6.3.1 In order to implement a coastal defence design, five generic policies need to be considered when reviewing the existing defences:

- Hold the existing line of defence, maintain or upgrade the level of protection;
- Managed realignment, by establishing a new line of defence and where applicable retreat the defences landwards of the existing defences;
- Advance the existing line of defence, by constructing defences on the seaward side of the current defences;
- Limited intervention, by allowing and aiding natural coastal change, for instance dune management, and cliff drainage **(not applicable)**;
- No active intervention, implement no coastal management operations **(not applicable)**.

4.6.3.2 As noted two of these generic policies can be discounted as there is a need for coastal defences along this section of shoreline due to existing infrastructure and development potential. Limited intervention and no active intervention would result in damaging and costly effects on the existing infrastructure, with the potential loss of commercial and domestic property.

4.6.3.3 The Severn Estuary Shoreline Management Plan Review (SMP2) was issued for public consultation in 2009. The SMP2 policy outlined for the SFRA study area is Hold the Line.

4.6.3.4 It should be noted that 'Hold the Line' as per the SMP2 may mean maintain existing defence levels rather than maintaining the current standard of protection into the future (which would require defence improvement). The implementation strategy (SEFRMS) is still in development and not available for the SFRA to compare recommended defence works in this study with the wider strategy.

Site Constraints

4.6.3.5 The strategic assessment of flood risk in Section 7 identifies the need to upgrade the flood defences due to the surrounding low-lying land and the need to protect existing infrastructure. However, these factors are also constraints which may limit the implementation of the generic policies.

4.6.3.6 A number of specific constraints apply to the study area, these are listed below;

Environmental

- Sites of Special Scientific Interest (SSSIs)
- RAMSAR Sites
- Special Protection Areas (SPAs)
- Special Areas of Conservation (SACs)
- Other protected zones
- Topographical and landform constraints

Infrastructure

- Infrastructure Services (mainly transport and utilities)
- Access (mainly public safety and emergency services access)

4.6.3.7 Other potential constraints include the development vision as set out in the Regional Spatial Strategy or local planning strategies as well as land owner issues and costs. In particular the existing planning consent for the ICI site places restrictions on the flexibility of this site for other uses and developer contributions. *(NB. At the time of issue it is the government's intention to rescing the RSS).*

4.6.3.8 Information in the draft SMP2, environmental designations, OS mapping and site reconnaissance inspections (undertaken in April 2005) were used to establish the limits and boundaries of constraints on the delivery of defence improvement. They were also used to assess the topographical nature of the surrounding land in order to establish coastal defence polices most applicable to individual sections of the Estuary coastline. A summary of these constraints can be seen in Table 4.66.4.6 and further details are described in paragraphs 4.6.3.15 to 4.6.3.29.

Table 4.66.4.6 – Summary of Potential Constraints on Delivery

Section	Physical Constraints	Environmental Designations	Linkages with Adjacent Defence Improvements
A – B	-	RAMSAR Site, SPA, SSSI, SAC	-
B – C	Severn beach residential area / infrastructure	RAMSAR Site, SPA, SSSI, SAC	Works need to be undertaken in combination with sections A-B and C-D to be effective
C – D	Railway line Roads	RAMSAR Site, SPA, SSSI, SAC	-
D – E	Railway line	RAMSAR Site, SPA, SSSI, SAC	-
E – F	Railway line Road (A403)	RAMSAR Site, SPA, SSSI, SAC	-
F – G	Railway line	RAMSAR Site, SPA, SSSI, SAC	Works need to be undertaken in combination with sections D-E and E-F to be effective
G – H	Railway line	RAMSAR Site, SPA, SSSI, SAC	-
H – I	-	SSSI, SAC	-
I – J	Docks and general Infrastructure	SSSI, SAC	Works need to be undertaken in combination with sections J-N to be effective
J – K	Docks and general Infrastructure	SSSI, SAC	Works need to be undertaken in combination with sections K-N to be effective
K – L	Docks and general Infrastructure	RAMSAR Site, SPA, SSSI, SAC	Works need to be undertaken in combination with sections J-N to be effective
L – M	Docks and general Infrastructure	RAMSAR Site, SPA, SSSI, SAC	Works need to be undertaken in combination with sections J-N to be effective
M – N	Docks and general Infrastructure	RAMSAR Site, SPA, SSSI, SAC	Works need to be undertaken in combination with sections J-N to be effective
N – O	Docks and general Infrastructure	RAMSAR Site, SPA, SSSI, SAC	Works need to be undertaken in combination with sections J-N to be effective

Section	Physical Constraints	Environmental Designations	Linkages with Adjacent Defence Improvements
O – P	Docks and general Infrastructure	RAMSAR Site, SPA, SSSI, SAC	-

Natural England Considerations

4.6.3.9 Natural England (NE), previously English Nature (EN), were consulted during Phase 2 with regard to the ecological impacts associated with upgrading flood defences in the Severn Estuary. The Estuary is designated as a SSSI, SPA, SAC and Ramsar site. NE has responsibility for protecting such sites.

4.6.3.10 The area is designated for the saltmarsh and intertidal mudflat habitats, which support internationally important numbers of overwintering birds. It is anticipated that any upgrading of flood defences will require direct loss of designated land and it is therefore likely that any works to the flood defences will have a significant effect on the European designated sites. An appropriate assessment will need to be undertaken to determine whether flood defence proposals will have adverse impacts on the site's integrity.

4.6.3.11 The effects of the development, either alone or in combination with other projects, need to be assessed. Development causing significant impact on a designated site may only be undertaken for reasons of over-riding public interest. Any loss of designated habitat is likely to require compensation through the creation of such habitats elsewhere within the estuary, consequently incurring associated financial costs.

4.6.3.12 NE advised that, when reviewing potential for improvements to flood defences, consideration will need to be given to maintaining bird sight lines by avoiding significant increases in heights of defences. NE also advised that consideration is to be given to minimising disturbance to birds by avoiding work during the most sensitive period between October and March.

4.6.3.13 Meeting notes recording the consultations are provided in Appendix A4.3.

4.6.3.14 These constraints and the requirement for detailed and specific assessment of the impacts of flood defence improvement works on the designated sites will affect the delivery of flood defence improvement works. Design and Engineering will need to take the environmental impacts into account, planning and delivery times may be lengthened and there will be cost implications as a result of the tight restrictions on development.

Local Coastal Defence Policy Selection

4.6.3.15 Each section of the tidal coastal defences, as described in section 4.5 and shown on Figure 4.3 – Flood Defence Review: Assessment and Current / Future Levels of Protection, provides a different scenario on which to base the policy selection. It is therefore critical to individually review each section as a separate element.

Section A-B Aust to Binn Wall

4.6.3.16 This part of the coastal defence is fronted by a SSSI comprising a salt marsh. The existing defence is an earth embankment and is in good/fair condition. There is no option to advance the line due to the environmental restrictions, therefore only two options remain:

- **Hold the line**, upgrade and improve the existing defences at their current location, and
- **Retreat**, although feasible there are no clear engineering or financial benefits from such a course of action.

4.6.3.17 Although there are no clear constraints to the landward side of this defence, it is reasonable to assume that there would be no point in relocating or retreating the existing line of defence other than to address the issue of coastal squeeze. Therefore, it is considered that upgrading the existing defences to compensate for the climate change crest standard is the most feasible option.

Section B-C The Binn Wall

4.6.3.18 This section, which includes Binn Wall, is formed solely of reinforced concrete and rock structures, fronted by armour stone and held in place by sheet piles. The structure is currently in a good/fair condition. There is no obvious reason why the structure cannot be maintained throughout its design span at its current position.

4.6.3.19 Restrictions and constraints imposed by surrounding infrastructure would prohibit any form of retreat.

4.6.3.20 There are design issues regarding the tie-ins with the adjacent coastal defence structures along the line of linear defence, both of which are concurrently lower.

Section C-D Severn Beach to ICI Landfill

4.6.3.21 This section of the tidal coastal defences is an embankment with a grouted stone revetment fronted by a SSSI. Railway and road links are in place to the landward side of the structure, and prohibit any form of local retreat. The nature and design of the structure however, would permit increasing its height along the current alignment. Therefore holding the line and upgrading the existing structure is an appropriate policy.

4.6.3.22 A short section of this defence is constrained by a residential road to the landward side, and a small retaining wall will be required at the toe of the extended embankment.

Section D-E ICI Landfill

4.6.3.23 This section of the coastal defence consists of an area of raised ground in the form of a disused landfill (formerly an ICI tip), currently lying within the SSSI designation. Over the length of this section there is a level deficit of 1.2mAOD from the current required design levels / crest heights.

4.6.3.24 The option to retreat is partially prohibited due to the proximity of infrastructure; the actual current alignment along this section of defence is unclear and should generally be accepted as the high water mark. Local or restrained retreat and construction of an embankment to the landward side of this structure is an option.

Section E-F ICI Landfill to Crooks Marsh (Chittening Warth)

4.6.3.25 A raised railway embankment forms this part of the tidal defence and there are problems associated with upgrading along its current alignment because the line remains in use. Physical (A403) and environmental (SSSI) constraints prohibit any form of retreat or advance locally or otherwise. Therefore raising the railway line either locally or along its entire length is perhaps the only practical option, although with associated complexities. As ownership of the structure would remain with Network Rail, no maintenance or monitoring controls could be introduced by the EA. It is uncertain whether Network Rail would support the proposal of raising the embankment so that it could act as "formal flood defence". The structure would therefore not fulfil the requirements of a flood defence structure. This option needs to be compared against advancing the line and constructing a completely new and freestanding structure to the landward side. This would be an intrusion into the SSSI and the costs and impact to the environment would require significant evaluation. There are practical difficulties with implementing all options for this section of defence.

Section F-G Crooks Marsh to Esso Fuel Depot (Severn Way)

4.6.3.26 This section is an earth embankment which supports the Severn Way Footpath, it passes over two flapped outfalls and has SSSI designation. The structure is located within the designated boundaries and it can be assumed that local retreat or revision of the current alignment are both applicable policies. As the current structure falls short of the required design height, raising the structure at its current location should be the chosen policy.

4.6.3.27 There are design issues regarding the tie-ins with the adjacent coastal defence structures along the line of linear defence, both of which are concurrently lower.

Section G-P Bristol Port Company Avonmouth Docks

4.6.3.28 The entire defence section encompassing the Avonmouth Docks is subject to heavy infrastructure constraints, with the presence of roads, buildings (both domestic and commercial), services and environmental designations limiting any form of retreat or advance. There is one exception, section H-I, which comprises a masonry / concrete wall fronted by a network of pipes. The SSSI designation along this stretch of the coast is limited to the high water mark and, due to the depth of the prevailing foreshore, advance of the current defence alignment is an option. This may also be necessary due to the difficulty of tying into the other existing coastal protection structures in order to maintain a continuous line of defence.

4.6.3.29 The lock and dock gates located at the entrance to the harbour are a major concern. The gates do not form a functional part of the existing defences due to their current design height restrictions. New gates or raising of the existing lock gates will be required. Upgrading and constructing new defences in order to tie-in with the lock gates will require detailed examination and it is proposed that these will follow the alignment of the existing defences. It should be noted that there are plans for a new deep sea terminal at this location and therefore the measures noted above may be replaced by the approval of the new terminal. It is recommended that the plans for the new terminal are reviewed to establish if they meet the requirements of the defence improvements or whether further work may be needed.

4.6.3.30 Table 4.66.4.7 summaries the generic policies that could be adopted for each flood defence section.

Table 4.66.4.7 – Generic Policies for Each Flood Defence Section

Section	**Option 1** Hold the Line/ Upgrade	**Option 2** Retreat/ Construct	**Option 3** Advance/ Construct	**Option 4** Do nothing/ Maintain
A-B	✓			
B-C	✓			
C-D	✓			
D-E	✓	✓		
E-F	✓		✓	
F-G	✓			
G-H	✓			
H-I	✓		✓	
I-J	✓		✓	
J-K	✓			
K-L	✓			
L-M	✓			
M-N	✓			
N-O	✓			

Section	**Option 1** Hold the Line/ Upgrade	**Option 2** Retreat/ Construct	**Option 3** Advance/ Construct	**Option 4** Do nothing/ Maintain
O-P	✓			

Generic Design Selection

4.6.3.31 The construction of any coastal defence requires that several stages of assessment and evaluation be carried out prior to the design phase. This review has been carried out and as such fulfils the requirements set by DEFRA and the EA under Coastal Defence Design and Practice Guidance (R&D Technical Summary W5B-004/TS).

4.6.3.32 A number of criteria were considered in selecting generic designs and preparing broad order cost estimates including:

1) Tide Levels and Wave conditions;
2) Beach or Shore Platform levels;
3) Geotechnical characteristics of the ground conditions;
4) Existing tidal flood defence construction and crest levels; and
5) The need to avoid failure and maintain sustained structural integrity through early upgrade rather than permitted failure and a complete rebuild.

4.6.3.33 Table 4.6.4.8 summarises possible design scenarios for the chosen policies on each section of the defences. Average heights for the defence sections were obtained using the 2009 crest level survey. For defence sections not surveyed in 2009, 2004 survey data was used.

Table 4.6.4.8 – Design Scenarios for Chosen Policies

Section	Phase 2 Design Scanarios and Conceptual Designs	Phase 4 Design Scenario 1 – Hold Existing Line	Phase 4 Design Scenario 2 – Retreat Defences Landwards	Phase 4 Design Scenario 3 – Advance Defences Seawards	Appropriateness of phase 2 conceptual design.	Scale of implication of change from phase 2
A-B	**Hold existing line:** Increase embankment height by approximately 1.00m. (Allowance for masonry structures at outfall points)	Increase embankment height by approximately 1.50m. (Allowance for masonry structures at outfall points)	N/A	N/A	Phase 2 conceptual design with increased crest height likely to be appropriate. Design feasibility review recommended.	Cost - Medium; Environmental - Medium; Engineering - Medium
B-C	**Hold existing line:** Maintain and monitor existing defences	Requires raising by ~0.5m.	N/A	N/A	Design review essential for increased crest height.	Cost - High; Environmental - Medium; Engineering - High
C-D	**Hold existing line:** Increase grouted stone revetment / embankment by approximately 0.10m (Allowance for retaining walls)	Requires raising by ~1m.	N/A	N/A	Design review essential for significant increase in crest height	Cost - High; Environmental - Medium; Engineering - Medium

Section	Phase 2 Design Scanarios and Conceptual Designs	Phase 4 Design Scenario 1 – Hold Existing Line	Phase 4 Design Scenario 2 – Retreat Defences Landwards	Phase 4 Design Scenario 3 – Advance Defences Seawards	Appropriateness of phase 2 conceptual design.	Scale of implication of change from phase 2
D-E	**Retreat Defences Landwards:** Construct new embankment to landward side of raised ground at disused ICI tip.	N/A	Construct new embankment to landward side of raised ground at disused ICI tip.	N/A	No change to Phase 2 conceptual design. Design review not required at this stage	Cost - Low; Environmental - Low; Engineering - Low
E-F	**Retreat Defences Landwards:** Increase the height of the railway locally and retreat the current alignment. **Advance Defences Seawards:** Construct a new embankment to the seaward side of the existing structure.	N/A	Increase the height of the railway locally and retreat the current alignment.	Construct a new embankment to the seaward side of the existing structure.	No change to Phase 2 conceptual designs. Design review not required at this stage	Cost - Low; Environmenal - Low; Engineering - Low
F-G	**Hold existing line:** Increase embankment height by approximately 1.00m. (Allowance for masonry structures at outfall points)	Increase embankment height by approximately 1.00m. (Allowance for masonry structures at outfall points)	N/A	N/A	No change to Phase 2 conceptual design. Design review not required at this stage	Cost - Low; Environmental - Low; Engineering - Low

Section	Phase 2 Design Scenarios and Conceptual Designs	Phase 4 Design Scenario 1 – Hold Existing Line	Phase 4 Design Scenario 2 – Retreat Defences Landwards	Phase 4 Design Scenario 3 – Advance Defences Seawards	Appropriateness of phase 2 conceptual design.	Scale of implication of change from phase 2
G-H	**Hold existing line:** Replenish existing embankment and place armour stone at toe, secured by sheet piling. (Allowance for geotextiles and geomaterials)	Requires raising by ~1m.	N/A	N/A	Design review essential for increased crest height.	Cost -High; Environmental - Medium; Engineering - Medium
H-I	**Hold existing line:** Upgrade existing masonry/ concrete structure Construct reinforced retaining wall approximately 1.2m in height. **Advance Defences Seawards:** Extend adjacent embankments and allow for tie-ins to masonry structures behind pipe work. (Allowance for fill material around pipes)	Upgrade existing masonry/ concrete structure Construct reinforced retaining wall approximately 1.2m in height.	N/A	Extend adjacent embankments and allow for tie-ins to masonry structures behind pipe work. (Allowance for fill material around pipes)	No change to Phase 2 conceptual designs. Design review not required at this stage	Cost - Low; Environmental - Low; Engineering - Low

Section	Phase 2 Design Scenarios and Conceptual Designs	Phase 4 Design Scenario 1 – Hold Existing Line	Phase 4 Design Scenario 2 – Retreat Defences Landwards	Phase 4 Design Scenario 3 – Advance Defences Seawards	Appropriateness of phase 2 conceptual design.	Scale of implication of change from phase 2
I-J	**Hold existing line:** Increase height of existing embankment by approximately 0.5m along parts of this section of defence. Implement toe protection.	Increase height of existing embankment by approximately 0.5m along parts of this section of defence. Implement toe protection.	N/A	N/A	No change to Phase 2 conceptual design. Design review not required at this stage	Cost - Low; Environmental - Low; Engineering - Low
J-K	**Hold existing line:** Upgrade existing lock gates and construct concrete tie-ins to embankments either side of the Dock entrance. (Allowance for ramp to access harbour control)	Upgrade existing lock gates and construct concrete tie-ins to embankments either side of the Dock entrance. (Allowance for ramp to access harbour control)	N/A	N/A	No change to Phase 2 conceptual design. Design review recommended in light of improvements needed to defence sections K – P and proposed deep sea terminal.	Cost - Low; Environmental - Low; Engineering - Low
K-L	**Hold existing line:** Place armour stone at toe of embankment, held in place by sheet piling.	Requires raising by ~0.5m.	N/A	N/A	Design review essential for increased crest height.	Cost – High; Environmental - Medium; Engineering - Medium

Section	Phase 2 Design Scenarios and Conceptual Designs	Phase 4 Design Scenario 1 – Hold Existing Line	Phase 4 Design Scenario 2 – Retreat Defences Landwards	Phase 4 Design Scenario 3 – Advance Defences Seawards	Appropriateness of phase 2 conceptual design.	Scale of implication of change from phase 2
L-M	**Hold existing line:** Place armour stone at toe of embankment, held in place by sheet piling.	Requires raising by ~0.5m.	N/A	N/A	Design review essential for increased crest height.	Cost - High; Environmental - Medium; Engineering - Medium
M-N	**Hold existing line:** Maintain and monitor existing defences	Requires raising by ~0.5m, design feasibility review required	N/A	N/A	Design review essential for increased crest height.	Cost – High; Environmental – Medium; Enginering - High
N-O	**Hold existing line:** Upgrade existing masonry structure	Requires raising by ~0.5m, design feasibility review required	N/A	N/A	Design review essential for increased crest height.	Cost – High; Environmental – Medium; Engineering - Medium
O-P	**Hold existing line:** Maintain and monitor existing defences	Requires raising by ~0.5m, design feasibility review required	N/A	N/A	Design review essential for increased crest height.	Cost – High; Environmental – Medium; Engineering - High

4.6.3.34 Where the chosen policy is to upgrade the existing defences along their current alignment, then the designs have been based on increasing the average height of the existing defence sections to the industry accepted minumum design standards. These generic conceptual designs will help provide a tenable preliminary estimate of the costs.

Conceptual Designs

4.6.3.35 For the purpose of producing broad cost estimates, nine conceptual designs were developed in order to categorize and illustrate potential improvement works to the existing defences. It should be noted that these designs were carried out for phase 2 of this SFRA and have not been updated for phase 4. Table 4.6.4.8 outlines where these designs are still applicable and where a design review is recommended. The proposed conceptual designs are:

1) Upgraded Grouted Stone Revetment: Increase the height of the existing structure by 0.20m. (Drawing 002563/01)

2) Upgraded Grouted Stone Revetment and Retaining Wall: Increase the height of the existing structure by 0.20m and construct retaining wall to the landward side. (Drawing 002563/02)

3) New Embankment (ICI tip): Construct a 0.20m to 1m high earth / clay embankment landward of raised ground. (Drawing 002563/03)

4) New Embankment (Chittening Warth): Construct a 2.5m high earth / clay embankment seaward of the existing line of defence. (Drawing 002563/04)

5) Upgraded Embankment with Rock Armour: Replenish existing embankment, place rock armour at toe and secure with sheet piling. (Drawing 002563/05)

6) Upgraded Embankment (Aust Warth): Increase the height of the existing structure by approximately 1m. (Drawing 002563/06)

6a) Upgraded Embankment: Increase the height of the existing structure by approximately 1m. (Drawing 002563/06a)

7) Concrete Wall (Avonmouth Docks): Construct reinforced concrete wall approximately 1.2m high. (Drawing 002563/07)

8) Concrete Wall (Avon Bridge): Construct reinforced concrete wall approximately 2m high. (Drawing 002563/08)

4.6.3.36 No specific details or designs have been considered for modification to the lock gates at the dock entrance (Section J-K) at Avonmouth and a lump sum cost has been included based on consultation with BPC and evaluations of the existing structures. Likewise specific details for tie-ins (either side of Section H-I and B-C) have been omitted and provisional lump sum costs are included.

Additional Protection to Prevent Wave Overtopping

4.6.3.37 Even if a defence system was constructed to 10.74 mAOD, floodwater could still overtop the defences as a result of wave action. However when the joint probability of extreme still water level and wave height is taken into account this becomes less significant. . Table 4.6.3a provides details of the extreme water levels and significant wave heights experienced along Avonmouth, however it should be noted that these do not take account of the joint probability of extreme still water level and wave height as described in chapter 5 and therefore to combine these values is conservative.

Table 4.66.3a – 200 year Extreme water levels and significant wave heights (2110)

Location	Extreme Water Level (mAOD)	Significant Wave Height (m)
From northern boundary to M4 bridge (JPA 3, refer to Table 5.8.1)	10.48	1.21
From the M4 bridge to Severn Way (JPA 2, refer to Table 5.8.1)	10.28	1.57
From Severn Way to Avon mouth Bridge (JPA 1, refer to Table 5.8.1)	10.19	2.15

4.6.3.38 In order to establish new crest heights which would eliminate the effects of wave overtopping, two different design criteria need to be assessed:

- The tolerable mean discharge at the peak of the tidal flood;
- The tolerable total volume that enters the study area.

4.6.3.39 The tolerable discharges (m^3/s/m) are based on Box 5.1 of Technical Report W178 (HR Wallingford, 1999) and all flood defences are defined as Revetment Seawall and no damage is accepted. Tolerable total volumes have been based on engineering judgement and the applied tolerable inflow volume is 40m^3 / m of defence. The wave overtopping volumes along Avonmouth have been calculated using the future 1 in 200 year return period extreme water level and significant wave heights (as shown above)

4.6.3.40 Table 4.66.4.9 shows the target flood defence crest heights needed to completely negate the effects of wave overtopping, within the foregoing stated tolerances, and associated engineering requirements and implications. The table only shows those sections which have been assumed to be exposed to direct and significant wave attack (see Section 5).

Table 4.66.4.9 – Required Crest Levels to Prevent Wave Overtopping

Section	Target Crest Level mAOD	Engineering Requirements	Implications
A-B	11.9	Existing embankment may be raised by additional land take to landward side. New outfall structures at Cake Pill and Chestle Pill needed.	Additional land take High cost
B-C	12.0	Over 1.5m to be added to the existing Binn Wall structure. This may require a major reconstruction. There may be difficulties at Severn Crossing because of implications for maintenance access.	Very high cost
C-D	12.0	Extension of Binn Wall to the south in front of existing houses. Additional land take to raise the existing faced embankment.	High cost Additional land take
D-E	12.0	Embankment over existing landfill area.	Loss of habitat – environmental impact
E-F	12.0	Either: High embankment on existing foreshore; or: Major structure to seaward of the railway; or: New embankment at location of railway, possible realignment of A403 New structure at New Pill.	Very high, environmental impact Very high cost, some environmental impact Closure of railway, high cost High cost
F-G	12.0	Either: High embankment on existing foreshore; or: Major structure to seaward of the railway; or: New embankment at location of railway, possibly some encroachment on SSSI. New structures at Stup Pill and Mitchell's Outfall.	Very high environmental impact Very high cost, some environmental impact Closure of railway, environmental impact High cost
G-H	12.2	New sea wall structure including reconstruction at Holesmouth outfall.	Very high cost

Section	Target Crest Level mAOD	Engineering Requirements	Implications
H-I	12.4	New sea wall structure. New structure at Elbury/Kingsweston outfall.	Very high cost High cost
I-J	12.4	Embankment.	Some land take within port
J-K	12.4	New lock gates to be extended to required height. Tie-in structures required.	High cost Restriction of access to jetties

4.6.3.41 Table 4.66.4.9, which is based on defence design levels for a 1 in 200 year return period still water tidal surge event with climate change plus the highest significant wave height estimates, shows that significant increases to the current crest levels of the defences would be required to ensure no significant additional inundation as a result of wave overtopping and hence significantly reduce residual risks.

4.6.3.42 All sections would have to be raised between 1.2m and 1.7m higher than the conceptual design crest level at 10.74 mAOD. This would be a substantial engineering scheme having considerable infrastructure and environmental constraints.

4.6.3.43 Considering the Joint Probability Assessment (undertaken by ABPmer, 2005) the extreme water level and significant wave height detailed in table 4.6.3a would have a return period greater than 200 years. These values have been used to demonstrate the importance of accounting for wave overtopping. Consequently the values detailed in Table 4.6.4 veer on the conservative side. Prior to upgrading the defences a more detailed study would need to be undertaken to properly assess the residual risk from wave overtopping, in accordance with the requirements of PPS25, and the optimum defence crest level.

Cost Estimates for Raising Defences

4.6.3.44 During Phase 2 of this SFRA, broadly based cost estimates for raising the existing defences to crest levels of 9.59mAOD and 10.09mAOD were prepared on the basis of indicative average civil engineering works required for each section. As mentioned in 4.6.3.35; revised conceptual designs have not been carried out for phase 4 however an indication of the revised costs have been provided. The increases in cost have been categorised into low, medium and high based on the level of additional works required. A percentage increase has then been applied to the linear costs as follows:

- Low estimated increase in cost:, a 10% increase in cost has been applied

- Medium estimated increase in cost:, a 25% increase in cost has been applied
- High estimated increase in cost:, a 50% increase in cost has been applied

4.6.3.45 It should be noted that defence sections B-C, M-N and O-P were not identified as requiring work in phase 2 but do not meet the 10.74mAOD required crest level. Consequently, linear costs for these improvements have been taken from similar sections as specified in Table 4.6.4.10.

4.6.3.46 The linear cost rates used in phase 2 were based on unit rates from SPONS 2004 Price Guide with additional allowances for preliminaries, profit, and land acquisition. The costs include an 'optimism bias' of 1.6 to allow for cost uncertainties inherent in this type of work. With the inclusion of the 'optimism bias' the cost estimates can be expected to represent the worst case scenario.

Table 4.6.4.10 – Broad Order Cost Estimates for Raising Defences

Conceptual Design Sections	Drawing Ref	Length of Section (m)	Raising Defences to 10.24mAOD		Raising Defences to 10.74mAOD	
			Linear Cost (£/m)	Cost (£m)	Linear Cost (£/m)	Cost (£m)
1 (C-D)	002563/01	700	429	0.30	585	0.41
2 (C-D)	002563/02	100	1265	0.13	1898	0.19
3 (D-E)	002563/03	600	281	0.17	351	0.21
4 (E-F)	002563/04	1550	1285	1.99	1285	1.99
5 (G-H)/ (K-M)	002563/05	2600	1694	4.40	2118	5.51
6 (A-B)	002563/06	2700	515	1.39	773	2.09
6a (F-G)	002563/06a	900	515	0.46	515	0.46
7 (H-I)	002563/07	400	2060	0.82	2060	0.82
8 (N-O)	002563/08	40	281	0.01	351	0.01
(B-C)*	n/a	3000			1540	4.62
(M-N)**	n/a	1000	515	0.52	644	0.64
(O-P)**	n/a	200			515	0.10
Subtotal 1				**10.20**		**17.06**
Lock Gates				5.20		5.20
Tie Ins				0.55		0.60
Subtotal 2				**15.95**		**22.86**
Preliminaries				2.39		3.43
Contingencies				1.56		2.29
Profit				1.56		2.29
Subtotal 3				**21.53**		**30.86**
Optimism Bias				12.92		18.52

Conceptual Design Sections	Drawing Ref	Length of Section (m)	Raising Defences to 10.24mAOD		Raising Defences to 10.74mAOD	
			Linear Cost (£/m)	Cost (£m)	Linear Cost (£/m)	Cost (£m)
Total Estimated Cost				**34.4**		**49.4**
Total Estimated Cost including inflation (15%)				**39.6**		**56.8**

*based on costs from K-M

**based on costs from F-G

4.6.3.47 The original cost estimates were based on 2004 prices and made no allowances for future inflation in construction costs or ongoing maintenance and monitoring of the flood defences. Furthermore, the costs make no allowances for any additional pump storage schemes which may become necessary as sea levels rise and when the rhine system may no longer be able to drain to the sea by gravity. To provide an indication of the cost at 2010 prices an inflationary factor of 15% has been applied; therefore the total estimated cost for raising defences to the target crest level of 10.74m AOD is £56.8m.

4.6.3.48 However, based on the cost estimates prepared for raising the crest levels to 10.74mAOD it is envisaged that the construction cost of defences to protect the immediately adjacent land and infrastructure from overtopping from extreme tidal waves could be in the order of £200 - £300m. It is emphasised that this estimate is indicative only.

4.7. Funding Assessment

4.7.1 Potential for Developer Contributions

4.7.1.1 Work has begun on the Avonmouth and Severnside Integrated Development, Infrastructure and Flood Risk Management Study, aimed at identifying a long term planned approach to future development and infrastructure provision to 2050. Flood risk management will be a key element of this. The Study will quantify the extent to which infrastructure can be financed through Section 106, Community Infrastructure Levy (CIL), Tax Increment Funding (TIF), Accelerated Development Zone (ADZ) or other tariff mechanisms. Once available this study is expected to provide further information on the scope for develop contributions to add to the preliminary assessment completed for the Level 2 SFRA, as described in the following sections.

4.7.1.2 Section 106 of the Town and Country Planning Act 1990 enables a condition to be applied to planning consents in which the developer agrees to pay for the flood defence improvements necessary to alleviate flooding of the new development and / or flooding caused to other areas as a result of the new development.

4.7.1.3 Where flood defence works would provide a wider benefit, the funding provided by the developer is proportionate to the benefit provided to the new development.

4.7.1.4 A preliminary assessment on the scope for developer contributions has been undertaken by considering the likely scale and nature of new development and the approximate cost burden (based on estimates outlined in table Table 4.6.4.10).

4.7.1.5 By assigning values to the estimated area of new development, scale/type of development and approximate cost burden, a semi-quantified rating for the potential for developer contributions has been analysed. Table 4.7.4.11 outlines how these values were assigned.

Table 4.7.4.11 – Developer Contribution Classification

Estimated Area of New Development (ha) benefiting from flood defences	Value	Scale/Type of Potential Development	Value	Estimated Cost Burden to Developers (£m per ha of contributing development)	Value
≤100	1	Small infill	1	>0.2	1
>100 and ≤300	2		2	>0.1and ≤0.2	2
>300	3	Large Scale	3	≤0.1	3

4.7.1.6 By multiplying the three assigned values, a subsequent potential for developer contributions rating can be determined.

for instance, Estimated Area x Scale/Type x Estimated Cost Burden = Potential for Developer Contributions Rating

Table 4.77.4.12 – Developer Contribution Definition

Value	Potential for Developer Contributions Rating
<6	LOW
≥6 - 12	MEDIUM
≥12	HIGH

4.7.1.7 This assessment has assumed that the larger the area of development, the greater the area benefiting from improvements to flood defences. As shown in table 4.7.1, larger areas of development have been assigned higher values contributing to the potential for developer contributions rating.

4.7.1.8 The nature of small scale infill development could potentially make it difficult to programme and plan contributions and the development may take place over several years. Consequently developer contributions from small scale developments are expected to be less significant than for large scale developments.

4.7.1.9 An estimated cost burden to developers has been established for each of the defence sections. This has been calculated by dividing the cost of the relevant defence improvements by the area of contributing development. Figure 4.15 – Developer Contributions Assessment – Future Development shows the details of these calculations.

4.7.1.10 The calculation of areas of contributing development in Figure 4.12 – Flood Defence Review Summary – Generic Policies, Design Scenarios, Costings, Environmental Constraints are based on information on likely development areas provided by Bristol City council and on the assumptions that the former ICI area, which holds an existing consent, and the Bristol Port Authority area, which is exempt form developer contribution, are not included in the contributing development calculations.

4.7.1.11 Classifications have then been assigned as shown in Table 4.7.4.11 these are based on the assumption that for a typical 4ha development, £400,000 would be a reasonable contribution, £400,000 -£800,000 is unlikely and a contribution in excess of £800,000 is very unlikely. It should be noted that for defence sections where no contributing development has been identified, a value of 1 (maximum cost burden to developers) has been assigned; this assumes that should a development be proposed, the cost burden would be high.

4.7.1.12 The outcome of this assessment can be seen in Table 4.7.4.13. It should be recognised that no account has been taken of the effect of contributions on the viability of development. Further work is recommended to consider whether the order of cost to developers could be such as to deter developer investment in the area.

Table 4.7.4.13 – Potential for Developer Contributions

Defence Sections	Potential development benefiting from defence improvements	Estimated area of new development (ha)	Comments on scale/type of potential development	Estimated Cost Burden to Developers (£m per ha of contributing development)	Potential for developer contributions' rating

Defence Sections	Potential development benefiting from defence improvements	Estimated area of new development (ha)	Comments on scale/type of potential development	Estimated Cost Burden to Developers (£m per ha of contributing development)	Potential for developer contributions' rating
A – B	None indentified	Small	Small-scale development in this zone may take place but it is expected that scope for developer contributions would be limited.	N/A (£3.60m / none) Should a development be proposed, it is expected that the cost burden would be high.	Low
B – E	Build out of ICI Consent (450ha) Wastes Sites (13ha) Small scale infill and replacement in Severn beach	463	Development in this zone is likely to be a mix small-scale infill and larger developments on the ICI site; reasonable scope for developer contributions.	1.76 (£11.45m / 6.5ha) Note that the ICI Consent is not included in the contributing development.	Medium
E – G	Wastes Sites (20ha) Avonmouth Industrial Area (60ha) Build out of ICI Consent (20ha)	100	Developments are likely to be of a reasonably large scale, with direct benefits from defence improvements.	0.28 (£5.30m / 19ha) Note that the ICI Consent is not included in the contributing development.	Medium

Defence Sections	Potential development benefiting from defence improvements	Estimated area of new development (ha)	Comments on scale/type of potential development	Estimated Cost Burden to Developers (£m per ha of contributing development)	Potential for developer contributions' rating
G – I	Avonmouth Industrial Area (330ha) Avonmouth Port (60ha) Wastes Sites (40ha)	430	Developments are likely to be of a reasonable scale, with direct benefits from defence improvements.	0.1 (£8.53m / 85ha) Bristol Port Authority is not included in the contributing development as it is exempt from contributions to defence improvements.	High
I – P	Avonmouth Port (110ha) Deep Sea Terminal (180ha)	290	Development in this zone is likely to be small-scale infill around the port area.	N/A (£20.97m / none) Bristol Port Authority is exempt from contributions to defence improvements.	Low

4.7.2 Potential Funding Regimes

4.7.2.1 There are a number of possible sources of funding for flood defence improvements including:

- Implementation of SMP / CFMP policies
- Grant in Aid
- Local Levies
- Community Infrastructure levy
- Voluntary contributions form businesses and residents that would benefit from defence improvements

Implementation of the SMP / CFMP policies:

4.7.2.2 The Draft SMP2 states that the short term policy adopted (0-20yrs) is Hold the Line (HTL). This may mean repairing or replacing defences in the same place as they currently exist. There are two ways in which HTL may be implemented;

- maintaining the same Standard of Protection (SoP) as today
- not increasing the height of defences so that the SoP gradually decreases over time

4.7.2.3 Whether or not a HTL policy means increasing the size of built defences or not is not considered at an SMP2 level. The decision on how a HTL policy will be implemented will be considered in more detail by the SEFRMS.

4.7.2.4 A HTL policy does not guarantee funding for defence maintenance and / or capital works along these sections of the shoreline but it is expected that there will be a commitment to implementation of SMP policy. Similarly, the adopted CFMP policies are to 'take further action to reduce flood risk into the future'. Whilst CFMPs are primarily aimed at management of fluvial flooding, the drivers behind selection of the policy will apply to tidal flooding also. Identified actions to implement the CFMP policies include:

- Carry out multi-agency review of flood risk management led by the Environment Agency and involving South Gloucestershire Council and the Internal Drainage Board.

- Review maintenance operations to make sure they are proportionate to flood risk.

Grant in Aid:

4.7.2.5 Defra provide central government funding in the form of grant in aid for large flood and coastal defence works that meet the required cost benefit scores. Scheme assessments and allocation of funds are carried out by the Environment Agency.

4.7.2.6 Scheme selection is based on a priority score system, embracing a strong cost-benefit analysis approach. Schemes are formally assessed, normally through a project Appraisal Report (PAR) which provides information on the associated costs, benefits (monetary and non-monetary) and risks associated with the preferred scheme and rejected options.

4.7.2.7 The potential impact of increased flooding on existing development in the vicinity of Avonmouth, Avonmouth Docks and Severn Beach (Defence sections F to P, and B to C) is such that Defra funding for defence improvements may well be available, even in the absence of significant new development or developer contributions. This would be subject to the assessment procedures set out in the Defra Policy Statement: Appraisal of Flood and Coastal Erosion Risk Management (FCERM). Grant funding is less likely to be available for less developed areas where damages are subsequently lower and funding of improvements may not be justified on economic grounds.

Local Levies

4.7.2.8 Funds can be rasied for flood defence schemes which do not attract Defra grant in aid through levies imposed by the Environment Agency on Local Authorities, and by the Local Authorities themselves. Similar to grant in aid, schemes will normally be subject to scrutiny and assessed based on a cost-benefit analysis. As described above, due to the level of existing development, local levy funding is more likely to be available in the vicinity of Avonmouth, Avonmouth Docks and Severn Beach.

Community Infrastructure Levy (CIL)

4.7.2.9 The Community Infrastructure Levy was introduced in April 2010 and was intended to replace tariff based Section 106 obligations. The Government issued an overview document in November 2010, explaining the key features of CIL. This indicates that CIL is intended be tariff based and to be levied on new developments across a Local Authority area. Authorities can collaborate to pool their revenue to support the delivery of “sub-regional infrastructure”. CIL revenue can also be used in conjunction with other funding sources, including prudential borrowing, to cover funding gaps. It will be possible for revenue to be accumulated over time to fund larger projects.

4.7.2.10 Although the overview document is only indicative of Government intentions at this stage, it suggests that the funding of flood defence improvements is likely to benefit from the introduction of CIL. It should be emphasised, however, that Local Authorities will need to balance any aspirations for funding flood defences with the need to meet other infrastructure needs, including, transport, schools, social care facilities, etc.

4.7.2.11 The anticipated introduction of CIL points to the need for Local Authorities, the Environment Agency and the Lower Severn Internal Drainage Board to develop an agreed joint strategy, which will allow economic development to continue in the short term, whilst developing strategic proposals which could be delivered in the medium term.

4.7.3 Quick wins

4.7.3.1 As discussed in 4.6.3.29, the lock and dock gates located at the entrance to Avonmouth harbour are a major concern. Improvements to these gates could significantly improve the standard of protection of the defences around the Avonmouth docks; raising them to tie in with the neighbouring defences would increase the standard of protection to over 1000yr (based on the standard of protection of the surrounding defences as suggested by comparison of average crest level and still tide level).

4.7.3.2 The Masonry/Concrete wall stretching along defence section H-I and 200m north of I, lies approximately 0.5m lower than the neighbouring defence sections. In addition to the defence being lower than neighbouring defences, as discussed in section 4.7.4.10, it has also been identified as being in a potentially inadequate condition. Improving and raising this 500m defence to tie in with defence section I-J could increase the local standard of protection to >1000yr in the year 2010.

4.7.3.3 As discussed in section 5.5, at the request of the Environment Agency six defence systems were removed from the model due to a lack of confidence in, or knowledge about the details of these defences. Improvements to the condition of these defences could provide a significant increase to the standard of protection provided to the area.

4.7.3.4 These improvements have been identified as quick wins due to the relatively large impact that the work would have on the standard of protection provided. Costs and constraints taking these defence improvements works forward are not expected to be significantly different from the other improvements identified, however the relative benefit is high.

4.7.3.5 In considering potential quick win scenarios it would appear that a large benefit to SoP could be achieved through a relatively small level increase of the railway line. However this would not be a practical option due to the infrastructure constraints, furthermore Environment Agency guidance advises against the consideration of railway embankments as flood defences due to deficiencies in inspection and maintenance regimes.

Conclusions of Flood Defence Assessment

4.7.4 Flood Defence Assessment

4.7.4.1 The study has identified that the various failure scenarios, which have been presented and analysed, are diverse in their structure, composition and mode. It has also been suggested that several failure mechanisms are inherent in the different types of defence structure. Given time, some of these structures may fail. However, frequency or duration over which this will occur could vary widely.

4.7.4.2 The summary of the assessment for each of the sections illustrated in Figure 4.0 – Tidal Defence Assessment is as follows. The risk assessment considers the present day situation. As described previously many of the defence sections will become below standard (regardless of condition) in the future as sea levels rise.

4.7.4.3 The defence assessement risk scores have been revisited during phase 4 although the original data used for the assessment was not available for a thorough comparison. Risk scores have therefore been adjusted where the change in 200 year + climate change water levels from phase 2 to phase 4 leads to a change in the state of the defence at the peak water level, i.e. where defences are within their freeboard or are overtopping in the phase 4 assessment and were not in the phase 2 assessment (affecting the likelihood of a defence breach). The defence assessment risk scores are considered appropriate indicative measures, however as the assessment is largely based on information that is several years old, and is based solely on visual defence condition it is recommended that more detailed assessments are completed to inform future site specific studies.

Section A-B

4.7.4.4 This structure is in very good condition and is neither undergoing, nor is it foreseeable that it will undergo any continuous or sustained erosion in the near future. Predicted increases in extreme tides and the reduction of the warth will in time have an effect on this structure although it is expected that given the length of time that any encroachment might take, that suitable remediation or mitigation measures would be implemented. However this defence section is currently below the preferred design standard, therefore the risk category has been raised to intermediate. **Risk – INTERMEDIATE**

Section B-C

4.7.4.5 Despite undergoing constant wave attack at every high tide, this section of defence appears to be in good condition. Although these and associated processes are occurring continuously the rate at which the structure will decay is lessened due to its size, design and integral strength. Although any failure would have severe consequences it is likely that due to its constant use and regular inspection that remedial measures would be undertaken prior to any collapse of the structure. **Risk – INTERMEDIATE**

Section C-D

4.7.4.6 The faced earth embankment does not appear to be affected by any current erosive processes and due to its construction, design and the sizeable width of the warth, is unlikely to undergo an increased rate of decay. Thus any failure of this structure may result from internal failures, however, once again mitigation measures are likely to be undertaken prior to failure. **Risk – LOW**

Section E-F

4.7.4.7 Due to its use and the large fore-shore, this structure should be expected not to fail under any circumstances, although loading by trains may augment possible failure mechanisms. It should be considered that its construction and design is suitable, and the railway's monitoring regime would prevent even a partial degree of failure. The unlikely event of a sudden failure could be attributed to internal weaknesses and/ or excessive loading. **Risk – LOW**

Section F-G

4.7.4.8 This stretch of tidal defence in the form of an earth embankment exhibits the same attributes as section A-B and accordingly should be treated so. **Risk – LOW**

Section G-H

4.7.4.9 This scenarios falls within the boundaries of Avonmouth docks and it should therefore be considered that even partial failure would carry a degree of severity, when assessing the consequences. Although various forms or combinations are present in these defence structures, none are in good condition and it is unlikely that a monitoring scheme is in place to assess the effects of ongoing erosive processes on a regular basis. In the event of a significant failure, this may go unnoticed until the next high tide and could have an extremely detrimental effect on the surrounding infrastructure. **Risk – INTERMEDIATE**

Section H-I

4.7.4.10 Although comprising a combination of defence structures including rock armour, earth embankment and a brick wall, once again this section has been identified as possibly inadequate. The rate of erosion along the narrow foreshore is sustained and increased due to ongoing wave action, it should be expected that a rise in extreme tide levels would have a severe effect on the existing defences, undermining of which could lead directly to the collapse of the overlying pipe work and damage to surrounding infrastructure. **Risk – HIGH**

Section I-J

4.7.4.11 This small ballast bund forms a 'rudimentary' crest to the landscape and as such merely makes up the remaining height in order to attain the required level. Although insubstantial it is apparent that this structure is easily replaceable, due to the probability that it is most likely to fail once an extreme tide has receded, it should be considered adequate. **Risk – LOW**

Section J-K

4.7.4.12 It should be noted that the crest of the lock gates is beneath the level of the existing tidal defences and due to the fact that they open when the estuary tide reaches 7.5m AOD do not actually form part of the tidal defence and cannot therefore be assessed as such.

Section K-L

4.7.4.13 The flood embankment along this stretch of defences is in good condition, although this is to be expected as it was only constructed and completed in 2003. The slope angles are approximately 1:2 and greater. Near the lock it is set back from the sea wall and is relatively secure. For the remainder of this section the embankment rests at the edge of the revetment that is under constant wave attack during high tide and is in danger of being undermined. **Risk – INTERMEDIATE**

Section L-M

4.7.4.14 As with section K-L, an earth embankment backs this part of the defence, however, it is fronted by a revetment with rock armour in the form of demolition waste and reinforced concrete rubble. It is apparent that this has deteriorated since its installation and is no longer fulfilling the role for which it is designed. This has led to significant erosion along the toe of the embankment and the displacement of parts the structure. **Risk – HIGH**

Section M-N

4.7.4.15 The rest of the earth embankment which continues south east along the River Avon, is in good condition, with an increasing foreshore providing protection against erosive processes. Due to their location these defences are not susceptible to such severe wave attack as elsewhere, and generally erosion occurs through scour, surface weathering and degradation. In some areas this appears to have resulted in the reduction in the width of the embankment, substantial vegetation however, has increased the stability in other areas. **Risk – LOW**

Section N-O

4.7.4.16 A brick wall forms this length of the defence and although visibly in good condition, it is unclear what potential effectiveness it would have if an extreme tide were reached. It should also be noted that the land adjacent to this section is relatively high and the effect of a breach event may be constrained. **Risk – LOW**

Section O-P

4.7.4.17 Once again an earth embankment forms the final part of this defence, it is in good condition and merges into high ground, little or no erosion appears to be occurring. **Risk - LOW**

4.7.5 Flood Defence Engineering Assessment

4.7.5.1 It has been estimated that to raise the existing defences to a minimum level of 10.24 mAOD could potentially cost £39.6M to provide protection up to the predicted maximum 1 in 200 year return period still water level in 2110, and to raise the defences to a level of 10.74 mAOD which will provide 500mm freeboard could potentially cost £56.8M (both cost estimates have contingencies added). However, it has been demonstrated through hydraulic modelling that the Area Benefiting from the minimum defence upgrade to 10.24mAOD is insignificant to justify the expenditure. The Areas Benefiting from raising the defences a further 500mm to 10.74mAOD are notable, but these areas are located generally in marginal rural locations at the back of the floodplain (see Figure 4.13 – Flood Defence Review Areas Benefiting from Flood Defence Solution Minimum Level of 9.59 mAOD Achieved 200 Year Tide, 2 Year Fluvial, Future Case).

4.7.5.2 The implications of raising the defences in the Avonmouth/Severnside area against overtopping from extreme tidal waves in the Severn Estuary have been examined. These estimates indicate that the defences would need to be raised to levels up to 12.4mAOD and would cost in the region of £200 - 300m. The environmental impact of such significant works would probably preclude their implementation and the information provided in this report in this regard should only be used for guidance in this context.

4.7.6 Areas for Further Investigation

4.7.6.1 This study has highlighted several areas that would benefit from further investigation. It is recommended that the following points are addressed in the development of a Flood Management Strategy for Avonmouth / Severnside:

- A review of target crest levels / standard of protection to identify the optimum standard of protection provided (against a multi critera assessment (economic, engineering, environmental and social factors)). This should consider residual risks associated with overtopping of defences and breach and the safety of development, in accordance with PPS25 guidance.

- A review or the conceptual defence improvement designs and re-design to the phase 4 target crest levels, including an assessment of how the imrpvements can be delivered.

- An investigation and assessment of the permissions and consents required to implement the improvements

- Environmental Appraisal (a full Environmental Impact Assessment and associated studies are likely to be required for many of the improvement works)

- Consideration of how proposed improvement works relate to the wider Severn Estuary Flood Risk Management Strategy

- Timescales for improvements and phasing taking into consideration when funding may be available and timescales for developments to come forward.

- The assessment criteria for grant funding and likelihood of achieving successful applications

- Further work to consider whether the order of cost to developers could be such as to deter developer investment in the area.

- The feasibility of bringing forward ‘quick wins’ and associated timescales

- The feasibility of any improvements / raising of the railway embankment, particularly for defence section E-F, where there are significant difficulties associated with alternative improvements.

Mapping and Figures

Figure 4.2d – Defence Locations and Breach Locations

Figure 4.2e – Defence Locations and Breach Locations

Figure 4.2f – Defence Locations and Breach Locations

Figure 4.3 – Flood Defence Review: Assessment and Current / Future Levels of Protection

Figure 4.4 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 9.59mAOD Peak Flood Depths, With Defences, Future Case 200 Year Tide, 2 Year Fluvial

Figure 4.5 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 9.59mAOD Peak Flood V x D Products, With Defences, Future Case 200 Year Tide, 2 Year Fluvial

Figure 4.6 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 9.59mAOD Peak Flood Depths, With Defences, Future Case 1000 Year Tide, 2 Year Fluvial

Figure 4.7 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 9.59mAOD Peak Flood V x D Products, With Defences, Future Case 1000 Year Tide, 2 Year Fluvial

Figure 4.8 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 10.09mAOD Peak Flood Depths, With Defences, Future Case 200 Year Tide, 2 Year Fluvial

Figure 4.9 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 10.09mAOD Peak Flood V x D Products, With Defences, Future Case 200 Year Tide, 2 Year Fluvial

Figure 4.10 – Flood Defence Solution Actual Risk, Minimum PPG25 Level Achieved: 10.09mAOD Peak Flood Depths, With Defences, Future Case 1000 Year Tide, 2 Year Fluvial

Section 4 Appendices

A4.1 Site Photography

Appendix A4.1.doc

A4.2 Cross Sections

Appendix A4.2.xls

A4.3 Flood Defence Review 27 March 2005 Meeting Minutes

EN Meeting notes.pdf

Revision Status and Schedule of Changes

Section Revision Status

All technical revisions of the SFRA November 2010 release for Section 4 – Flood Defence Assessment are outlined below:

- Defence breach assessment reviewed based on the updated defence and tide level estimates (including the update to the Defra 2006 climate change guidance);

- Generic policies and conceptual design options reviewed based on the latest information. Target defence crest level reviewed and implications of the revised target level on the conceptual design feasibility and broad cost estimates assessed;

- Standard of protection for defences updated based on the Haskoning (2008) extreme tide level estimates. Standard of protection does **<u>not</u>** take into account wave action. Draft information from SEFRMS provided by EA used to inform SoP.

- Hydraulic model has **not** been re-run to estimate the benefit provided by defence improvements. Revised crest heights to prevent significant wave overtopping have been estimated. These do not take account of extreme still water level / wave height joint probability as this has not been updated to take account of the most recent tide level estimates.

- Broad assessment of funding sources and potential for developer contributions completed.

All technical revisions of the SFRA January 2007 release for Section 4 – Flood Defence Assessment are outlined below:

- Broad costs adjusted based on actual defence crest levels surveyed, previously approximated from LiDAR and NextMap SAR digital terrain models (DTM).

- Standard of protection for defences based on extreme water levels obtained from the PDMM (2003), and previous MAFF (1993) climate change guidance. Standard of protection has **<u>not</u>** been revised to comply with ABPmer (2005) tide levels for 2005 or the latest DEFRA (2006) climate change guidance.

- Indicative design crest levels and hydraulic modelling of design scenarios are **<u>not</u>** based on latest hydraulic model improvements as outlined in

Section 5, **nor** does it take into consideration the joint probability analysis of extreme surge levels and significant wave height from the ABPmer (2005) study.

Commentary on revisions

Defence breach assessment

The increases in future tide level estimates, largely resulting from the use of the current climate change guidance (Defra 2006) means that in general the future defence standard is lower than originally estimated in the initial phase of the study. The risk category for breaches 8 – 12 has been increased due to the greater likelihood of the defence being overtopped due to extreme tide levels. The design target crest level used for the defence assessment increased by 0.65m to 10.74 mAOD.

Generic policies and conceptual design options

The appropriate policies have been revisited with the latest information. In some cases policies such as do nothing are no longer considered appropriate as the future defence standard has reduced. A broad assessment of the implications of the design revisions has been completd for Phase 4. This has highlighted locations where the original conceptual design may no longer be appropriate and a design review is required. The broad cost estimates to implement the conceptual designs have been revised and increase from £32million to £56million (including inflation) to achieve the target crest level.

Standard of protection of defences

The revised estimate of defence standard baed on crest and still tide levels is similar for the present day to the original estimates but is significantly lower in the future. EA design SoP information also provided which is significantly lower tha previous assessments in places.

Assesment of funding sources developer contributions

The broad assessment completed for the SFRA indicates that securing sufficient funding for defence improvements is not guaranteed. This may have implications for existing and future development and it is therefore recommended that this is reviewed in greater depth as part of a specific flood management study (possibly linked with development of the SEFRMS).

Schedule of Changes – Latest release only

Numerous revisions have been made throughout section 4 as part of the Phase 4 (2010) update to the SFRA. Therefore it is not appropriate to provide a detailed schedule of changes. The bulk of the revisions relate to the items noted previously.

Section 5. Hydraulic Modelling

5.1. Revision Status

5.1.1.1 The hydraulic modelling was updated for the November 2010 (Phase 4) release of the SFRA, to take account of new LiDAR and defence crest survey data; updated extreme still tide levels and to provide results for additional scenarios. Revised wave height data was not available for this revision and therefore this has not been updated.

5.2. Previous Modelling Studies

5.2.1.1 A number of reports on previous modelling studies relating to the study area were reviewed. These included:

- River Severn Tidal Model Haw Bridge to Avonmouth Hydraulic Modelling Report, JBA Consulting, 2001;
- Avonmouth COMAH Sites: Flood Risk Assessment. Final Report, JBA Consulting March 2004;
- Avonmouth to Aust Tidal Defence Scheme: Joint Probability Analysis of Waves and Water Levels. Final Report, APBmer, October 2005

5.2.1.2 The full reviews of these studies are contained in Appendix A5.1.

5.3. Current Flood Mapping and Flood History

5.3.1.1 Figure 5.8.1 to Figure 5.3 – Environment Agency Midlands Region, Lower Severn Area Historic Flood Mapping Commission November 2000 Flood Event show flood inundations for three historical flood events (1976, 1981, 2000 respectively). The 1976 flood event indicates that this inundation was dominated by tidal flooding in the Severn Beach area. The 1981 flood event indicates that this inundation was dominated by tidal flooding north of Severn Beach. Of most interest to validating the fluvial performance of the TUFLOW flood model is the 2000 flood event. This flood map indicates inundation in the Dyer's Common and Almondsbury area.

Figure 7.2 – Environment Agency Flood Zones

5.3.1.2 shows the Environment Agency Flood Zones 3 and 2. These maps show that the majority of the study area is included in Flood Zone 2 and that nearly all the study area except the area around Avonmouth is within by Flood Zone 3.

5.4. Hydraulic Modelling of Study Area

5.4.1 Introduction

5.4.1.1 In order to establish the level of flood risk, and prepare extent, depth and velocity maps in line with the specification, a hydraulic model has been developed of the study area.

5.4.2 Type of Model Selection

5.4.2.1 The interaction between flood flows in the various channels, the flow across floodplains and the flood storage will all influence predictions of flood flow magnitude and water level.

5.4.2.2 Accordingly, a fully hydrodynamic model is deemed to be a means of accommodating factors relating to storage and the interaction of flows in the respective watercourses. To adequately represent the complex overland flow characteristics of this area, a two-dimensional model was developed.

5.4.3 Modelling Software Selection

5.4.3.1 In order to investigate the local flooding mechanisms in more detail, as required for a site specific Flood Risk Assessment, a 2D modelling approach has been chosen.

5.4.3.2 In order to achieve the required level of accuracy and degree of confidence in the results, the 2D computational hydraulic modelling package TUFLOW has been used.

5.4.3.3 The software calculates flood flow across a rectangular grid, using mass balance and momentum equations to accurately describe the flooding mechanism. The term “two dimensional” in relation to model type, refers to the ability of the software to resolve equations for flow and level in the X and Y horizontal planes. This allows simulation of water movement in any direction across the floodplain. Conventional 1D modelling (for example, iSIS), routinely used for estimating depth and flow in river channels, cannot achieve this.

5.4.3.4 The numerical model is built using remotely sensed topographic data, in this case from EA supplied LIDAR, to produce a digital terrain model of the catchment and its features.

5.4.3.5 TUFLOW also contains a 1D model (ESTRY Version 2006-06-BD), which allows representation of flow through channels and structures, such as culverts and weirs.

5.4.3.6 ESTRY was developed by WBM (the makers of TUFLOW) in 1972 and has been used on over 200 flood models over the past 30 years. ESTRY uses an explicit finite difference, second-order, Runge-Kutta solution technique (Morrison and Smith, 1978) for the 1D Shallow Water Equations (SWE) of continuity and momentum. The governing equations contain the essential terms for modelling periodic long waves in estuaries and rivers, that is:

- wave propagation;
- advection of momentum (inertia terms); and
- bed friction (Manning's equation).

5.4.3.7 In addition to the normal open channel flow, a number of special types of channel are available including:

- uniform open channel, with or without specified bed gradient;
- sub-critical and supercritical flow regimes;
- non-inertial channels;
- multiple circular or rectangular box culverts;
- bridges;
- weir channels for flow across roadways, levees etc;
- user defined structures; and
- uni-directional channels of any type capable of being specified, to allow flow in only one direction.

5.4.3.8 The development of the 1D elements in the 2D/1D model is discussed in this section.

5.5. Hydraulic Modelling of Study Area

5.5.1 Development of 2D Model Domain

Elevations for 2D Model

5.5.1.1 The basis of 2D model domains is usually a Digital Terrain Model (DTM) representing the ground levels of the model area. For this study, the DTM was derived through combining the following data sets, in order of preference:

- LiDAR from 2009 (2m resolution)
- LiDAR from 2007 (2m resolution)
- LiDAR from 2006, 2003, 2002 (1-2m resolution)

Figure 5.12 – LiDAR Coverage shows the LiDAR used for the model.

5.5.1.2 In accordance with usual modelling practice, it was decided to use filtered LiDAR data. Filtered LiDAR has buildings and vegetation removed, and is effectively the estimated ground surface. Due to the 2D domain cell size (5m / 20m), there is potential that critical flow paths could be blocked should the buildings remain in the DTM. The non-conveyance properties of the large buildings has been accounted for by increasing the assigned Manning's n roughness coefficient. Removing the buildings further aids the mapping, as it removes the 'dry' islands incorrectly shown for the buildings.

5.5.1.3 The combination of the LiDAR data sets (with priority in the order listed above) created a DTM for the derivation of 2D cell elevations. This DTM is shown in Figure 5.9 – Digital Elevation Model.

5.5.1.4 The extent of the 2D model was chosen to be slightly beyond the study area. The eastern extent was defined by an approximation of the 12.0mAOD contour as this was expected to be the highest flood level simulated in the study area.

Resolution of 2D Model

5.5.1.5 Two grid sizes have been used to represent the Avonmouth floodplain, 5m and 20m grid. The size of these cells was determined by consideration of the following issues:

- Desired level of detail in representing the hydraulic features of the area for the purposes of the SFRA, in particular the rhine network.
- Area of model
- Simulation times (expected to be over three tidal cycles)
- Expected time-step

The 5m grid size was used to model scenarios with small tidal events (1 in 2 year and 1 in 20 year return period) and large fluvial events. The 20m grid was used to model scenarios with large tidal events (1 in 200 year and 1 in 1000 year) and small fluvial events.

5.5.1.6 A 5m grid was chosen for the fluvial events to provide adequate representation of the rhine network. The larger (20m) grid size was used for the large tidal events, as the rhines are overwhelmed and reasonably unimportant for these events. In addition the 5m grid model had stability issues for the larger tidal flood events due to large volumes of the water inundating the model for these flood events, which results in large flood depths in the floodplain (2D domain) compared to the cell size. Instabilities are caused by large flood depths on small grid sizes.

5.5.1.7 Elevations at the centre of these cells and mid-points of cells edges were calculated from the DTM, shown in Figure 5.9 – Digital Elevation Model.

Manning's n for 2D Model

5.5.1.8 Manning's n values for each cell were derived from GIS representations of land use provided from Environment Agency MasterMap data. The Manning's n chosen for the various land surfaces are as follows:

- Roads = 0.025
- Paths = 0.030
- Roadsides = 0.040
- Rail Areas = 0.030
- Wooded Areas = 0.100
- Multi-surface = 0.050
- Natural Surface = 0.045
- Rocky Areas = 0.055
- Marshes = 0.060
- Rough Grass = 0.040
- Man-made Surface = 0.030
- Buildings = 1.000
- Water Surface of docks = 0.030

5.5.1.9 As discussed in paragraph 5.5.2.6, channels in the area north of the Cardiff - London railway line were modelled in the 2D. The channels in this area were represented with a Manning's n value of 0.025.

5.5.1.10 The OS MasterMap data was also used to identify polygons representing building outlines. As discussed previously, high Manning's n roughness coefficients were applied to these areas to effectively impede flood water conveyance.

5.5.2 Development of 1D Model Network

5.5.2.1 Bettridge Turner and Partners (BTP) had developed four models of the drainage system in the study area for the Lower Severn Drainage Board. These models were developed using the flood modelling package InfoWorks CS. The survey data used in developing these models was provided and funded by the Lower Severn Drainage Board.

5.5.2.2 The geometry of these InfoWorks CS models was converted into a GIS format and used in the 2D/1D TUFLOW model. BTP were then instructed by the Lower Severn Drainage Board to provide the requested data, which included hydrological inflows for various flood events.

5.5.2.3 Using this data, a 1D network representing the drainage system (open channels and pipes) for the majority of the study area was developed. This 1D network did not include any representation of floodplain areas as these were represented in the 2D domain.

5.5.2.4 The areas not covered by the existing InfoWorks CS models included an area at the southern end of the study area (bordering the Avon River) and a large area of relatively undeveloped land to the north of the London to Cardiff railway.

5.5.2.5 The southern area was not modelled in detail in the 1D network. The drainage of this area is largely dictated by an underground pipe drainage system, the details of which are not available in a suitable format. Furthermore, it was expected that BTP would create an InfoWorks CS model of this area in the near future. This model could then be easily integrated into the 2D/1D TUFLOW model.

5.5.2.6 Channels in the latter area (north of the railway line) were represented in the 2D domain using elevations from LiDAR. This northern area contains a number of culverts which were modelled in the 1D network and linked to the 2D domain. Details of the major structures included in the model were provided by Lower Severn Drainage Board.

5.5.2.7 Channels in the Marsh Common area were represented in the 1D and defined using the 2007 ground survey of the area.

5.5.2.8 The outlet details were derived either from the BTP InfoWorks CS models or data provided by the Environment Agency.

5.5.2.9 A review of the major connections included in the 1D network was undertaken by Lower Severn Drainage Board. The review concluded that connections represented in the existing BTP model under the M49 Motorway and the M5 interchange were no longer functional. Subsequently, they were removed from the 1D network in the TUFLOW model.

5.5.2.10 The Lower Severn Drainage Board review included an assessment of the rhine standing water levels. This data has been included in the hydraulic model to part-represent the ground water interaction.

5.5.2.11 The combined 1D network (nodes and channels) is shown in Figure 5.10 – 1D Model Network. The total 1D network includes over 700 channels and nodes. The entire 1D network has been included in the 20m grid model however for the 5m grid the 1D network to the north of the London to Cardiff railway line have been removed as the rhine network has been represented in the 2D domain.

5.6. Representation of Sea Defences

5.6.1 Crest Levels and Defences in 2D Model

5.6.1.1 The 2D model cell elevations (derived from the DTM) were supplemented with specific data to represent features such as road crests and flood defences. Infomaps Survey Ltd carried out a defence crest level survey in April 2009. This was supplied to Capita Symonds by the Environment Agency and was used to define the flood defence crest levels. It should be noted that this survey data did not cover the entire study area and as such defence sections I-P were derived from the Avonmouth to Aust Tidal Defence Survey, August 2005.

5.6.1.2 As discussed in Section 4, a number of sections of defences were identified during this study that were thought to be of a less than desirable standard. The decision was made that for the case of the defences in place (for instance, actual and residual risk assessments) these defences were assumed to make no contribution to protection of the area from inundation (they were not included in the model). The location of these defences (assumed to be removed) is shown in Figure 5.8 – Flood Defences Assumed to be Removed.

5.7. Development of Inflows and Known Water Levels for Model

5.7.1.1 Flood models require boundary conditions in order to represent various fluvial and tidal events. These boundary conditions are known water levels or inflows at various locations in the model.

5.7.1.2 For the 2D/1D TUFLOW model used in this study, there are three types of model boundary conditions:

1) Tidal boundary conditions (for instance, extreme storm surge water levels) were derived from combining estimated surge peaks and tidal curves;
2) Inflows from wave overtopping of the sea defences were derived from empirical formulae;
3) Inflows from rainfall on the catchment and the floodplain were derived from various hydrological techniques.

5.7.1.3 The derivation of these boundary conditions is detailed in this section.

5.8. Development of Tidal and Surge Boundary Conditions

5.8.1.1 The tidal boundary conditions for the 2D/1D TUFLOW model were derived from combining estimated surge peaks and tidal curves.

5.8.1.2 In general, storm surges are caused by the following effects:

- Barometric effect (low atmospheric pressure)
- Wind set-up
- Dynamic effect due to amplification of surge-induced motions and the geometry of the land (seiches, funnelling etc.)

5.8.2 Extreme Storm Surge Water Levels and Sea Level Rise

5.8.2.1 Extreme storm surge water levels used for this SFRA have been obtained from two sources. The first was obtained from a study that was undertaken by ABPmer in 2005: *"Avonmouth to Aust Tidal Defence Scheme: Joint Probability Analysis of Waves and Water Levels*" [ABPmer (2005)]. The ABPmer reports extreme water levels for a variety of return periods for the design year 2005, and are detailed in Table 5.1.

Table 5.1 – Extreme Water Levels (ABPmer, 2005)

Water level with a return period of	Avonmouth (m AOD)	JPA Site 1 (m AOD)	JPA Site 2 (m AOD)	JPA Site 3 (m AOD)
1 in 2 year in 2005	8.40	8.42	8.51	8.70
1 in 200 year in 2005	9.03	9.06	9.15	9.35
1 in 1,000 year in 2005	9.21	9.24	9.33	9.53
1 in 2 year in 2105	9.35	9.37	9.46	9.65
1 in 200 year in 2105	9.98	10.01	10.10	10.30
1 in 1,000 year in 2105	10.16	10.19	10.28	10.48

5.8.2.2 The second and current set of extreme storm surge water levels used in this SFRA have been obtained from a study undertaken by Royal Haskoning in 2008: "*Report on Regional Extreme Tide Levels, Extreme Tide Levels Update, Environment Agency, South West Region*" [RH (2008)]. The Avonmouth extreme water levels from the RH (2008) study are detailed in Table 5.2.

Table 5.2 – Avonmouth Extreme Water Levels (RH, 2008)

Water level with a return period of	Extreme Water Level (m AOD) 2007
1 in 2 year in 2007	8.29
1 in 20 year in 2007	8.72
1 in 200 year in 2007	9.16
1 in 1,000 year in 2007	9.46

5.8.2.3 It should be noted that the Royal Haskoning (2008) study was an update to a study that was undertaken by a consortium of Posford Haskoning and Mott MacDonald in 2003: "*Report on Regional Extreme Tide Levels, Environment Agency, South West Region*" [PDMM (2003)].

5.8.2.4 Modelling performed for this study uses both the updated Royal Haskoning (2008) extreme still water levels and the joint probability analysis by ABPmer (2005) – water level and wave heights. Between the JPA sites, the water level has not been interpolated to represent a sloping water surface along the frontage. Rather, discrete lengths of frontage have been allocated a water level based on the nearest and most representative JPA site, including around Avonmouth. This is necessary when the joint probability of wave action is considered.

5.8.2.5 The Royal Haskoning (2008) levels for Avonmouth were extrapolated to obtain extreme water levels for the 3 JPA sites (by assuming the same difference in water level between each of the JPA sites and Avonmouth). Details of the levels used in the model can be seen in Table 5.3

Table 5.3 – Extreme Water Levels for Various Return Periods Used in Modelling

Water level with a return period of	Avonmouth (m AOD)	JPA Site 1 (m AOD)	JPA Site 2 (m AOD)	JPA Site 3 (m AOD)
1 in 2 year in 2010	8.29	8.31	8.40	8.59
1 in 20 year in 2010	8.72	8.75	8.83	9.03
1 in 200 year in 2010	9.16	9.19	9.28	9.48
1 in 1,000 year in 2010	9.46	9.49	9.58	9.79
1 in 2 year in 2110	9.29	9.31	9.40	9.59
1 in 20 year in 2110	9.72	9.75	9.83	10.03
1 in 200 year in 2110	10.16	10.19	10.28	10.48
1 in 1,000 year in 2110	10.46	10.49	10.58	10.79

5.8.2.6 For the extreme water levels in 2110, the extreme water levels of Royal Haskoning (2008) have been extrapolated to 2110 by taking into account net sea level rise (climate change). The DEFRA supplementary note to operating authorities on the impacts of climate change, released October 2006, outlines sea level rise allowances for the South West region, as detailed in Table 5.4. Based on the DEFRA guidance, an allowance of 1000 mm has been adopted to extrapolate the extreme water levels over the 100 year planning horizon to 2110. The extreme water levels listed in Table 5.3 have been used.

Table 5.4 – Net Sea Level Rise Allowance (DEFRA, Oct 2006)

Administrative or Developed Region	Net Sea-Level Rise (mm/yr)			
	1990-2025	2025-2055	2055-2085	2085-2115
South West and Wales	3.5	8.0	11.5	14.5

5.8.3 Sea Water Level Profile during Storm Surge Events

5.8.3.1 The sea water levels during the design storm surge event have been constructed by superimposing a surge profile on a mean spring tide. In other words, the water levels during the tidal flood event with a return period of 1 in 200 year in 2110 were derived by summing the spring tide level in 2110 and a storm surge level.

5.8.3.2 Research carried out in the UK has shown that significant storm surge events often occur during spring tides. Therefore, it was decided to superimpose a storm surge on a spring tide.

5.8.3.3 The current mean high water spring tide level (MHWS) and the current mean low water spring tide level (MLWS) have been obtained from The Admiralty Tide Tables Volume 1 [The Hydrographer of the Navy (1996)]. The mean spring water levels in 2010 are:

- Mean high water spring level in 2010 = 6.72 mAOD
- Mean low water spring level in 2010 = -5.48 mAOD

5.8.3.4 The profile of the normal spring tide was obtained from recorded water levels at Avonmouth Gauging Station, provided by Proudman Oceanographic Laboratory. The available water level records at Avonmouth Gauging Station were recorded in the period 1 January 2003 to 31 December 2003 and have a data interval of 15 minutes.

5.8.3.5 The recorded water levels during the first days of January 2003 incorporate a representative mean spring tide at the port of Avonmouth. The tidal fluctuation at Avonmouth during a mean spring tide for this period was found to be 12.2 m.

5.8.3.6 Due to climate change, it is expected that the mean sea level will rise by rates outlined in Table 5.4 (DEFRA, 2006). It is assumed that both the MHWS and MLWS will proportionally increase with the mean sea level. For design year 2110, the MHWS and MLWS have been obtained by adding 1000 mm (2010 to 2025 x 3.5 mm/yr, 2025 to 2055 x 8.0 mm/yr, 2055 to 2085 x 11.5 mm/yr & 2085 to 2110 x 14.5 mm/yr) to the figures from Hydrographer of the Navy (1996).

- Mean high water spring level in 2110 = 7.72 mAOD
- Mean low water spring level in 2110 = -4.48 mAOD

5.8.4 Surge Profile

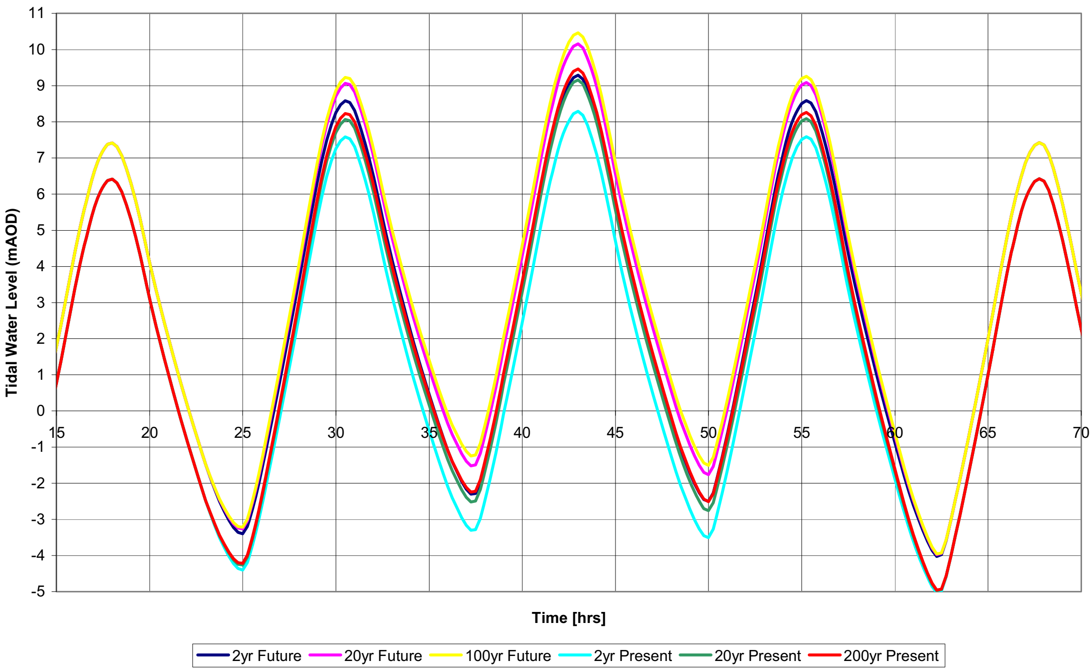
5.8.4.1 In general, it can be expected that a storm surge increases sharply, and has a relatively short period where it peaks and then decays. This trend can be best simulated by a water level with a regular half-sinusoidal shape.

5.8.4.2 The storm surges used have durations of 40 hours (equivalent to 1.7 days). The storm surge was assumed to peak at the same time as the astronomical high tide. This assumption is not based on any joint probability assessment. However, it is more likely that the effects of wind setup will be more pronounced at high tide due to the larger expanse of water (for instance, longer fetch lengths across water, more efficient conveyance of wind radiation stresses through deeper water).

5.8.4.3 The peak level of the storm surge is the residual of the estimated extreme water level minus the high water level during a normal spring tide. Storm surge-tide time-series have been developed for all 1 in 2 year, 1 in 200 year and 1 in 1,000 year JPA site scenarios as detailed in Section 5.9.2.

5.8.4.4 The water levels during a storm surge event with a return period of 1 in 2 year, 1 in 200 year and 1 in 1,000 year for the design year 2010 and for 2110 at Avonmouth are shown in Figure 5.8.1. Note that the tidal water levels at Avonmouth have not been used in the modelling, rather the extreme tidal water levels at each of the three JPA sites. Furthermore, the single spring tide profile has been used at all JPA sites. This may over estimate the trough of the wave profile further upstream the Severn Estuary.

Figure 5.8.1 – Tide and Surge Levels at Avonmouth



5.9. Development of Wave Overtopping Boundary Conditions

Samphire Hoe (Kent) in January 1996 (Photo courtesy of WCCP/Eurotunnel Developments Ltd)

5.9.1.1 Wave overtopping is a complex phenomenon in which the physics of the waves (for instance, the actual wave dynamics) exceed the capabilities of fluid flow numerical modelling. Hence, an empirical approach was used to calculate wave overtopping inflow rates. These inflow rates are a function of:

- The varying water level (derived from the tidal surge analysis described previously);
- The shape of the defence foreshore
- The crest of the defence
- The period and amplitude of the expected waves.

5.9.1.2 The sea defence was divided into wave exposed and non-wave exposed levee sections. Only the wave-exposed levees have been taken into account in the wave overtopping calculations. Along the Avonmouth site, there is 11.4 km of wave exposed sea defences.

5.9.2 Wave Overtopping Sections

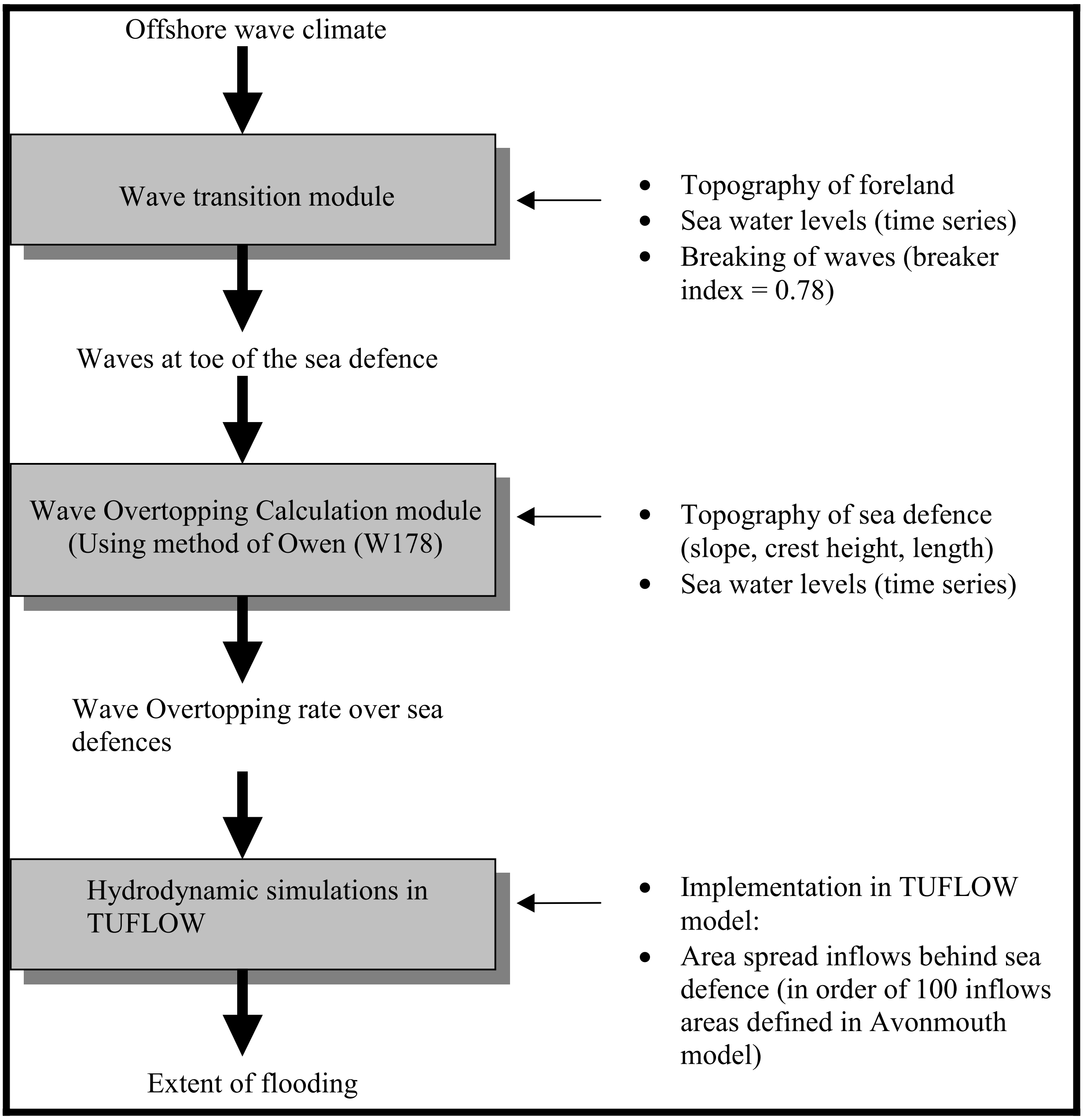
5.9.2.1 The wave exposed sea defences have been divided into eight sections. The eight distinct sections are shown in Figure 5.11 – Wave Overtopping Assessment Sections. For each section, one representative cross section profile was chosen by interrogating the DTM. The representative sections were later adjusted using point levels from survey collected along the flood defence from Avonmouth to Aust as part of the Sea Defence Topographic Survey commissioned by the EA.

5.9.2.2 Defence crest survey was taken in 2009 by Infomap survey Ltd. The new survey was compared against the Sea Defence Topographic Survey; the difference in levels was typically less than ~0.05m. This small change in the defence levels would have a negligible impact on the wave overtopping volume calculations, therefore it was decided that the defence levels would not be updated for the wave overtopping calculations. The characteristics of the eight levee sections are presented in Table 5.5 and the eight representative cross sections and corresponding JPA site locations are shown in Figure 5.11 – Wave Overtopping Assessment Sections.

5.9.2.3 The process to incorporate wave overtopping into the Avonmouth TUFLOW model involved using empirical formulae to derive time-varying inflows for various combinations of water levels and foreshore geometries, and is outlined in the following flow chart. This process was carried out for both defended and undefended cases as the height of the defence changes in these cases.

Table 5.5 – Wave Overtopping Sections

Reference Section	Section Length [m]	Typical Defended Crest Level (mAOD)	Corresponding JPA Site
WS_01	2,614	9.25	3
WS_02	1,203	10.54	2
WS_03	2,701	9.90	2
WS_04	1,501	9.73	1
WS_05	1,072	10.24	1
WS_06	921	10.53	1
WS_07	459	10.10	1
WS_08	903	10.74	1



5.9.3 Wave Transition Module

5.9.3.1 The wave transition module is used to assess the wave heights at the toe of the embankment for a given sea defence cross section, offshore wave climate and still water level time series at sea. The module results in a time series of the significant wave height at the toe of the embankment.

5.9.4 Offshore Wave Climate

5.9.4.1 In general, there are two types of waves: short waves and swells. Short waves are wind-generated waves and have a wave period in the range of 1 second to 10 seconds. Swells have typical wave periods in the range of 10 seconds to 20 seconds. In this study, only short waves have been considered with regard to wave overtopping over the sea defences.

5.9.4.2 Along the Avonmouth coastline, the *Severn Estuary Shoreline Management Plan Phase II Report (2000)*, reports the following nearshore, pre surf-zone wave conditions:

- Maximum significant wave height = 2.0 to 2.5 m
- Maximum mean wave period= 4 to 5 s

5.9.4.3 In this study, wave spectrum is based on the extreme surge water levels and significant wave height joint probability analysis performed by ABPmer (2005) on behalf of the Environment Agency, as discussed in Section A5.1.3. Details of the various extreme surge water level – significant wave height scenarios are presented in Table A5.18, Table A5.19 and Table A5.20 for the three JPA sites along the frontage of the study area. These water-level / wave-height combinations have not been updated as part of Phase 4 since the joint probability analysis has not been updated. The existing water levels and wave heights are based on a wave model of the Severn Estuary (as detailed in Appendix A5.1.3). If the joint probability analysis is updated in future, it is advised that the wave overtopping volumes are updated using this information and the impact of wave overtopping assessed.

5.9.4.4 The following offshore wave conditions have been used in the wave transition module:

- Maximum mean wave period of 5 s
- Angle of wave attack is perpendicular to coastline.

5.9.4.5 Since the waves during storm events break on the foreland, the maximum wave heights at the toe of the sea defences are dominated by the water depth at the foreland.

5.9.5 Wave Transition Calculations

5.9.5.1 At Avonmouth, the sea defence consists of a long, relatively shallow foreland with a relatively low embankment. During tidal flood events, the foreland is flooded and water will rise up to the embankment. Offshore waves will break on the relatively shallow foreland. Wave transition and wave breaking have a significant effect on the behaviour of waves and magnitude of forces in the vicinity of the crest of the sea defence.

5.9.5.2 Although mathematical prediction of these phenomena is still difficult, there are wave prediction tools available to predict wave transition (for example, ENDEC). Modelling wave transition using wave prediction tools was beyond the scope of the present study (strategic flood risk mapping) and no mathematical tools have been used to assess the wave transition

5.9.5.3 In the present study, only the effect of depth-limited wave breaking on the waves has been considered. The effects of breaking waves have been incorporated by a coastal engineering rule of thumb approach: maximum wave height is a function of local water depth. The applied breaker index is 0.78 (Theoretical maximum for depth initiated wave breaking). In general, the breaker index along natural coastlines like sandy beaches is smaller (order of 0.6). Therefore the local significant wave heights at the toe of the embankment resulting from the wave transition module are generally an overestimation of the wave height that can be expected (conservative approach).

5.9.6 Results Wave Transition Module

5.9.6.1 The joint probability of extreme surge water level and significant wave height was considered in the wave transition calculations, based on the joint probability analysis detailed in the ABPmer (2005) report and summarised in Section A5.1.3.

5.9.6.2 The basis of the analysis is that for a given probability of occurrence (return period), the likelihood of an extraordinarily extreme water level and a large wave occurring simultaneously is low, and visa versa. This means that many wave and tidal water level scenarios are possible for an event of a given return period. Depending on the topographical characteristics of the defence and foreland elevation, the critical over topping event could occur at a higher water level with smaller significant wave height, or lower water level with greater significant wave height, or both. The process of overtopping could either be a function of the elevated still water level, with continual weir flow over the structure, or from the volume of water intermediately dumped over the structure due to wave action.

5.9.6.3 Wave heights at the toe of the sea defences have been assessed for each of the ABPmer (2005) wave and tidal water level scenarios presented in Table A5.18, Table A5.19 and Table A5.20. Further scenarios were examined for the 2105 tidal levels based on future net sea level rise. Tidal levels are predicted to rise only 0.07m from 2105 to 2010; this increase is expected to have negligible effect on the extent and magnitude of flooding in Avonmouth.

5.9.6.4 The maximum wave heights that can be expected at the toe of the sea defence are fairly sensitive to the water levels at sea. Although the wave and tidal scenarios with the lower water levels are expected to have a greater significant wave height at sea (for a given return period), significantly smaller or no waves occur at the toe of the sea defence due to foreland elevation and wave breaking. For a given return period, the wave height at the toe of the defence therefore increases as the tidal water levels scenario increases above the foreland, before reaching a maximum height, then decreasing to become negligible at the maximum extreme surge water level. This situation implies that it is difficult to identify the particular wave and tidal scenario that would result in the greatest volume of overtopping, and will change along the frontage depending on the topography of the defence and foreland.

5.9.6.5 The maximum significant wave height resulting from the scenarios with a larger return period are significantly higher.

5.9.7 Wave Overtopping Calculation Module

5.9.7.1 The overtopping calculations to predict the overtopping rate due to wave overtopping were carried out using procedures outlined in the EA technical report W178 (HR Wallingford, 1999).

5.9.7.2 For defences with smooth and impermeable slopes, W178 describes two methods: Owen (1980) and Van der Meer (1992). The wave-overtopping rates have been assessed using both methods. Because the method of Owen (1980) is recommended in W178 for sea defences around the UK coastline, the results of this method have been used in the hydrodynamic simulations in the Avonmouth TUFLOW model.

5.9.7.3 In the wave overtopping calculation two modes can be distinguished:

- Wave overtopping when the crest height of the embankment is above still water level;
- Wave overtopping when the crest height of the embankment is below still water level;

Wave Overtopping When Crest Height is Above Water Level

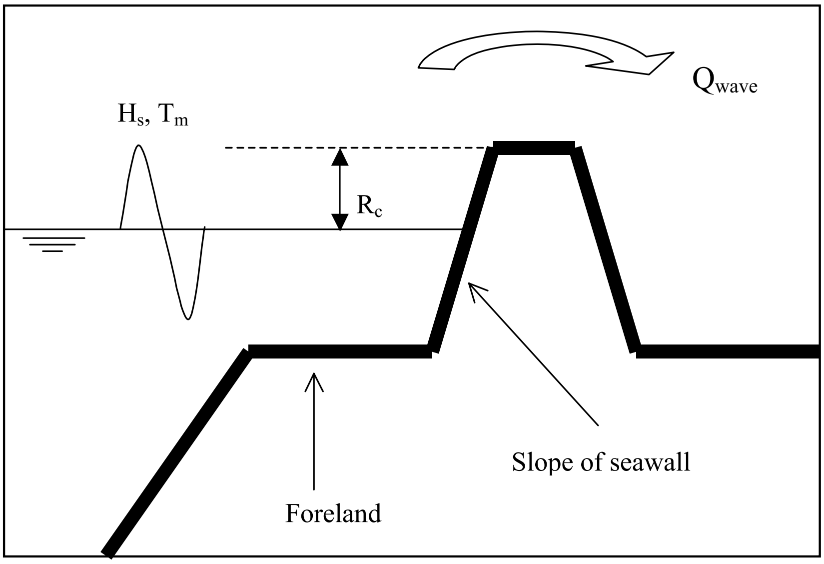
5.9.7.4 The following diagram shows the situation during a flood event when the crest height of the embankment is above still water level. For still water levels below the crest level of the embankment, the discharge over the seawall section A can be calculated by the following formula:

$$Q = \frac{A}{T_m \cdot g \cdot H_s} e^{\frac{-B \cdot R_C}{T_m \sqrt{g H_S}}} \cdot L_A$$

where:

Q = wave overtopping rate [m^3/s]
A, B = empirically derived coefficients which depend on the slope of seawall [-]
T_m = mean wave period at the toe of the seawall [s]
g = acceleration due to gravity [9.81 m/s^2]
H_s = significant wave height at the toe of the seawall [m]
R_c = freeboard of the seawall (crest height above still water level) [m]
L_a = length of seawall section [m]

The empirically coefficients A and B have been derived from Table 1 of W178.

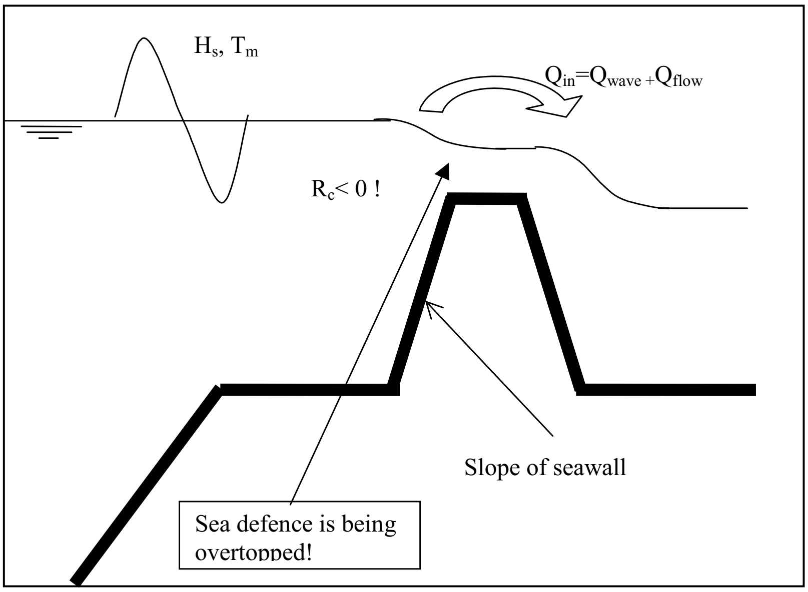


Wave Overtopping When Crest Height is Below Water Level

5.9.7.5 The wave overtopping method of Owen is designed to calculate the wave-overtopping rate in situations where the crest height of the embankment is above still water level. In cases when the still water level is above the crest height of the embankment, the wave overtopping rates resulting from the method of Owen are less reliable.

5.9.7.6 In situations where the still water level is above the crest height of the embankment, floodwater enters the floodplain due to two mechanisms: overtopping due to wave action and weir flow over the crest due to still water overtopping.

5.9.7.7 The following diagram shows the situation during a flood event where the crest height of the embankment is below still water level. It is expected that under normal conditions the rate of the flow that weirs over the seawall is of the same order as the overtopping due to wave action. The inflows due to still water overtopping have been modelled in the TUFLOW 2D/1D model. To estimate the wave overtopping discharge in situations where the still water level is above the crest height of the embankment, the (amended) formula of the method of Owen



has been used.

5.9.7.8 In situations where the still water level is above the crest height of the embankment, it is assumed that the growth of wave overtopping rate is no longer dependent on the relative height of the crest of the seawall (the freeboard is negative for still water levels above the crest height of the sea defence) and the wave overtopping rate can be calculated using the formula of Owen with a freeboard of 0 m. Using a freeboard of 0 m in the formula of Owen results in the following equation for the wave overtopping discharge per seawall section:

$$Q = \frac{A}{T_m \cdot g \cdot H_s} L_A$$

Where:
Q = wave overtopping rate [m^3/s]
A = empirically derived coefficient which depend on the profile of seawall [-]
T_m = mean wave period at the toe of the seawall [s]
g = acceleration due to gravity [m/s^2]
H_s = significant wave height at the toe of the seawall [m]
L_A = length of seawall section [m]

5.9.8 Resulting Inflows

5.9.8.1 The wave overtopping results indicate two “critical” wave and tidal water level scenarios for a given return period:

1) maximum instantaneous wave overtopping rate (m^3/s); and

2) maximum volume of water overtopping the defence during the duration of the simulation.

5.9.8.2 The first scenario occurs for lower tidal water levels, with the larger waves dominating the overtopping. The second scenario occurs for higher tidal water levels, which enable overtopping due to smaller waves over a longer duration.

5.9.8.3 The study area is confined by flood defences and drainage via flapped outfalls that experience tide locking, with flood levels very dependent on available storage. For this reason, the scenario corresponding to the maximum volume of overtopping was adopted as the critical event.

5.9.8.4 Additionally, the results indicate that the tidal water level for the critical event for each individual section has little correlation between adjacent sections. Thereby the scenario of critical overtopping events occurring at simulations along all eight sections is theoretically not possible as this would involve different tidal water levels along the Severn Estuary frontage. However, on the basis that a precautionary approach be adopted it is considered that this assumption is appropriate for strategic planning purposes.

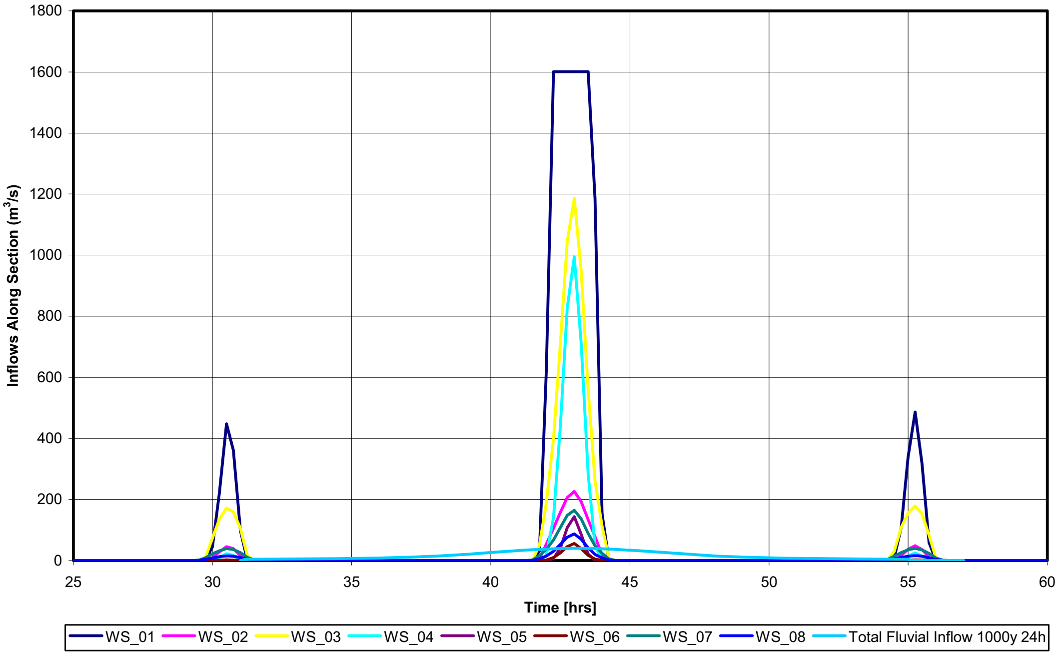
5.9.8.5 In calculating wave overtopping rates for the year 2105 (also considered appropriate for the year 2110), the DEFRA (2006) climate change guidance was applied and, as outlined in Table 5.6., a 10% sensitivity allowance was applied to extreme wave heights.

Table 5.6 - Wind and Wave Indicative Sensitivity Ranges (DEFRA, Oct 2006)

Parameter	1990 - 2025	2025 - 2055	2055 - 2085	2085 - 2115
Offshore wind speed	+5%	+5%	+10%	+10%
Extreme wave height	+5%	+5%	+10%	+10%

5.9.8.6 The resulting inflows for the defended case critical event (maximum volume of overtopping) for each section are presented as time series in Figure 5.9.1. Of note in this figure is the magnitude of the inflows. The figure also shows the cumulative inflows for the 1,000y fluvial event for the study area. It is apparent from this figure that the wave overtopping inflows far exceed the fluvial flows.

Figure 5.9.1- 1000 Year Wave Overtopping Inflows vs Fluvial Flows (with climate change allowance)



5.9.8.7 As discussed in Section A5.1.3, the rounding of the contours for the ABPmer (2005) joint probability analysis look-up tables, leads to a reduction in the associated wave height, and consequently a zero wave height for the maximum extreme water level. In line with the precautionary principle, the following three scenarios have been modelled:

1) the critical extreme surge water level – significant wave height scenario (based on maximum overtopping volume) at each wave overtopping section (unchanged from Phase 3);
2) the maximum extreme water level along the entire Avonmouth to Aust frontage, with no wave action (updated in Phase 4 with latest extreme tide level estimates); and
3) the highest extreme water level with a significant wave height (unchanged from Phase 3).

5.9.8.8 In some instances, the maximum extreme water level with a significant wave height corresponded to the critical extreme surge water level – significant wave height scenario, in which case only two scenarios were modelled (for example the 1 in 2 year tidal events).

5.9.8.9 These inflows were applied to the 2D/1D model using SA polygons, immediately to the east of the flood defences. The inflows have been distributed along the entire extent of the relevant defences. SA polygons apply the flow directly to the cells within the polygon. Distributing the flow across the relevant cells is an appropriate method of representing the overtopping flows and improves the stability of the model when the inflow is first applied to the floodplain (2D domain).

5.10. Development of Fluvial Boundary Conditions

5.10.1.1 The fluvial inflows for the majority of the study area were derived directly from the inflows used by BTP in the InfoWorks CS models. These inflows were derived using FEH rainfall estimates and hydrological routing in the InfoWorks CS program. This approach provides consistency between the fluvial assessment in this study and previous modelling by BTP. It is understood that the Lower Severn Drainage Board has completed an updated hydrological study however this was not available for Phase 4 of this study.

5.10.1.2 For the areas outside the sub-catchments covered by the InfoWorks CS models, sub-catchment areas were delineated using the DTM. Inflows for these sub-catchments were derived by using equivalent sub-catchments from the InfoWorks CS model areas. Equivalence was based on land use (developed or undeveloped) and steepness. The inflows were then scaled based on the ratios of the areas of the comparable sub-catchments.

5.10.1.3 The range of fluvial return period events used for this study were; 2yr, 20yr, 100yr and 1000yr. Both a 12 hr and 24hr storm duration were modelled for each event. It should be noted that the 20yr return period was not considered prior to phase 4 of this study. As a result, the origin of the 20yr hydrograph differs from that described in section 5.10.1.1.

5.10.1.4 The inflow hydrographs for the 20 year return period event were obtained by scaling the existing BTP 100 year return period hydrographs (for a range of storm durations) by the ratio of the corresponding FEH rainfall depths. Table 5.7 shows the rainfall depths obtained from the FEH CD-Rom, and the calculated ratios.

Table 5.7 FEH Rainfall Depths (NGR 355830 184020)

Return Period (years)	20		100
Storm Duration (h)	Rainfall Depth (mm)	Ratio*	Rainfall Depth (mm)
1	27.1	0.62	43.8
2	32.3	0.64	50.6
6	42.7	0.67	63.8
12	50.9	0.69	73.8
24	65.9	0.71	92.9

* X-year rainfall depth / 100-year rainfall depth

5.10.1.5 As part of the rhine network review performed by LSDB, assessments of standing water levels were made. The water levels were used in the model to define the initial water level conditions in the rhine network.

5.11. Hydraulic Modelling of Breaches

5.11.1.1 A total of six breaches have been modelled using the hydraulic model. The locations of the breaches were identified by the Steering Group. The widths of the breaches were determined using guidance from the Environment Agency's "Tidal Flood Risk Area – Simple Credible". A description of each of the breach scenarios have been provided in Table 5.8 below.

Table 5.8 - Breach location and widths

Breach No.	Location Description	Location NGR	Width
1	Environment Agency Earth Embankment, south Severn Beach	353850, 184049	100 m
2	Environment Agency Sea Wall, Station Road	353858, 184749	30 m
3	Environment Agency Sea Wall, along Beach Road	353883, 185274	30 m
4	Environment Agency Sea Wall, Severn Beach Chalet & Caravan Site	353960, 185570	30 m
5	Enivronment Agency Sea wall near Severn Farm Lodge	354290, 186369	30 m
6	EA Earth Embankment	355034, 186670	100 m

5.11.1.2 For each of the scenarios the breach has been applied for the entire duration of the model run.

5.12. Hydraulic Modelling Assumptions and Uncertainties

5.12.1.1 As discussed previously, a number of assumptions were necessary for the hydraulic modelling. Similarly, there are a number of uncertainties in the approaches and data used in the study. The assumptions and uncertainties are discussed and summarised below.

5.12.1.2 ***Ground Level Data:*** The hydraulic model uses the Digital Elevation Model (DEM). All DEMs have errors associated with various sources. The Environment Agency Science Group (Technology) state with regard to the height accuracy of point measurements of the LiDAR data used to create the DEM: *"The accuracy after transformation to OSGB36 (inclusive of LiDAR system errors) may be stated as +/- 11 to 25cm"*. It should be noted that all accuracies quoted here are the expected vertical range that 67% of all points on hard surfaces fall within. On non-hard surfaces (for example, grass, trees) accuracies are less but not specified by the supplier.

5.12.1.3 The accuracy of the survey data is likely to have the following influences on results:

- In areas where predicted depths are more than 1m, the error in the DTM is unlikely to influence results to any great degree;
- In the areas on the fringe of the floodplain (and inundation areas), the DTM errors will influence the exact extent of the inundation and zones. Where ground slopes are very flat, the lateral extent error in the flood extent may be in the order of 5m (which is the resolution of the 2D model grid). However, at the edge of the floodplain, where slopes are steeper, the lateral extent error would be more likely in the order of 2m.

5.12.1.4 ***Wave Height Estimates/Combined Probability of Waves/Tide/Surge:*** The derivation of the wave overtopping inflows is very dependant on the estimation of the off-shore wave height. The definition of tide/surge levels, off-shore wave heights and the joint probability between both is based on a study prepared by ABPmer (2005). The joint probability assessment has not been updated to account for the latest extreme still tide level estimates. Climate change allowances were included in the same way as the other model runs.

5.12.1.5 A significant finding of the ABPmer (2005) report suggests that due to the joint probability analysis technique used, for the maximum extreme water level for a given return period, zero wave height is predicted. In reality, such phenomenon of no waves for extreme water levels would be very unlikely, because meteorological conditions required to elevate to the extreme levels would result in a degree of wave action.

5.12.1.6 On the basis that a precautionary approach be adopted, three tidal-wave scenarios outlined have been simulated within the hydraulic model for each return period as follows:

1) Critical scenario (maximum wave overtopping volume) at each wave overtopping section simultaneously;
2) Highest extreme water level with a significant wave height; and
3) Extreme maximum water level with no waves.

5.12.1.7 Results presented indicate the most conservative of the three scenarios.

5.12.1.8 ***Fluvial Inflows and Groundwater Influences***: As discussed in Section 5.7, the inflows were derived from the previous InfoWorks CS modelling. However, the fluvial flooding of the area may also be influenced by high groundwater levels following a long period of heavy rainfall. Hence, the approach of using a hydrological model to simulate a fixed duration event (say 12 hour storm) is not able to properly represent the influence of groundwater inflows on resulting flood levels. During phase 4 of this study it was determined that there was less certainty over the importance and influence of groundwater levels on fluvial flooding. It is recommended that a data collection programme be initiated to determine the importance of high groundwater levels and enable the effects to be included in future updates.

5.12.1.9 ***Tide Locking of Outfalls:*** The 1D model has been developed with culverts representing the tidal outfalls from the drainage system to the Severn Estuary (and the Avonmouth River). The culverts have been included in the model as uni-directional elements (for instance, only allowing outflow). When water levels in the estuary are lower than those in the upstream drainage system, water can discharge into the estuary. When the opposite occurs, the culverts do not allow reverse flow, effectively simulating the tide locking behaviour.

Mapping and Figures

Figure 5.1 – Environment Agency Midlands Region, Lower Severn Area Historic Flood Mapping Commission January 1976 Flood Event

Figure 5.2 – Environment Agency Midlands Region, Lower Severn Area Historic Flood Mapping Commission December 1981 Flood Event

Figure 5.3 – Environment Agency Midlands Region, Lower Severn Area Historic Flood Mapping Commission November 2000 Flood Event

Figures 5.5 to 5.7 – Not Used

Figure 5.8 – Flood Defences Assumed to be Removed

Figure 5.9 – Digital Elevation Model

Figure 5.10 – 1D Model Network

Figure 5.11 – Wave Overtopping Assessment Sections

Figure 5.12 – LiDAR Coverage

Section 5 Appendices

A5.1 Review of Previous Modelling Studies

A5.1.1 JBA River Severn Tidal Model Haw Bridge to Avonmouth Hydraulic Modelling Report, 2001

A5.1.1.1 JBA Consulting were commissioned by the Environment Agency (EA) to produce a 1D hydraulic model to predict tidal and fluvial levels for a number of flood events, for the River Severn between Haw Bridge and Avonmouth. The upper extent of the study area is located at the Haw Bridge gauging station, approximately 6km south of Tewkesbury and just over 200km from the source of the River Severn at Blaenhafren in Mid Wales. The downstream boundary of the model is located at Avonmouth.

A5.1.1.2 Downstream of Epney the water levels in the Severn are almost completely dominated by the tide. Downstream of 'Arlingham Bend' the river widens into a classic funnel shaped macro-tidal estuary, with the fluvial channel meandering across the sand banks. Previous studies of estuarine processes show that tidal ranges greater than 4m produce strong residual currents, which may extend for hundreds of kilometres inland.[6] The Severn Estuary experiences a tidal range of 12m; therefore any study should take account of the tidal processes.

A5.1.1.3 The JBA model was constructed using ISIS software and incorporated three sets of existing data, comprising a Salmon-F Model (1991), 2D model and a topographic survey supplied by the EA. The model was to be used to predict tidal and fluvial levels for severe flood events (up to 1 in 250 year return period) and to determine the frequency of overtopping of defence embankments. This was achieved in two stages:

1) An in bank model was constructed that extended to the existing defences
2) Extension of the model to include tidal flood cells between Gloucester and Epney and fluvial floodplain cells between Haw Bridge and Gloucester

A5.1.1.4 River Severn water levels can be significantly affected by the retention and discharge from these cells. The flood cells included within the JBA model represented storage at Leigh Court Basin, Oakle Street, Longney, Rodley, Walmore Common, Priding, Weir Green and Hempsted.

A5.1.1.5 Tidal flood areas behind the embankments downstream of Epney were not included in the model, as it was considered that these would have little to no effect on water levels in the river and estuary, as the water levels downstream of Epney would be based on the tide level only.

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[6] An Introduction to Coastal Geomorphology – J Pethick 1984

A5.1.1.6 The model was calibrated for level and flow using data from the December 2000 flood event, at Haw Bridge. This event was estimated to represent a 2-year tidal and 20-year fluvial event. This data along with fluvial design inflows at Haw Bridge were provided by the EA.

A5.1.1.7 The model was then used to predict water levels for a combination of events, as presented in Table A5.9:

Table A5.9 – JBA Combined Probability Scenarios

Scenario	Tidal Return Period (years)	Fluvial Return Period (years)
1	200	2
2	100	2
3	10	2
4	2	100
5	2	10
6	2	150
7	250	2

A5.1.1.8 Tide levels for each return period were provided by the EA, based on a previous study by the Proudman Oceanographic Laboratory. Level information on the flood defence embankment levels was obtained from EA asset survey reports for input to the model.

A5.1.1.9 The report noted that the DEFRA guide to the standard of protection for the River Severn over the modelled reach, would vary according to the type of land/properties protected and whether the peak water levels were produced from fluvial or tide levels. The JBA model was run for a further series of 63 combinations of tide level and fluvial flow, to produce a combined probability analysis, giving a range of return periods for varying defence embankment heights, in addition to detailing the current standard of protection at these key locations.

A5.1.1.10 The hydraulic model was also run with variations to the embankment levels to provide a historical comparison of pre-improvement conditions. This included a scenario incorporating design embankment levels from the 1981 River Severn Avonmouth – Worcester Improvement report, some of which were never constructed due to the premature ending of the programme. The scenario, which removed the Minsterworth Ham embankments, produced the greatest reductions in maximum flood water levels. These reductions were evident from Haw Bridge through to Minsterworth and were most significant around Gloucester and Alney Island – at Lower Parting the greatest reduction in maximum flood water levels was 0.945m for the 50-year tide and 1-year fluvial event combination. However, removing the Minsterworth Ham embankments caused subsequent increases in the maximum water levels between Minsterworth and Newnham, typically approximately 0.02m, but for the 10-year tide and 10-year fluvial event combination increases were up to 0.2m.

A5.1.1.11 The report noted difficulties experienced in applying a single method of analysis to a study reach, which had both strong tidal and fluvial influences. The analysis produced the most satisfactory results in the mid reaches of the model, where these two influences were more evenly balanced. The combined analysis was found to produce a rather small range of return periods when undertaken at the upstream or downstream model extents.

A5.1.1.12 It was noted that this modelling did not account for outfall structures from the flood storage areas adjacent to the river. It was recommended that these be inserted if an accurate estimate of the water levels were required in the river, throughout a flood event.

A5.1.2 JBA. Avonmouth COMAH Sites: Flood Risk Assessment. Final Report, March 2004

A5.1.2.1 JBA were commissioned by the Environment Agency (EA) under the NAT/CON/257 framework to quantify the level of flood risk associated with a 37km^2 area of Avonmouth. The study area is bounded by the London-Wales railway to the north, M5 motorway to the east, River Avon to the south and River Severn to the west. The area has been subjected to past flooding, in particular around the Esso site, as a result of south westerly storms coinciding with high tide levels. The Esso site floods at least five times in any ten-year period, with the last notable event in October 2000.

A5.1.2.2 In 1998 the EA completed upgrading the defences from Chestle Pill Outfall to Mitchell's Pill to a 100-year standard. These consist of armoured earth embankments, walls, standard earth embankments and portions of the railway embankment.

A5.1.2.3 The foreshore land in front of the Esso site has been raised considerably by the Bristol Port Company to form a defence, along with the construction of several other sections around the perimeter of the dock area. However, a report by Babtie, Brown & Root found that some areas of the raised embankment experienced ongoing erosion and removal of the slope toe material, causing over-steep slopes and rotational slumping. It was not deemed possible to quantify the rate of failure.

A5.1.2.4 Particular focus was given to those organisations with duties under the Control of Major Hazards (COMAH) regulations. Flood events were based on tide levels at Avonmouth from the EA report on Extreme Tide Levels (2003), which used a series of present day return periods and values to simulate 50 years worth of climate change under current DEFRA guidelines. Table A5.10 shows the return periods used in this study.

Table A5.10 – Tidal Inundations Return Periods Used in The JBA Study

Return Period (years)	Peak Level m AOD
50	8.81
100	8.98
200	9.09
500	9.25
1,000	9.37
50 (+250mm climate change)	9.06
100 (+250mm climate change)	9.23
200 (+250mm climate change)	9.34
500 (+250mm climate change)	9.50
1,000 (+250mm climate change)	9.62

A5.1.2.5 The EA commissioned a LiDAR survey of the study area to provide JBA with a topographic ground model. The resolution of this data was 1m (Avonmouth West) and 2m (Avonmouth East). Floodplain barrier openings were identified by the Lower Severn Drainage Board (LSDB), and site visits by both EA and JBA staff and were simulated in the topographic LiDAR model by splicing 'gaps' onto the grid which were equal to the value of the adjacent ground level.

A5.1.2.6 The following assumptions were made:

- Ground saturation and loss of effective storage prior to a flood event was not accounted for;
- The water surface levels within the Avonmouth Dock basin taken at the time of capture were used within the model;
- No account of defence failure analysis was undertaken for breach assessments contained within this study;
- Tidal events and scenarios were chosen to produce the greatest extent of flooding.

A5.1.2.7 Three tidal flooding scenarios were examined. These were modelled with both the present day and climate change tide levels where applicable, see Table A5.11.

Table A5.11 – JBA Tidal Flooding Scenarios

Scenario	Location
Existing Conditions	Entire study area

Scenario	Location
Failure of Linear Defences (A simplified worst case scenario)	Mitchell's Pill Outfall – 1000m breach length Stup Pill to New Pill New Pill – 100m breach length
Failure of outfall structures (Removal of tidal flaps and non-operation of backup penstocks)	Mitchell's Pill Outfall Stup Pill Outfall New Pill Outfall

A5.1.2.8 The report notes that fluvial modelling relied heavily upon the completion of the updates to the Lower Severn Drainage Board's Hydro models. It was noted that these scenarios would be modelled at a later date to be included in an addendum to the JBA March 2004 report.

A5.1.2.9 Modelling was undertaken using the JFLOW v2.30 2D flood routing programme developed by JBA. This calculates the time water takes to travel across flood cells and simulate inundation based on the Digital Elevation Model (DEM). The JFLOW package is also capable of providing detailed results of water velocity and depth across the inundated flood cells.

A5.1.2.10 Inflows for the JBA model were derived from the EA South West Tide levels using a Broad Crested Weir Equation (for the Existing Conditions and the Failure of Linear Defences scenarios) and a Large Opening Orifice Equation (for the Failure of Outfall Structures Scenario).

A5.1.2.11 A total of 46 scenarios were modelled producing the following outputs for each:

- Thematic Map detailing Maximum Flood Depth and Extent
- Thematic Map detailing Maximum Velocities and Extent
- An AVI[7] animation clip showing the flood event in 0.1 hour frames

A5.1.2.12 This modelling showed that the main source of flooding is from overtopping of the Avonmouth Dock basins, the lock gates forming the lowest defence point in the study area (7.3m AOD). Under a present day tide scenario, the 200-year event (peak level of 9.09m AOD) is the lowest return period, for which flooding occurs at one or more of the COMAH sites. Flooding of the study area was shown to be significantly increased during each of the defence breach or outfall failure scenarios. Table A5.12 and Table A5.13 detail the minimum return period at which flooding occurs for each COMAH site for each of the modelling scenarios.

[7] Auto Video Interleaved

This was deemed to present severe implications for the majority of the COMAH sites.

Table A5.12 – JBA Minimum Return Period Which Directly Floods the COMAH Sites (Present Day)

	Existing Defences	2A 1000m Failure at Mitchell's Pill	2B Stup Pill - New Pill	2C 100m North of New Pill	3A Mitchell's Pill	3B Stup Pill	3C New Pill
Hydro Agri	500-year	500-year	500-year	500-year	500-year	500-year	500-year
Rhodia OF	200-year	200-year	200-year	200-year	200-year	200-year	200-year
BP Gas	200-year	200-year	200-year	200-year	200-year	200-year	200-year
BOSL	500-year	500-year	500-year	500-year	500-year	500-year	500-year
Albemarle	N/A	200-year	N/A	N/A	100-year	N/A	N/A
Esso	N/A	200-year	N/A	N/A	100-year	N/A	N/A
Transco LNG	N/A	N/A	N/A	50-year	N/A	100-year	N/A
Terra Nitrogen	N/A	N/A	1,000-year	50-year	N/A	100-year	100-year
Astrazeneca	N/A	N/A	N/A	50-year	N/A	100-year	100-year

Table A5.13 – JBA Minimum Return Period Which Directly Floods the COMAH Sites (50-Year Climate Change)

	Existing Defences	2A 1000m Failure at Mitchell's Pill	2B – Stup Pill - New Pill	2C – 100m North of New Pill
Hydro Agri	200-year CC	200-year CC	200-year CC	200-year CC
Rhodia OF	50-year CC	50-year CC	50-year CC	50-year CC
BP Gas	50-year CC	50-year CC	50-year CC	50-year CC
BOSL	100-year CC	100-year CC	100-year CC	100-year CC
Albemarle	100-year CC	100-year CC	100-year CC	100-year CC
Esso	500-year CC	50-year CC	500-year CC	500-year CC
Transco LNG	N/A	500-year CC	1,000-year CC	50-year CC
Terra Nitrogen	N/A	1,000-year CC	1,000-year CC	50-year CC
Astrazeneca	N/A	N/A	1,000-year CC	50-year CC

A5.1.2.13 It was noted in the report (Para 4.6.4) that it was necessary to increase the coarseness of the LiDAR grid cell sizes in JFLOW to reduce model run times. The report suggested that more site-specific investigations using a finer LiDAR grid could increase the accuracy of the results produced.

A5.1.3 ABPmer. Avonmouth to Aust Tidal Defence Scheme: Joint Probability Analysis of Waves and Water Levels, October 2005

A5.1.3.1 ABPmer were commissioned by the Environment Agency (EA) to undertake a Joint Probability Analysis (JPA) of extreme tidal and surge water levels and wave heights at three representative sites along the Avonmouth to Aust frontage. This work was done to support a commission to prepare overtopping calculations undertaken by Atkins on behalf of the EA. Table A5.14 details the location of the three JPA sites and shown in Figure 5.11 – Wave Overtopping Assessment Sections.

Table A5.14 – ABPmer Locations of JPA sites

Site	Easting (m)	Northing (m)	Location
1	351304	180419	Off Avonmouth
2	353620	185200	Off Severn Beach
3	355401	188125	Off Northwick Oaze

A5.1.3.2 The ABPmer study performed a statistical analysis to predict extreme surge water levels at Avonmouth using water level records. The analysis was based on annual maximum water levels, compiled from records dating from 1924 to 2004, and daily records of high water level from 1970 to 2004. Table A5.15 details the extreme surge water levels predicted at Avonmouth for the year 2005 for various return periods from the ABPmer (2005) study.

Table A5.15 – ABPmer Extreme Water Levels Predictions for Avonmouth

Return Period	Predicted Extreme Water Level (m ODN)
0.2	7.93
0.5	8.14
1	8.27
2	8.4
5	8.55
10	8.65
20	8.75
25	8.78
50	8.87
100	8.95

Return Period	Predicted Extreme Water Level (m ODN)
200	9.03
250	9.06
500	9.13
1,000	9.21

A5.1.3.3 The report outlines that to undertake joint probability analysis (JPA) requires long-term time-series of primary inputs of water levels and wave heights. Suitable long-term observation data of water levels was available from local tide gauges at Avonmouth, however, no long-term data was available for wave heights.

A5.1.3.4 The report describes that wave action experienced along the Avonmouth to Aust frontage is a function of wind blowing across the water surface and is fetch-limited. The layout of the estuary, water levels and strong tidal currents further complicate the local wave regime. A detailed wave model previously developed for the Environment Agency as part of the Gwent Levels Foreshore Management Plan (GLFMP) using the Delft3D-FLOW modelling software developed by Delft Hydraulics, was used to predict wave behaviour in the Severn Estuary. The tidal and wave models were simulated for a 35-year time series of wind speed, wind direction and water levels.

A5.1.3.5 The study was performed in two stages. The first involved collation and assessment of primary inputs and modelling. The second looked at refinement of the model, generation of look-up tables, JPA and reporting. Table A5.16 and Table A5.17 show the look-up tables developed for extreme surge water level and extreme significant wave height at the three JPA site locations from the wave and tidal modelling.

Table A5.16 – ABPmer Extreme water level predicted at the JPA sites

Return Period (years)	Predicted Extreme Water Level (m ODN)		
	Site 1	Site 2	Site 3
0.2	7.95	8.04	8.22
0.5	8.15	8.25	8.43
1	8.29	8.38	8.57
2	8.42	8.51	8.70
5	8.57	8.66	8.85
10	8.68	8.77	8.96
20	8.78	8.86	9.06
25	8.81	8.89	9.09
50	8.90	8.99	9.18
100	8.98	9.07	9.27

Return Period (years)	Predicted Extreme Water Level (m ODN)		
	Site 1	**Site 2**	**Site 3**
200	9.06	9.15	9.35
250	9.09	9.18	9.38
500	9.17	9.25	9.46
1,000	9.24	9.33	9.53

Table A5.17 – ABPmer Extreme significant wave height predicted Hs for the JPA sites

Return Period (years)	Predicted Extreme Wave Height (m)		
	Site 1	**Site 2**	**Site 3**
0.2	0.60	0.49	0.38
0.5	0.76	0.61	0.48
1	0.89	0.71	0.55
2	1.03	0.81	0.63
5	1.23	0.95	0.73
10	1.38	1.06	0.81
20	1.54	1.18	0.90
25	1.59	1.22	0.93
50	1.76	1.33	1.01
100	1.94	1.46	1.1
200	2.12	1.58	1.19
250	2.17	1.62	1.22
500	2.36	1.75	1.32
1,000	2.55	1.88	1.41

A5.1.3.6 Joint probability analysis was undertaken using the method outlined in Hawkes & Svensson (2003). Figure A5.13, Figure A5.14 and Figure A5.15 illustrate the predicted joint probability contours for the three JPA sites. Table A5.18, Table A5.19 and Table A5.20Table A5.20 detail the underlying data extreme water levels and significant wave height for selected events.

Figure A5.13 – ABPmer Joint Probability Results for Extreme Water Levels and Significant Wave Heights JPA Site 1

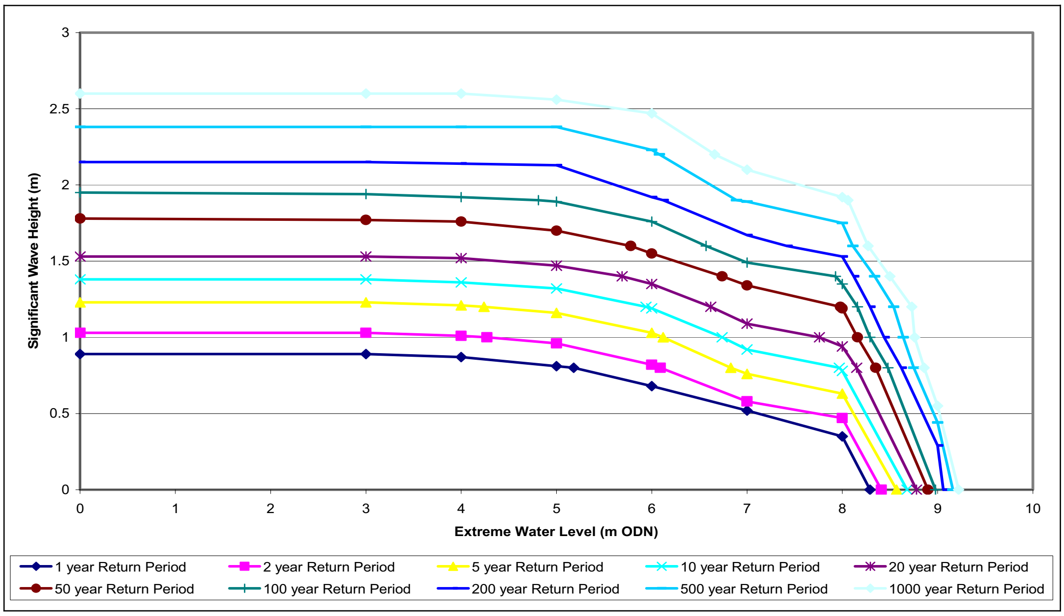


Table A5.18 – ABPmer Joint Probability Results for Extreme Water Levels and Significant Wave Heights JPA Site 1 (selected events)

2 Year Return Period		200 Year Return Period		1,000 Year Return Period	
Extreme Water Level (m ODN)	Significant Wave Height (m)	Extreme Water Level (m ODN)	Significant Wave Height (m)	Extreme Water Level (m ODN)	Significant Wave Height (m)
0.00	1.03	0.00	2.15	0.00	2.60
3.00	1.03	3.00	2.15	3.00	2.60
4.00	1.01	4.00	2.14	4.00	2.60
4.27	1.00	5.00	2.13	5.00	2.56
5.00	0.96	6.00	1.92	6.00	2.47
6.00	0.82	6.12	1.90	6.66	2.20
6.09	0.80	7.00	1.67	7.00	2.10
7.00	0.58	7.42	1.60	8.00	1.92
8.00	0.47	8.00	1.53	8.06	1.90
8.41	0.00	8.12	1.40	8.27	1.60
		8.29	1.20	8.50	1.40
		8.44	1.00	8.73	1.20
		8.62	0.80	8.76	1.00
		9.00	0.29	8.86	0.80
		9.06	0.00	9.00	0.55
				9.22	0.00

Figure A5.14 – ABPmer Joint Probability Results for Extreme Water Levels and Significant Wave Heights JPA Site 2

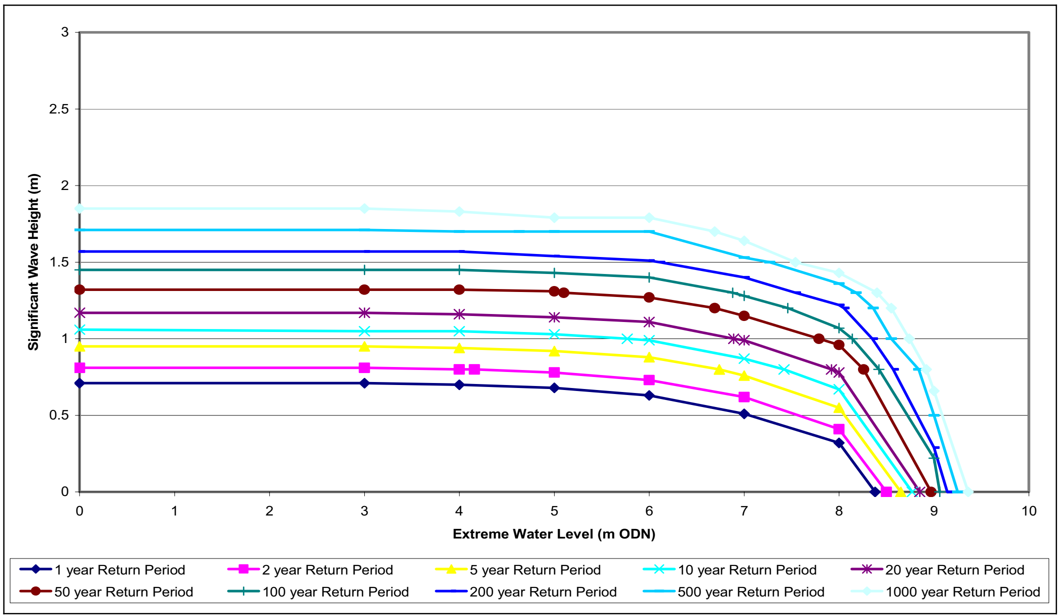


Table A5.19 – ABPmer Joint Probability Results for Extreme Water Levels and Significant Wave Heights JPA Site 2 (selected events)

2 Year Return Period		200 Year Return Period		1,000 Year Return Period	
Extreme Water Level (m ODN)	**Significant Wave Height (m)**	**Extreme Water Level (m ODN)**	**Significant Wave Height (m)**	**Extreme Water Level (m ODN)**	**Significant Wave Height (m)**
0.00	0.81	0.00	1.57	0.00	1.85
3.00	0.81	3.00	1.57	3.00	1.85
4.00	0.80	4.00	1.57	4.00	1.83
4.16	0.80	5.00	1.54	5.00	1.79
5.00	0.78	6.00	1.51	6.00	1.79
6.00	0.73	6.11	1.50	6.69	1.70
7.00	0.62	7.00	1.40	7.00	1.64
8.00	0.41	7.54	1.30	7.54	1.50
8.50	0.00	8.00	1.22	8.00	1.43
		8.05	1.20	8.40	1.30
		8.35	1.00	8.55	1.20
		8.57	0.80	8.74	1.00
		9.00	0.29	8.92	0.80
		9.14	0.00	9.00	0.66
				9.36	0.00

Figure A5.15 - ABPmer Joint Probability Results for Extreme Water Levels and Significant Wave Heights JPA Site 3

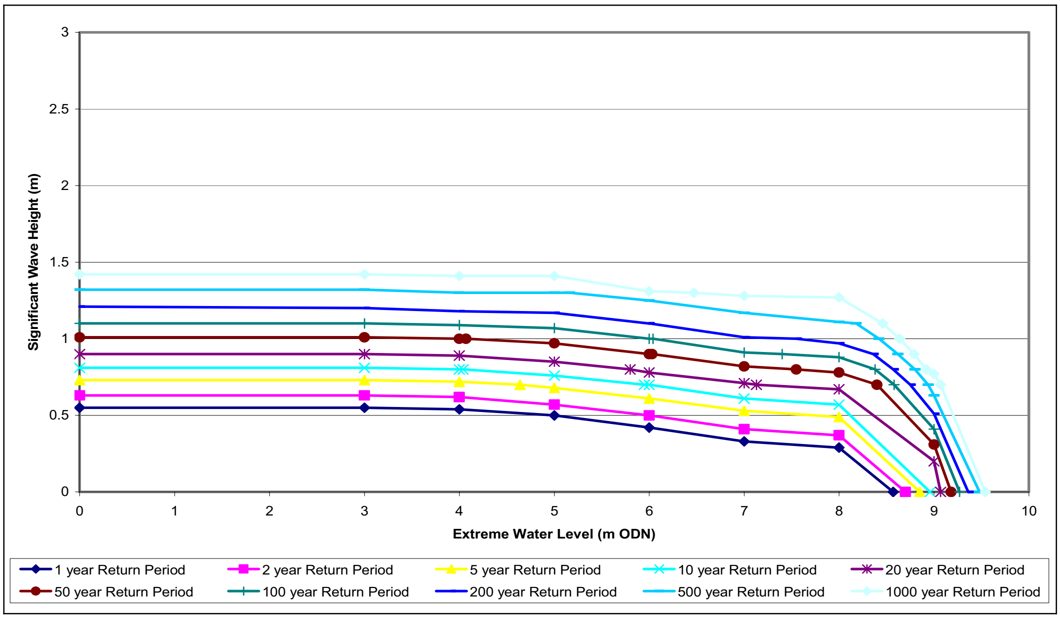


Table A5.20 – ABPmer Joint Probability Results for Extreme Water Levels and Significant Wave Heights JPA Site 3 (selected events)

2 Year Return Period		200 Year Return Period		1,000 Year Return Period	
Extreme Water Level (m ODN)	**Significant Wave Height (m)**	**Extreme Water Level (m ODN)**	**Significant Wave Height (m)**	**Extreme Water Level (m ODN)**	**Significant Wave Height (m)**
0.00	0.63	0.00	1.21	0.00	1.42
3.00	0.63	3.00	1.20	3.00	1.42
4.00	0.62	4.00	1.18	4.00	1.41
5.00	0.57	5.00	1.17	5.00	1.41
6.00	0.50	5.99	1.10	6.00	1.31
7.00	0.41	6.00	1.10	6.47	1.30
8.00	0.37	7.00	1.01	7.00	1.28
8.70	0.00	7.55	1.00	8.00	1.27
		8.00	0.97	8.46	1.10
		8.36	0.90	8.64	1.00
		8.57	0.80	8.79	0.90
		8.75	0.70	8.92	0.80
		9.00	0.51	9.00	0.77
		9.36	0.00	9.07	0.70
				9.54	0.00

A5.1.3.7 The ABPmer report states that rounding of the contours in the vicinity of the marginal return period (maximum) water levels leads to some reduction in the associated wave height. ABPmer suggest that the results of the joint probability solution provides some alleviation in wave overtopping rates, when compared to adopting the marginal values and extreme water level and significant wave height together.

A5.1.3.8 In reality, such phenomenon of no waves for extreme surge water levels would be very unlikely, with meteorological conditions required to elevate to the extreme levels would result in a degree of wave action.

A5.1.3.9 From the ABPmer study, a non linear relationship of extreme tidal and surge water levels is predicted along the frontage and extreme return period wave heights decrease upstream from Avonmouth to Aust.

Revision Status and Schedule of Changes

Section Revision Status

All technical revisions of the SFRA November 2010 release for Section 5 – Hydraulic Modelling are outlined below:

- Grid size of 2D model reduced to 5m (previously 20m) for fluvial scenarios, 20m grid size retained for large tidal events.
- Still water tidal levels adjusted to 2007 levels (previously 2005)
- Hydraulic model updated to use 2009 LiDAR
- Hydraulic model amended to represent the rhine network to north of railway line in the 2D domain using 2009 LiDAR data
- Coastal defence levels updated using the Infomaps Survey Ltd defence crest level survey from 2009
- 1 in 20 year tidal and 1 in 20 year fluvial return periods modelled

Schedule of Changes

<u>Section 5.1 – Release Status included, and following sections renumbered accordingly.</u>

<u>Paragraph 5.4.3.5 supersedes following:</u>

TUFLOW also contains a 1D model (ESTRY Version 2006-06-BD), which allows representation of flow through channels and structures, such as culverts and weirs. TUFLOW also allows dynamic linkage to iSIS models. However, this feature is still being tested.

<u>Paragraph 5.5.1.1 supersedes the following (from phase 3):</u>

The basis of 2D model domains is usually a Digital Terrain Model (DTM) representing the ground levels of the model area. For this study, the DTM was derived through combining the following data sets, in order of preference:

- LiDAR from 2006 (2m resolution)
- LiDAR from 2002 (1m resolution)
- LiDAR from 2003 (2m resolution)

<u>Paragraph 5.5.1.1 supersedes following (from phase 3):</u>

It was decided to use filtered LiDAR data. Filtered LiDAR has buildings and vegetation removed, and is effectively the estimated ground surface. Due to the 2D domain cell size (20m), there is potential that critical flow paths could be blocked should the buildings remain in the DTM. The non-conveyance properties of the large buildings, has been accounted for by increasing the assigned Manning's n roughness coefficient. Removing the buildings further aids the mapping, as it removes the 'dry' islands incorrectly shown for the buildings.

A 2D grid using 20m x 20m cells was chosen at the commencement of the study to represent the floodplain. The size of these cells was determined by consideration of the following issues:

- Desired level of detail in representing the hydraulic features of the area for the purposes of a SFRA
- Area of model
- Simulation times (expected to be over three tidal cycles)
- Expected time-step
- Desirable run times

Paragraphs 5.5.1.1 and 5.5.1.2 supersede the following (from phase2):

The basis of 2D model domains is usually a Digital Terrain Model (DTM) representing the ground levels of the model area. For this study, the DTM was derived through combining the following data sets:

- LiDAR data over the area south of the M5 from 2001 (1m resolution);
- LiDAR data over the area south of the M5 from 2003 (2m resolution);
- NextMap data over the area north of the M5 (5m resolution).

It was decided to use unfiltered LiDAR data. This data includes representations of buildings as it was anticipated that the 2D model would not include flow through or storage in buildings in order to be conservative. This decision was made recognising the expected quick rate of flood inundation.

Paragraph 5.5.1.5 supersedes following:

A 2D grid using 20m x 20m cells was chosen at the commencement of the study to represent the floodplain.

The 20m cell size resulted in a 2D domain with approximately 130,000 cells. Elevations at the centre of these cells and mid-points of cells edges were calculated from the DTM, shown in Figure 5.9 – Digital Elevation Model.

A finer resolution model would result in a better representation of the flooding characteristics and behaviour of the study area. However, this increase in definition needs to be balanced against the increased simulation times of the model.

Given that this study is a Strategic Flood Risk Assessment, the focus is expected to be on deriving and assessing strategic level measures. In this regard, a 20m x 20m model is deemed to be satisfactory for the purposes of the SFRA.

A finer resolution model would not provide significantly different result to those presented in this study. This is based on the reasons that follow.

The 2D domain only represents the floodplain areas. The hydraulic behaviour of the open channels and pipe system, of which most is considerable smaller than 20m in width, is represented by a 1D network. The elements in this 1D network accurately reflect the size and hydraulic characteristics of these finer features.

Whilst a 20m x 20m grid will not adequately represent a narrow flowpath on the floodplain such as a roadway a grid size in the order of 5m x 5m would be required to represent this level of detail. The impact of this smaller grid size on simulation times is that simulation times would increase by a factor in the order of 50. This is because the number of grids increases by a factor 16 and the time-step would decrease by a factor of 4 to achieve a numerically stable model. Hence, a 5 hour simulation would take in the order of 250 hours for the smaller grid.

However, the modelling approach and model platform chosen is sufficiently flexible to allow a finer scale 2D model domain of specific areas to be developed at a later date. These finer scale 2D model domains can be dynamically linked to the broader scale 20m x 20m grid.

<u>Last 2 bullet points incorporated to paragraph 5.5.1.8.</u>

<u>Paragraph 5.5.1.9 supersedes following:</u>

> The Environment Agency MasterMap data was also used to identify polygons representing building outlines. As discussed previously, it was decided that these areas are assumed to not contain or convey floodwaters. Hence, all cells falling within these polygons were raised to 15mAOD (i.e, above all expected flood levels).
>
> The relative influence of this approach can be determined by considering the area of all buildings (1.7 km^2) against the study area (47 km^2) and the Zone 3 area (41 km^2). Hence, the area of buildings is a relatively small proportion of the inundated area (4%) and would represent an even smaller proportion of the inundated volume as the buildings are generally in the shallow parts of the floodplain.

<u>Paragraphs 5.5.2.6 to 5.5.2.11 supersedes following:</u>

> The latter area was represented in the 1D network using estimated channel dimensions. These estimates and locations of the major drains were derived from inspection of aerial photography and OS mapping. The majority of these channels

were estimated to have a base width of 3m to 5m with a 1:1 side slopes and a depth of 1.5m (for instance, top width of 6m to 8m).

The outlet details were derived either from the BTP InfoWorks CS models or data provided by the Environment Agency.

The 1D network is shown in Figure 5.10 – 1D Model Network showing the combined 1D elements (nodes and channels). The total 1D network includes over 700 channels and nodes.

Paragraph 5.6.1.1 supersedes following (from phase 2):

Due to the resolution of the 2D model with a 20m cell size, it was necessary to supplement the base elevation of the cells (derived from the DTM) with specific data to represent features such as road crests and flood defences. This data was derived from flood defence crest level topographic survey collected for the entire water frontage, for the Avonmouth to Aust Tidal Defence Survey, August 2005.

Paragraph 5.6.1.1 supersedes following (from phase 1):

Due to the resolution of the 2D model with a 20m cell size, it was necessary to supplement the base elevation of the cells (derived from the DTM) with specific data to represent features such as road crests and flood defences. This data was derived from the following sources:

- Flood defence crest levels from the M4 crossing of the River Avon to the northern extent of Bristol Port were derived from Bristol Port Company plans (varying 10.2m to 11.5 mAOD);
- Flood defence crest levels from Bristol Port to Severn Beach were derived from interrogation of the DEM (varying from 9.3m to 10.0 mAOD). *It should be recognised that this process will result in crest levels that will have an accuracy of approximately ±250mm for hard surfaces and less for soft (for example, grassed) surfaces;*
- Flood defence crest levels at Severn Beach (for instance, Binn Wall) were derived from Environment Agency information that the crest level is 10.5mAOD;
- Flood defence crest levels north of Severn Beach were derived from Environment Agency advice (varying from 9.0mAOD to 9.2mAOD).

Section 5.5.2 was removed:

Assumptions Regarding M49 and London-Cardiff Railway

The Environment Agency advised that the M49 road embankment and the London-Cardiff railway embankment should not be assumed to be in place for the purposes of defining the Flood Zones. This assumption is consistent with advice from the Highways Agency and

Network Rail that these features should not be considered as water retaining structures for flood defence purposes.

However, because of the significant incidental impact on flooding and flood risk that the features might have on Flood Zone definition, sensitivity-modelling runs were also undertaken with the features included, to show clearly what effect this different approach would have produced. The modelling results for this sensitivity analysis are discussed and presented in Appendix **Error! Reference source not found.**. It was apparent from these sensitivity analyses that the removal of these features will have only a minor impact on the extent of flood zones. In summary of this issue, the assumption to remove the M49 road embankment and the London-Cardiff railway embankment has resulted in the most conservative approach to defining the extent of the flood zones. This is in keeping with the precautionary approach adopted throughout this study.

Section 5.8.2 supersedes following (from phase 3):

Extreme storm surge water levels have been obtained from two sources. The first was obtained from a study that was undertaken by a consortium of Posford Haskoning and Mott MacDonald in 2003: "*Report on Regional Extreme Tide Levels, Environment Agency, South West Region*" [PDMM (2003)]. The extreme water levels from the PDMM (2003) study are detailed in Table 5.2.

Table 5.21 – Extreme Water Levels (PDMM, 2003)

Water level with a return period of	Extreme Water Level (m AOD)
1 in 2 year in 2004	8.24
1 in 200 year in 2004	9.09
1 in 1,000 year in 2004	9.37

The second and current set of extreme storm surge water levels used in this study have been obtained from the study that was undertaken by ABPmer in 2005: *"Avonmouth to Aust Tidal Defence Scheme: Joint Probability Analysis of Waves and Water Levels*" [ABPmer (2005)]. The ABPmer reports extreme water levels for a variety of return periods for the design year 2005, and are detailed in Table 5.1.

Table 5.22 – Extreme Water Levels for Various Return Periods Used in Modelling (ABPmer, 2005)

Water level with a return period of	Avonmouth (m AOD)	JPA Site 1 (m AOD)	JPA Site 2 (m AOD)	JPA Site 3 (m AOD)
1 in 2 year in 2010	8.40	8.42	8.51	8.70
1 in 200 year in 2010	9.03	9.06	9.15	9.35
1 in 1,000 year in 2010	9.21	9.24	9.33	9.53
1 in 2 year in 2110	9.35	9.37	9.46	9.65
1 in 200 year in 2110	9.98	10.01	10.10	10.30

Water level with a return period of	Avonmouth (m AOD)	JPA Site 1 (m AOD)	JPA Site 2 (m AOD)	JPA Site 3 (m AOD)
1 in 1,000 year in 2110	10.16	10.19	10.28	10.48

For the extreme water levels in 2105, the extreme water levels of ABPmer (2005) have been extrapolated to 2105 by taking into account net sea level rise (climate change). The DEFRA supplementary note to operating authorities on the impacts of climate change, released October 2006, outlines sea level rise allowances for the South West region, as detailed in Table 5.4. Based on the DEFRA guidance, an allowance of 945 mm has been adopted to extrapolate the extreme water levels over the 100 year planning horizon to 2105. The extreme water levels listed in Table 5.1 have been used.

Table 5.23 – Net Sea Level Rise Allowance (DEFRA, Oct 2006)

Administrative or Developed Region	Net Sea-Level Rise (mm/yr)			
	1990-2025	2025-2055	2055-2085	2085-2115
South West and Wales	3.5	8.0	11.5	14.5

Modelling performed for this study uses the ABPmer (2005) extreme still water levels for the three extreme water level – wave height joint probability (JPA) sites. Between the JPA sites, the water level has not been interpolated to represent a sloping water surface along the frontage. Rather, discreet lengths of frontage have been allocated a water level based on the nearest and most representative JPA site, including around Avonmouth. This is necessary when the joint probability of wave action is considered.

<u>Paragraphs 5.8.2.1 to 5.8.2.4 supersede following (from phase 2):</u>

The extreme storm surge water levels used in this study have been obtained from a study that was undertaken by a consortium of Posford Haskoning and Mott MacDonald in 2003: *"Report on Regional Extreme Tide Levels, Environment Agency, South West Region*" [PDMM (2003)].

PDMM (2003) reports extreme water levels for a variety of return periods for the design year 2002. In this study the extreme water levels of PDMM (2003) have been used for the design year 2004 as it is assumed there are negligible changes between 2002 and 2004.

For the extreme water levels in 2104, the extreme water levels of PDMM (2003) have been extrapolated to 2104 by taking into account sea level rise (climate change). The expected sea level rise in the South West Region is 5 mm/year [MAFF (1993)]. The extreme water levels listed in Table A.5.4.1 have been used.

Water level with a return period of 1 in 2 year in 2004	8.24 mAOD

Water level with a return period of 1 in 200 year in 2004	9.09 mAOD
Water level with a return period of 1 in 1,000 year in 2004	9.37 mAOD
Water level with a return period of 1 in 2 year in 2104	8.74 mAOD
Water level with a return period of 1 in 200 year in 2104	9.59 mAOD
Water level with a return period of 1 in 1,000 year in 2104	9.87 mAOD

<u>Paragraph 5.8.3.1 supersedes following:</u>

The sea water levels during the design storm surge event have be constructed by superimposing a surge profile on a mean spring tide. In other words, the water levels during the tidal flood event with a return period of 1 in 200 year in 2105 were derived by summing the spring tide level in 2105 and a storm surge level.

<u>Paragraph 5.8.3.6 supersedes following (from phase 3):</u>

Due to climate change, it is expected that the mean sea level will rise by rates outlined in Table 5.4 (DEFRA, 2006). It is assumed that both the MHWS and MLWS will proportionally increase with the mean sea level. For design year 2105, the MHWS and MLWS have been obtained by adding 945 mm (2005 to 2025 x 3.5 mm/yr, 2025 to 2055 x 8.0 mm/yr, 2055 to 2085 x 11.5 mm/yr & 2085 to 2105 x 14.5 mm/yr) to the figures from Hydrographer of the Navy (1996).

- Mean high water spring level in 2105 = 7.65 mAOD
- Mean low water spring level in 2105 = -4.56 mAOD

<u>Paragraph 5.8.3.6 supersedes following (from phase2):</u>

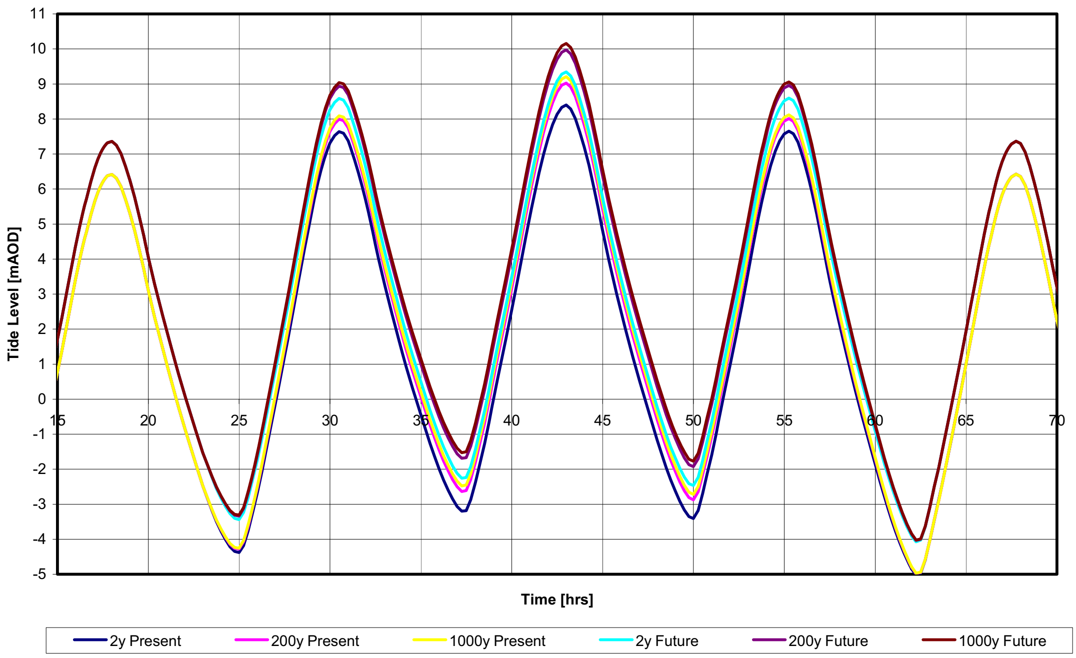
Due to climate change, it is expected that the mean sea level will rise by 5 mm/year [MAFF (1993)]. It is assumed that both the MHWS and MLWS will proportionally increase with the mean sea level. For design year 2104, the MHWS and MLWS have been obtained by adding 500 mm (100 years x 5 mm/year) to the figures from Hydrographer of the Navy (1996).

- Mean high water spring level in 2104 = 7.2 mAOD
- Mean low water spring level in 2104 = -5.0 mAOD

<u>Paragraph 5.8.4.4 supersedes following (from phase 2):</u>

The water levels during a storm surge event with a return period of 1 in 2 year, 1 in 200 year and 1 in 1,000 year for the design year 2005 and for 2105 at Avonmouth are shown in Figure 5.8.1. Note that the tidal water levels at Avonmouth have not been used in the modelling, rather the extreme tidal water levels at each of the three JPA sites. Furthermore, the single spring tide profile has been used at all JPA sites. This may over estimate the trough of the wave profile further upstream the Severn Estuary.

Figure 5.16 – Tide and Surge Levels at Avonmouth

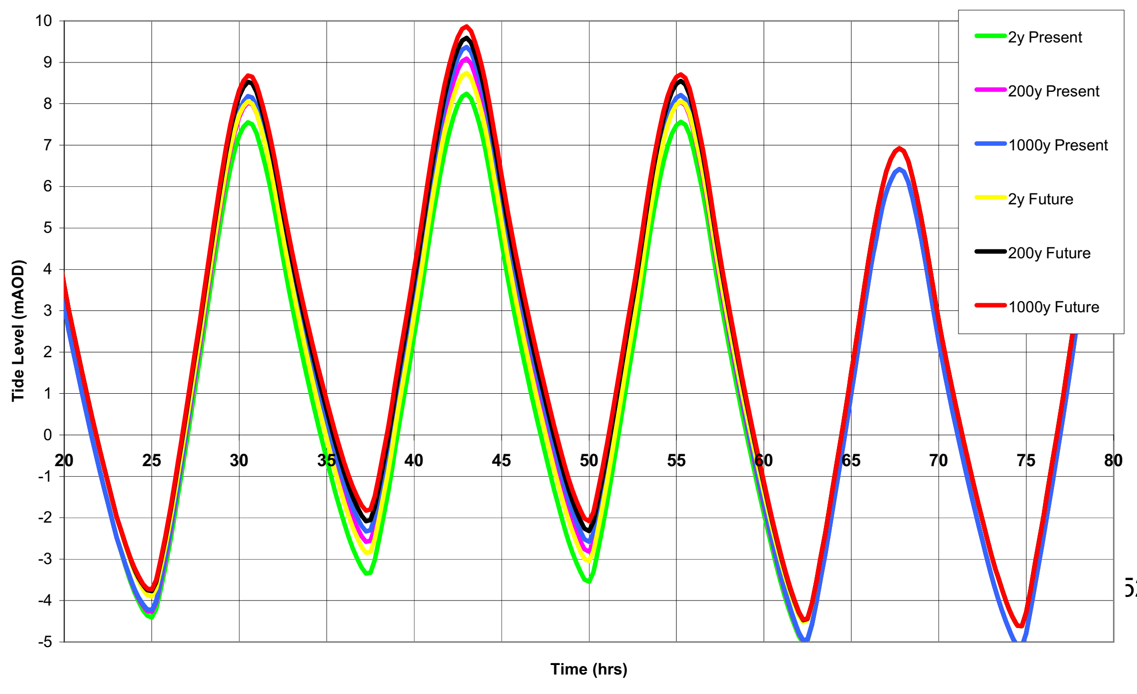


Paragraphs 5.8.4.2 to 5.8.4.4 supersedes following (from phase 1):

The peak level of the storm surge is the residual of the estimated extreme water level minus the high water level during a normal spring tide.

The water levels during a storm surge event with a return period of 1 in 2 year, 1 in 200 year and 1 in 1,000 year for the design year 2004 and for 2104 are shown in Figure A5.3.

Figure A5.3 – Tide and Surge Levels



Section 5.9.2 supersedes following (from phase 2):

The wave exposed sea defences have been divided in eights sections. The eight distinct sections are shown in Figure 5.11 – Wave Overtopping Assessment Sections. For each section, one representative cross section profile was chosen by interrogating the DTM. The representative sections were later adjusted using the survey cross sections collected along the flood defence from Avonmouth to Aust as part of the Sea Defence Topographic Survey commissioned by the EA. The characteristics of the eight levee sections are presented in Table 5.5 and the eight representative cross sections and corresponding JPA site locations are shown in Figure 5.11 – Wave Overtopping Assessment Sections (plan view).

The process to incorporate wave overtopping into the Avonmouth TUFLOW model involved using empirical formulae to derive time-varying inflows for various combinations of water levels and foreshore geometries, and is outlined in the following flow chart. This process was carried out for both defended and undefended cases as the height of the defence changes in these cases.

Table 5.5 supersedes following:

Table 5.24 – Wave Overtopping Sections

Reference Section	Section Length [m]	Cross-Section ID	Corresponding JPA Site
WS_01	2,614	Section_08	3
WS_02	1,203	Section_11	2
WS_03	2,701	Section_17	2
WS_04	1,501	Section_20	1
WS_05	1,072	Section_23	1
WS_06	921	Section_25	1
WS_07	459	Section_26	1
WS_08	903	Section_28	1

Paragraphs 5.9.2 to 5.9.2.2 supersedes following (from phase 1):

The wave exposed sea defences have been divided in eights sections. The eight distinguished sections are outlined in Figure 5.11 – Wave Overtopping Assessment Sections. For each section, one representative cross section profile has been chosen by interrogating the DTM. The characteristics of the eight levee sections are presented in Table A.5.5.1 and the eight representative cross sections are shown in Figure 5.11 – Wave Overtopping Assessment Sections (plan view).

The process to incorporate wave overtopping into the Avonmouth TUFLOW model is shown in the flow chart. This process was carried out for both defended and undefended cases as the height of the defence changes in these cases.

Table A5.5.1 – Wave Overtopping Sections

Reference Section	Section Length [m]	Cross-Section ID
WS_01	2,614	Section_08
WS_01	2,614	Section_08
WS_02	1,203	Section_11
WS_03	2,701	Section_17
WS_04	1,501	Section_20
WS_05	1,072	Section_23
WS_06	921	Section_25
WS_07	459	Section_26
WS_08	903	Section_28

<u>Paragraphs 5.9.4.2 to 5.9.4.5 supersedes following:</u>

For this study, no wave spectrum analysis has been undertaken. The nearshore, pre surf-zone wave conditions used were obtained from the *Severn Estuary Shoreline Management Plan, Phase II Report* (2000). In this report, the wave conditions within the Severn Estuary have been calculated using the 2D wave model MIKE21-NSW (Nearshore Spectral Wave module). The wave conditions resulting from the study are upper limit conditions and must be seen as probable maximum conditions (extreme return periods).

Along the Avonmouth coastline, the Severn Estuary SMP reports the following wave conditions:

- Maximum significant wave height = 2.0m to 2.5m
- Maximum mean wave period= 4s to 5s

In this study the following offshore waves have been used (precautionary approach):

- Maximum significant wave height of 2.5m for the 200y and 1,000y tidal surges
- Maximum significant wave height of 1.2m for the 2y tidal surge
- Maximum mean wave period of 5 s

- Angle of wave attack is perpendicular to coastline.

Notes On Wave Conditions Used

It should be noted that the *Severn Estuary Shoreline Management Plan, Phase II Report* (2000) did not ascribe a return period or probability to the maximum significant wave height of 2.0m to 2.5m. The wave conditions resulting from the Severn Estuary shoreline management plan study are probable maximum conditions and must be seen as an absolute upper limit. The likelihood of these waves is unknown.

Hence, it was assumed that this wave could occur during a 200-year and 1,000-year return period tidal surge event. However, it was considered that this wave height is overly conservative for the 2-year return period tidal surge event. Hence, in the absence of any wave probability analyses for the Severn Estuary, a significant wave height of 1.2m for the 2-year return period tidal surge event was assumed.

For assessing the occurring offshore waves, it is recommended to undertake a joint probability analysis where the likelihood of a certain extreme still water level and a certain wave condition could be investigated. Although extreme waves and storm surges are strongly correlated (both likely to occur during storms), it must be noted that the probability of an event where there is a surge with a 1 in 100 year return period in combination with wave conditions with a return period of 1 in 100 years is smaller (i.e, rarer) than 1 in 100 years.

Since the waves during storm events break on the foreland, the maximum wave heights at the toe of the sea defences are dominated by the water depth at the foreland and are significantly smaller than the offshore wave conditions as estimated in the Severn Estuary SMP.

<u>Paragraphs 5.9.6.1 to 5.9.6.5 supersedes following:</u>

The wave heights at the toe of the sea defence have been assessed for six tidal flood scenarios in the Severn estuary. The analysed scenarios are:

- A tidal flood event with return period of 1 in 2 years in 2004
- A tidal flood event with return period of 1 in 200 years in 2004
- A tidal flood event with return period of 1 in 1,000 years in 2004
- A tidal flood event with return period of 1 in 2 years in 2104
- A tidal flood event with return period of 1 in 200 years in 2104
- A tidal flood event with return period of 1 in 1,000 years in 2104

From analysing the results of the scenarios analysed, the following can be noted. During a tidal flood event with a return period of 1 in 2 years, the waves at the toe of the sea defence are significantly smaller than the offshore waves due to wave breaking on the foreland. For example, the maximum significant wave height at section 2 during the 1 in 2 year event in 2004 is only 0.50 m due to the high elevations of the foreland. The maximum significant wave height during the 1 in 2 year event in 2004 (with a extreme water level of 8.24 mAOD) occurs at levee section 7 and is 1.90 m.

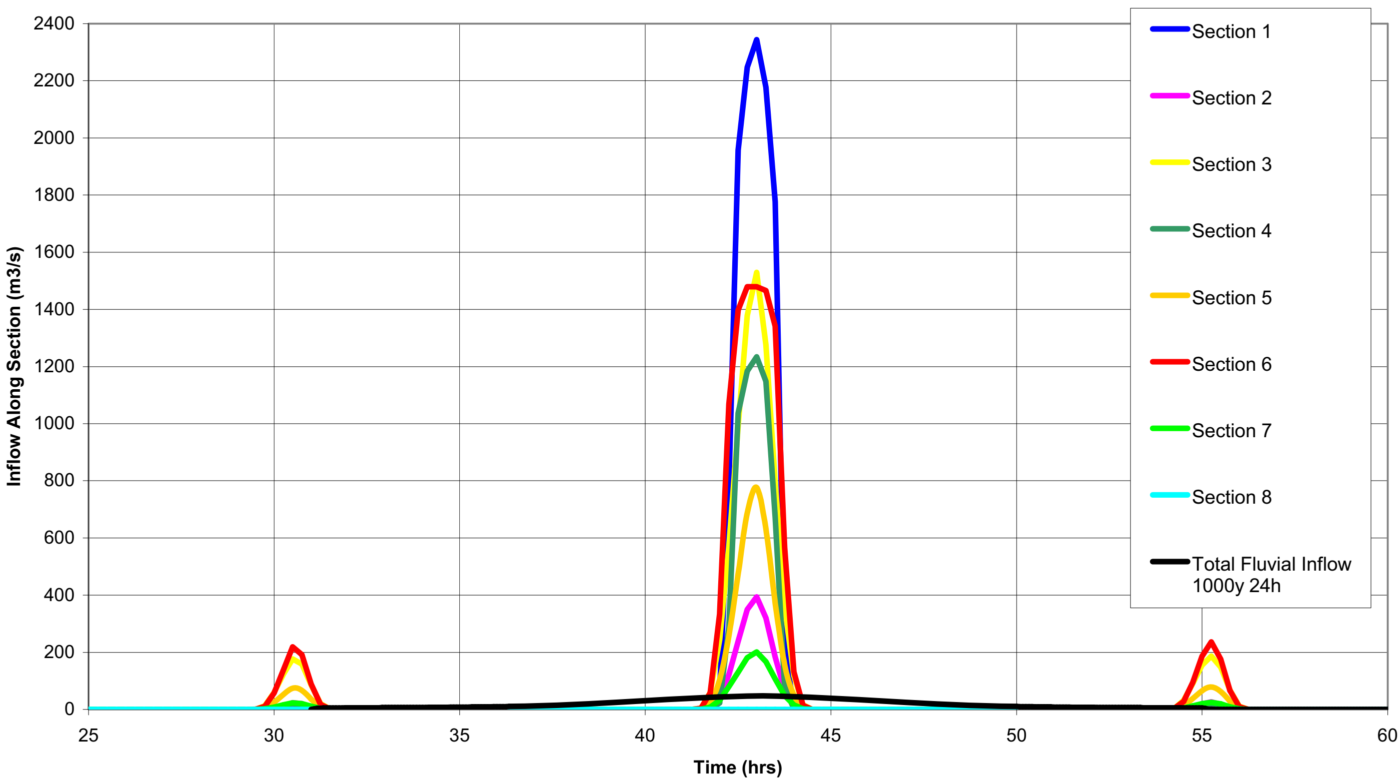
The maximum wave heights that can be expected at the toe of the sea defence are fairly sensitive to the water levels at sea. The maximum significant wave height resulting from the scenarios with a larger return period are significantly higher. During the 1 in 1,000 year tidal flood with climate change event, the expected extreme water levels are overtopping the crest of the sea defence at a number of locations and the water depths on the foreland are so deep that waves can pass the foreland without breaking, resulting in a maximum significant wave height of 2.5 m at the toe of the sea defence.

Paragraphs 5.9.8.1 to 5.9.8.8 supersedes following:

The resulting inflows for the defended case are presented as a time series in Figure A5.5. Of note in this figure is the magnitude of the inflows. The figure also shows the inflows for the 1,000y fluvial event cumulated over the study area. It is apparent from this figure that the wave overtopping inflows far exceed the fluvial flows.

These inflows were used in the 2D/1D model as inflows directly into the 2D domain immediately to the east of the flood defences.

Figure A5.5 –Wave Overtopping Inflows vs Fluvial Flows



Paragraphs 5.10.1.3 and 5.10.1.5 included.

The following paragraphs have been removed (formally Section 5.10).:

The 2D model resolution of 20 m cells is adequate to represent the flooding mechanisms for the two sub-areas:

- Sub Area A; Hallen Marsh and
- Sub Area B; Severnside (Redrow Homes).

If it is considered, at a later date, that more detailed modelling of these areas is warranted, then a finer detail model can be created and dynamically linked to the 2D 20m cell model.

The accuracy of the survey data is likely to have the following influences on results:

- In areas where predicted depths are more than 1m, the error in the DTM is unlikely to influence results to any great degree;
- In the areas on the fringe of the floodplain (and inundation areas), the DTM errors will influence the exact extent of the inundation and zones. Where ground slopes are very flat, the lateral extent error in the flood extent may be in the order of 20m (which is the resolution of the 2D model grid). However, at the edge of the floodplain, where slopes are steeper, the lateral extent error would be more likely in the order of 2m.

Paragraph 5.12.1.2 supersedes following:

Ground Level Data: The basis of the hydraulic model is the Digital Elevation Model (DEM). All DEM's have errors associated with various sources. The Environment Agency Science Group (Technology) state the following in regard to the height accuracy of point measurements of the LiDAR data used to create the DEM (south of Wales-England railway): *"The accuracy after transformation to OSGB36 (inclusive of LiDAR system errors) may be stated as +/- 11 to 25cm"*. For the area north of Wales-England railway (where NextMap data was used) the accuracy of the DEM used for this study is expected to have an accuracy of approximately 50cm. It should be noted that all accuracies quoted here are the expected vertical range that 67% of all points on hard surfaces fall within. On non-hard surfaces (for example, grass, trees) accuracies are less but not specified by the supplier.

Paragraph 5.11.1.3 supersedes following:

The accuracy of the survey data is likely to have the following influences on results:

- In areas where predicted depths are more than 1m, the error in the DTM is unlikely to influence results to any great degree;

- In the areas on the fringe of the floodplain (and inundation areas), the DTM errors will influence the exact extent of the inundation and zones. Where ground slopes are very flat, the lateral extent error in the flood extent may be in the order of 20m (which is the resolution of the 2D model grid). However, at the edge of the floodplain, where slopes are steeper, the lateral extent error would be more likely in the order of 2m.

<u>Paragraphs 5.12.1.4 to 5.12.1.6 supersedes following:</u>

Wave Height Estimates: The derivation of the wave overtopping inflows is highly dependant on the estimation of the off-shore wave height. As discussed above, definition of off-shore wave heights for a range of probabilities was not available for the SFRA study. Hence, it was assumed that the 2.5m wave height would have a probability suitable for the 1 in 200 year and 1 in 1,000 year tidal/surge simulations. For the 1 in 2 year tidal / surge simulation, a 1.2m wave height was assumed in the absence of any analysis of wave data.

Combined Probability of Waves/Tide/Surge: As discussed above, this study assumed that the probability of a rare wave (2.5m height) would occur at the same time as the 1 in 200 year and 1 in 1,000 year return period tidal/surge simulations. This assumption of the probability of wave heights occurring coincidently with a tidal/surge event is an extremely influential parameter in determining the outcome, and re-analysis of the flood extents is advised as soon as better data becomes available. Alternatively the scope of the SFRA could be extended to further examine this aspect and seek to reduce the uncertainty.

<u>Paragraphs 5.12.1.8 supersedes following:</u>

Fluvial Inflows and Groundwater Influences: As discussed in Section 5.7, the inflows were derived from the previous InfoWorks CS modelling. However, the fluvial flooding of the area is most probably strongly influenced by high groundwater levels following a long period of heavy rainfall. Hence, the approach of using a hydrological model to simulate a fixed duration event (say 12 hour storm) is not able to properly represent the influence of groundwater inflows on resulting flood levels. It is recommended that a data collection programme be initiated to rectify this situation.

<u>Section A5.1.3 included,</u>

Section 6. Planning, Socio-Economic and Environment Appraisal

6.1. Revision Status

6.1.1.1 This section has not been reviewed for the Phase 4 (2010) release of the SFRA. Much of the the information presented may therefore be out of date and not reflect current policy and guidance. The following documents are known to have been issued since this assessment was completed and the implications of their release may need to be considered:

- **Planning Policy Statement 25 (replacing PPG25)**
- **Planning Policy Statement 20 (replacing PPG20)**
- **South West Regional Flood Risk Appraisal and Regional Spatial Strategy (since rescinded)**
- **Bristol City Council & South Gloucestershire Council Strategic Flood Risk Assessments**
- **Bristol City Council & South Gloucestrshiore Council Local Development Frameworks (in development)**

6.2. Introduction

6.2.1.1 This Chapter provides a review of the land use planning, environmental and socio-economic context for a Strategic Flood Risk Assessment in the Avonmouth / Severnside area.

6.2.1.2 The conclusions of this Assessment will inform a wider body of work to review land use strategy for the West of England area (the former Avon County). Avonmouth / Severnside has previously been identified as a potential strategic employment site within the South West Region. Its future role will be re-examined through the preparation of Joint Study Area work being undertaken by Local Authorities in the West of England on behalf of the South West Regional Assembly. This work was to be completed by the end of July 2005. In conjunction with assessments of the need for employment land and emerging findings of the Greater Bristol Strategic Transport Study, information from the Strategic Flood Risk Assessment will inform recommendations on a land use strategy for Avonmouth / Severnside with a view to its inclusion within a Regional Spatial Strategy for the South West.

6.3. Method of Assessment

6.3.1.1 A desk-based study of the relevant planning and environmental documents, which pertain to the study area, has been undertaken.

6.3.1.2 The following planning documents were reviewed:

- Directive 2001/42/EC of the European Parliament and of the Council on the Assessment of the Effects of Certain Plans and Programmes on the Environment;
- Planning Policy Guidance (PPG) 9 Nature Conservation 1994;
- PPG 20 Coastal Planning 1992;
- PPG25 Development and Flood Risk 2001;
- Regional Planning Guidance 10 for the South West 2001;
- Sustainable Communities Plan 2003;
- The West of England Partnership 'Your Area, Your Vision - Directions for Change – Sub-Regional Spatial Strategy' November 2004;
- Sub Regional Vision for 2026 and delivery priorities – Draft for Public Consultation, The West of England Partnership, November 2004;
- Greater Bristol Strategic Transport Study 2004;
- Joint Replacement Structure Plan for Bath and North East Somerset, Bristol, North Somerset and South Gloucestershire September 2002;
- Bristol Local Plan 1997;
- Bristol Local Plan Proposed Alterations – First Deposit Draft for Consultation February 2003;
- South Gloucestershire Local Plan Revised Deposit Draft June 2002;
- Inspectors Report South Gloucestershire Local Plan (November 2004);
- South Gloucestershire Local Plan - Topic Paper to Public Local Inquiry June 2003: TP6 Severnside;
- Avon Biodiversity Action Plan; and
- Bristol Biodiversity Action Project.

6.4. Description of Study Area

6.4.1.1 The study area is located to the north west of the City of Bristol and east of the River Severn. It is bounded to the north by the M48 and to the south by the River Avon and the A4. Its eastern boundary comprises the urban edge of Bristol and a number of small settlements located west of the M5. The western boundary comprises the banks of the River Severn. The M48 diverges from the M4 southwest of Olveston. It spans the River Severn via the Severn Bridge prior to merging with the M4, west of Caldicot. The Severn Bridge is a toll bridge into

Wales. The M4 comprises a major transport link, which runs from London to Swansea.

6.4.1.2 The area includes an intricate network of transport infrastructure. In addition to the aforementioned motorways, the A403 runs in a north south direction adjacent to the banks of the River Severn, serving a number of settlements including Avonmouth, Severn Beach, Pilning, Aust and a number of industrial estates. It links with the A4 south west of Bristol. The M49 runs through the centre of the study area. It diverges from the M5 at Avonmouth and runs in a northwest direction prior to linking with the M4. At this point the M4 spans the River Severn, south of the Severn Bridge. Numerous other secondary roads serve the area.

6.4.1.3 The First Great Western Railway serves the area, running from London to Cardiff. The Royal Portbury Dock is located to the south of Avonmouth Docks.

6.4.1.4 The main settlements, located from north to south include Aust, Almondsbury, Pilning, Severn Beach, Easter Compton and Avonmouth. The principal land uses comprise agricultural land and industrial development.

6.4.1.5 The area is rich in environmental resources, which boast a wealth of national and international designations. The most important of these is the River Severn, which is both a Ramsar site and Natura 2000 site. There are numerous BAP habitat sites and nature conservation sites, protected by the local planning framework. These are referred to in more detail in Appendix A6.1.16.

6.4.1.6 Various GIS layers collected from both the Environment Agency Midlands and South West Regions are shown in Figure 6.1 to Figure 6.9 – Special Area of Conservation (SAC) Environment Agency Southwest Region

6.4.1.7 The Steering Group has also provided a Developed Areas Layer as shown in Figure 6.10 – Avonmouth Severnside Developed Areas

6.4.1.8 A comprehensive Planning, Environmental, and Socio-Economic Appraisal was performed to established key planning policies and objectives, which direct the type and level of development within the area and is presented in Appendix A6.1. A summary is presented in this section.

6.5. Planning

6.5.1.1 This review indicates that the study area is recognised as an employment resource of regional significance and which is promoted for further employment development in the longer term. The Structure Plan refers to proposed employment uses in the area over a long-term period, at a scale appropriate to the capacity of the transport network and the environment. The South Gloucestershire Local Plan mirrors these aspirations. Similar planning objectives are proposed for Avonmouth, via the Bristol Local Plan, which highlights the area for promotion and regeneration. However, a more constrained approach to development potential in the area has been taken in the Proposed Alterations to the Bristol Local Plan, that reflects the precautionary principle in relation to flood risk advocated by PPG25.

6.5.1.2 The host of environmental designations within the study area places major constraints on such development, underlining its sensitive nature with regard to employment expansion. Nature conservation and other environmental objectives contained in relevant national and European legislation, and reflected in numerous development plan policies contained in local plans for Bristol City Council and South Gloucestershire Council, are a major consideration in assessing development and flood alleviation options alongside the Severn Estuary.

6.5.1.3 Section 6.6 details the range of environmental designations, which pertain to the study area and which highlights its sensitivity. The Severn Estuary, which is an internationally protected habitat and the catalogue of other sensitive areas, highlight this as a region, which requires protection.

6.5.1.4 It is apparent that while the study area has economic potential this needs to be very carefully balanced against the protection and enhancement of the ecologically important and fragile environment centred on the Severn Estuary.

6.6. Environmental

6.6.1.1 The Severn Estuary has been notified as a Site of Special Scientific Interest (SSSI) and is protected under the Wildlife & Countryside Act 1981 (as amended) and the Countryside & Rights of Way Act 2000. It is also designated as a Special Protection Area (SPA) under EC Directive 79/409 on the Conservation of Wild Birds ('the Birds Directive') and a Ramsar site under the Ramsar Convention on the Conservation of Wetlands of Importance.

6.6.1.2 The Estuary is also a Possible Special Area of Conservation (pSAC) under European Directive 92/43/EEC on the Conservation of Natural Habitats and Wild Fauna and Flora ('the Habitats Directive 1992'), implemented in Britain by the Conservation (Natural Habitats & c.) Regulations 1994 ('the Habitat Regulations'). Any present and future planning proposals need to meet the requirements of these pieces of national and international legislation'. *(Phase 4 update – estuary is now a designated SAC.)*

6.6.1.3 Development of any kind has the potential to impact on environmental resources, through loss of habitat, changes in ground water levels, increases in human interaction and by general disturbance. The provision of flood alleviation works has the potential to directly or indirectly impact on the rich array of environmental resources located within or adjacent to the study area, which includes the Severn Estuary. Such environmental resources are protected via the Countryside and Rights of Way (CROW) Act 2000, which states that all authorities have responsibility in law to contribute towards conserving and enhancing SSSIs in the course of discharging their statutory and non-statutory duties. In addition, English Nature must be consulted prior to development being permitted to protect environmental resources.

6.6.1.4 Proposals for a Strategic Flood Risk Solution should be conditional on further more detailed studies of the likely impacts of any flood alleviation strategy on the SSSI and its wildfowl, including loss of wet-field feeding habitat and changes in ground water levels. Loss of any of these inland feeding areas at Severnside/Avonmouth could potentially result in the loss of an area of land used by a species constituting one of the features of interest for which the Estuary is notified as a SSSI. It could have a direct and deleterious impact on the conservation of the Severn Estuary SSSI, contrary to the legal requirements laid down in the CROW Act 2000.

6.6.1.5 Government advice also states that Ramsar sites are to be treated in the same manner and subject to the same processes as European sites. The Habitats Regulations 1994 stipulates that where a plan or project is likely to have a significant effect on a European site it should be subject to an 'appropriate assessment' of its implications for the site's 'conservation objectives'. These 'objectives' refer to the European Features of Interest for which the site was designated. It further states that the authority should only agree to a plan or project having first ascertained that it will not adversely affect the *'integrity of the European site'*.

6.6.1.6 Any works to alter the flood defences could have major archaeological implications. There is the possible survival of an earlier flood defence north of the oil terminal site, west of the railway line and previous work in improving flood defences at Stup Pill revealed evidence for the survival of organic materials, including timber. Any proposals for works to the flood defences must be preceded by detailed archaeological evaluation in the form of targeted trial trenches and boreholes, to determine the likely survival of archaeological deposits and features. Such work could be carried out as part of a programme of geotechnical investigation, although all archaeological works must be undertaken by a qualified archaeologist.

6.7. Socio-Economics

6.7.1.1 Within the study area, the Avonmouth Ward is of particular importance in the context of flood risk to its population and scale of industry located within the floodplain. Annual Business Inquiry data suggests some 12,700 people worked in

Avonmouth in 2003. The data also indicates that there were some 780 businesses in the area. From 2001 Census: Theme table T10, Table 6.7.1 has been created outlining the key statistics.

Table 6.7.1 – Avonmouth Ward, 2003 Census Data

Census Category	Population
Population	12,177
Dwellings	5,254
Males	5,930
Females	6,247
'Resident' population aged 16-74	8,499
Out Commuters	3,217
Lives and works in area	2,255
In Commuters	10,138
Lives in area but does not work	3,027
'Workplace' population	12,393

Mapping and Figures

Section 6 Appendices

A6.1 Planning Appraisal

A6.1.1 Directive 2001/42/EC of the European Parliament and of the Council on the Assessment of the Effects of Certain Plans and Programmes on the Environment

A6.1.1.1 The objective of Directive 2001/42/EC is the protection of the environment and the integration of environmental considerations into the preparation and adoption of plans and programmes, with a view to promoting sustainable development. Article 3 states that an environmental assessment shall be carried out for all plans and programmes which are prepared for agriculture, forestry, fisheries, energy, industry, transport, waste management, water management, telecommunications, tourism, town and country planning or land use and which set the framework for future development consent of projects listed in Annexes I and II to Directive 85/337/EC.

A6.1.2 PPG 9 Nature Conservation

A6.1.2.1 The Government's objectives for nature conservation aim to ensure that its policies contribute to the conservation of the abundance and diversity of British wildlife and habitats. It also aims to minimise the adverse effects on wildlife where conflict of interest is unavoidable, and meet its international responsibilities and obligations for nature conservation. PPG 9 therefore sets out the principles and policies that apply to the integration of nature conservation priorities and land use planning.

A6.1.2.2 Nature conservation objectives should be taken into account in all planning activities, which affect rural and coastal land use. They should be reflected in regional planning guidance, structure plans, unitary development plans and local plans and on a strategic basis. Nature conservation can be a significant material consideration in determining many planning applications, especially in or near SSSIs. However, local planning authorities should not refuse permission if development can be subject to conditions that will prevent damaging impact on wildlife habitats or important physical features, or if other material factors are sufficient to override nature conservation.

A6.1.3 PPG20 Coastal Planning 1992

A6.1.3.1 PPG20 covers planning policy for the coastal areas of England and Wales. The coast is an important national resource and supports a range of economic and social activities, which require coastal locations. Concerns about rising sea levels and the need for development to be sustainable focus increased attention on the special value of the coast. It is the responsibility of the planning systems via development plans and planning decisions to implement policies which protect, conserve and improve the landscape, environmental quality, wildlife habitats and recreational opportunities of the coast. PPG20 highlights issues relevant to coastal planning, referring to the link between environmental protection and opportunities for development. It also proposes the need to plan for hazards including flooding, erosion and unstable land.

A6.1.3.2 The key policy issues for coastal planning are:

- Conservation of the natural environment;
- Development, particularly that which requires a coastal location;
- Risks, including flooding, erosion and land instability; and
- Improvement of the environment, particularly of urbanised or despoiled coastlines.

A6.1.3.3 With reference to flooding, policy should aim to avoid putting further development at risk. In particular, new development should generally not require expensive engineering works, designed either to protect developments on land subject to erosion by the sea, or to defend land, which may be inundated by the sea. Policies should specifically control development in low-lying coastal areas, on land close to eroding cliffs/coastlines and on land in coastal areas subject to instability.

A6.1.3.4 PPG20 further states that protection against erosion and defence against flooding can have a considerable effect on the coastal environment. In low-lying, undeveloped coastal areas, options for coastal defence may include a policy of managed retreat. It may be appropriate to restrict development in such areas pending decisions on coastal defence.

A6.1.4 PPG25 Development and Flood Risk 2001

A6.1.4.1 Flood issues have long been recognised as being material planning considerations. Due to the increased severity and frequency of flooding, the Government is looking for a step change in the responsiveness of the land use planning system to the issues of flood-risk management as they affect the planning process. This guidance aims to strengthen the co-ordination between land-use planning, land management and the building regulations.

A6.1.4.2 The incidences of problems due to river flooding may be getting worse both in frequency and in scale. This arises from changes in river hydrology due to human activity, changes in land management, variations in the intensity of rainfall and increases in development in areas at risk. Furthermore, climate change also contributes to sea-level rise and more intense rainfall.

A6.1.4.3 PPG25 details how flood risk should be considered at all stages of the planning and development process to reduce damage to property and possible loss of life. It specifies how local planning authorities undertake flood risk assessment for particular sites or over a particular development area. It states that by reducing the vulnerability of the country to unmanaged floods, it would contribute to the achievement of a better quality of life and the objectives of sustainable development".

A6.1.4.4 With reference to flooding and land-use planning, the government through PPG25 recognises the importance of avoiding the provision of artificial defence against flooding. Local planning authorities should consider the information available on the nature of flood risk and its potential consequences and accord it appropriate weight in the preparation of development plans and in determining applications for planning permission.

A6.1.5 Regional Planning Guidelines 10 for the South West 2001

A6.1.5.1 The principal objectives of RPG 10 are as follows:

- Provision of a regional spatial strategy which local transport plans and development plans should be prepared;
- Provision of a broad development strategy up to 2016; and
- Provision of a spatial framework for other strategies and programmes.

A6.1.5.2 The Bristol area is the largest urban area within the region, which claims high environmental quality, extensive lengths of coastline and valued landscapes. The vision for the region is one, which 'develops in a sustainable way, as a national and European region of quality and diversity, where the quality of life for residents, the business community and visitors will be maintained and enhanced'. The aims which will realise this vision are as follows:

- Protection of the environment;
- Prosperity for communities and the regional and national economy;
- Progress in meeting society's needs and aspirations;
- Prudence in the use and management of resources.

A6.1.5.3 Chapter 3 details Sub-Regional Profiles. The Bristol area is the largest urban centre in the region and extends into North Somerset, South Gloucestershire and BANES (Bath and North East Somerset). The area has a key role for economic growth, both regionally and nationally. Constraints to physical expansion are detailed and include risks to coastal flooding, limited crossings of the River Avon and areas of ecological and agricultural importance. Policy SS8 details the following objectives for the Bristol area:

- New and improved urban facilities;
- Redevelopment to provide for mixed uses;
- Balanced provision of additional housing, employment, social and recreational facilities;
- Integrated public transport facilities;
- An enhanced economic base;
- Effective use of Bristol International Airport;
- A review of the Green Belt; and
- Economic, physical and social regeneration especially within the disadvantaged areas.

A6.1.5.4 Policy RE2 refers to flood risk. It states that local authorities, the Environment Agency and developers should protect land liable to river and coastal flooding by directing development away from river and coastal floodplains; promote sustainable drainage systems; and adopt an approach to the allocation and development of sites, having regard to their flood risk potential.

A6.1.5.5 Development plans should identify areas at risk from flooding and provide criteria for redevelopment proposals in flood plains, in order to minimise their cumulative adverse impact and secure enhancement of the floodwater storage and ecological role of flood plains. Map 5 illustrates the floodplains within the region. The study area is delineated as being both a Tidal and Fluvial Floodplain.

A6.1.6 Sustainable Communities Plan 2003

A6.1.6.1 The Sustainable Communities Plan, ‘Sustainable Communities – Building for the Future’ was launched in February 2003. It sets out a long-term programme of action for delivering sustainable communities in both urban and rural areas. The South West is a diverse region with a high quality built and natural environment. It is a predominantly rural area, with over 50% of the regions population of 5 million living in rural authorities. Since 1981 the population of these authorities has grown by 17%, compared with 8% for urban authorities.

A6.1.6.2 The action plan for the area aims to do the following:

- Make effective use of the regions £2.8bn that the Government will be providing nationally over the next three years to help improve council housing;
- Deliver 460 new homes for key workers over a three-year period, through the starter homes initiative;
- Make effective use of increased resources available to build new affordable homes for rent, which should deliver around 2,000 new homes for the region in 2003/2004;

- Improve the standards of social housing and vulnerable people living in the private sector;
- Tackle problems caused by remoteness in the regions;
- Tackle congestion problems in urban areas;
- Improve access to services in rural areas; and
- Tackle quality of life in rural areas and deprived neighbourhoods.

A6.1.7 The West of England Partnership 'Your Area, Your Vision - Directions for Change – Sub-Regional Spatial Strategy' November 2004

A6.1.7.1 The West of England Partnership comprises four councils – Bath and North East Somerset Council (BANES), Bristol City Council, North Somerset Council and South Gloucestershire Council – and a range of social, economic and environmental partners. The partnership has compiled two public consultation documents, which will assist in guiding development in the sub-region up to 2026. The first of these comprises a 'Vision', which sets out what the sub-region should look like. The second consultation document will assist in the preparation of a 'Sub-Regional Spatial Strategy', to help shape the future of the area.

A6.1.7.2 The Spatial Study consultation suggests that 3,200 new jobs per year would be created up to 2026 which would require the provision of 4,700 new homes per year. The vision for the area is one of sustainable growth, supported by successful investment to improve the quality of life for all in the sub-region and guiding development into the 21st Century. The "Principal Urban Areas (PUA)" includes Bristol, Weston-super-Mare and Bath. The strategy should lead a process of renewal in the PUA including their suburban areas, the smaller towns and rural communities. Avonmouth and the industrial areas located to the east of the A403 are included within the PUA.

A6.1.7.3 The three scenarios proposed which help to highlight some future directions for development, but which are not distinct options are as follows:

- Focus major development and infrastructure improvements in South Bristol and North Somerset.
- Develop new sustainable communities to the north and east of the Bristol built-up area, including land north of the M4 and east of the Ring Road. An urban extension is highlighted south of the M4 at Pilning.
- Dispersed development in the vicinity of smaller towns, which would offer the potential for improving public transport, particularly in the key corridors linking Bristol, Bath and Weston, and north of Bristol.

A6.1.7.4 The strategy would also focus on issues such as the Environment, Residential Development, Economic, Transport and, Culture, Health and Education.

A6.1.8 The West of England Partnership - Sub Regional Vision for 2026 (Draft for Public Consultation, November 2004

A6.1.8.1 The document was produced to gather the public's views on the proposed development strategy and what the area should look like.

A6.1.8.2 It proposes that this area will, in 2026, be one of Europe's fastest growing and most prosperous regions, supported by major developments in employment and infrastructure, a buoyant economy, rising quality of life and cultural attractions, all of which will be delivered through sustainable means.

A6.1.8.3 To facilitate this delivery the strategy concentrates on four key areas; Strategic Capacity and Leadership, Quality of Life, Connectivity and Accessibility and, The Economy. A set of delivery criteria, which it is hoped will realise each of these visions, is also detailed.

A6.1.8.4 With regard to Connectivity and Accessibility, it refers to improved connectivity to the motorway in North Somerset and South Gloucestershire and the provision of a local link between Avonmouth and Portbury. This will support access to the Port and reduce local traffic. Key business sectors will be promoted at the Airport, Portbury and at Avonmouth/ Severnside (a green business waste park).

A6.1.9 Greater Bristol Strategic Transport Study, November/December 2004

A6.1.9.1 This study was commissioned to address the current and future strategic transport needs within Greater Bristol, up to 2031. The area covered includes the four local authorities of Bristol, North Somerset, South Gloucestershire and Bath and North East Somerset. It is hoped that over the next 20-30 years, the area would have a better quality of life, a high performing economy and better accessibility. The problems of congestion could jeopardise this vision. The three proposed transport strategies are as follows:

- Strategy 1 – Better public transport, including bus corridors, inter-urban coach services, rapid transit and improved rail services;
- Strategy 2 – Better public transport and controlled demand for travel by car. This involves merging the measure outlined in Strategy 1 with increased car parking charges etc;
- Strategy 3 – Better Roads. The illustrations refer to improvements in the Avonmouth Spine Road and the New Avonmouth Crossing. All three strategies have only been tested at this stage.

A6.1.10 Joint Replacement Structure Plan – Bath and North East Somerset, Bristol, North Somerset and South Gloucestershire September 2002

A6.1.10.1 The primary objective of the Structure Plan is to make proposals for the future scale, distribution and type of development, and transport policy for the area over a period of approximately 15 years. In this way, Structure Plans essentially provide the link in the planning system between the Government, policy statements and local plans.

A6.1.10.2 Chapter 2 sets out the strategy for the area. The overall aim and objectives of the structure plan are as follows:

A6.1.10.3 Aim: Utilise the planning system as a medium to secure sustainable development, which will help improve the area's environment and the quality of life of all its present and future residents. This will be incorporated through a number of objectives all of which follow the principle of sustainable development. These objectives include the following:

- Safeguarding and enhancing natural and historical resources;
- Minimising the consumption of natural resources and mitigate any damaging effects;
- Maintaining and enhancing economic prosperity;
- Meeting the needs of all residents in terms of housing, community services and convenient shopping;
- Providing a movement strategy which enables and enhances movement, through encouraging the usage of public transport;
- Conserving, regenerating and revitalising urban areas;
- Conserving and enhancing the character of rural areas; and
- Recognising the importance of existing communities.

A6.1.10.4 Policy 1 sets out the Sustainable Development principles, which will serve to guide the development of the area. Policy 2 refers to the locational strategy to be adopted in the Structure Plan through the medium of Policy 1.

A6.1.10.5 The key diagram delineates the locational strategy. Land to the south of M48 and north of the M49 is highlighted as a greenbelt area (Policy 16). The majority of the study area located between the M49 and the M48 is designated Green Belt area. The positive use of land will be promoted by allowing opportunities to access the countryside, recreation and outdoor sport and securing/safeguarding environmental resources.

A6.1.10.6 Land southwest of the M49 is delineated as a 'Built-up area. Policy 2 (e) states that the economic development potential of Avonmouth / Severnside and Royal

Portbury will be realised by a comprehensive and integrated approach to development at each location in conjunction with transport infrastructure, facilities for public transport services and the environmental framework.

A6.1.10.7 Policy 4 refers to transport improvements, which outline a number of key transport corridors within the structure plan area. Transport improvements will be secured between Portishead / Avonmouth and Bristol, providing park and ride facilities and improvements to the railway network.

A6.1.10.8 Policy 14 refers to development at Avonmouth / Severnside. Supporting text to the policy states that the area has the potential to become the region's premier location for manufacturing and distribution activity, and as such will perform a major role in meeting future requirements. It further states the need to upgrade the existing transport infrastructure to support such development. Environmental constraints such as hydrological and ecological issues will also need to be addressed.

A6.1.10.9 Policy 14 therefore aims to provide the expansion of a 'broad range of employment uses over a long term period', facilitated by a strong transport network and sensitive to the local rich environmental resources. Provision will be made for extensive infrastructure development.

A6.1.10.10 Policy 15 refers to the Royal Portbury Dock, stating that continued expansion of port operations will be supported, providing there will be no implications for environment.

A6.1.10.11 Chapter 3 refers to environmental and natural resources. The Severn Estuary is a designated Ramsar Site (Convention on Wetlands of International Importance) and Natura 2000 site. It is also an SSSI and SPA.

A6.1.10.12 Policy 24 refers to flood risk, stating that areas identified, as being vulnerable to flooding will continue to be safeguarded from development, which could result in the net loss of flood capacity, interrupt the free flow of water or adversely affect the areas environmental or ecological character. Provision will be made for development, which increases the risk of flooding only if environmentally acceptable mitigation measures are provided. It should be noted that this policy was adopted prior to the release of PPG25, which reflects the failure to mention the need for a risk-based sequential approach.

A6.1.11 South Gloucestershire Local Plan – Revised Deposit Draft June 2002

A6.1.11.1 The individual aims of the plan can be summarised as follows:

- Conserving and enhancing environmental resources and local distinctiveness;

- Providing residential development;
- Maintaining the local economy and increasing employment opportunities;
- Providing convenient access to retail and community services;
- Promoting safe and sustainable transport modes;
- Maintaining satisfactory provision of leisure, recreation, leisure facilities, health services and service infrastructure;
- Retaining and enhancing the variety and vitality of existing communities.

A6.1.11.2 Chapter 2 details the locational strategy of the Plan. It makes reference to the economic development potential of Severnside, stating that no provision will be made for the development of housing at this site. It will seek to

- Safeguard sensitive areas of nature conservation importance in the estuary;
- Protect the amenities of local communities; and
- Require the introduction of public transport facilities.

A6.1.11.3 Chapter 4, Section 1 refers to Landscape 'Natural and Cultural Heritage'. The Severn Estuary represents one of the four distinctive landscapes of South Gloucestershire in relation to Policy L1. Land adjacent to the coast falls within the Coastal Zone, subject to Policy L4. Development within the undeveloped coastal zone will only be permitted where a coastal location is required and the development in question cannot be located elsewhere.

A6.1.11.4 The environmental issues, which need to be addressed by any development proposals include:

- The Severn Estuary – Sites of International Conservation Interest (SPA, RAMSAR site, Natural 2000 site and a possible SAC);
- Sites of National Nature Conservation Interest (SSSI) and Sites of Regional and Local Nature Conservation Interest and Regionally Important Geological Sites interrelate with the estuary;
- The need to conserve and enhance the character and features of the historic landscape of the Severn Levels. This area extends from the River Avon to Pilning and Almondsbury, and from the M5 to the A403;
- Existing and proposed cycle and recreation routes serve the area;
- The study area is located within the coastal zone as per local plan designations;
- The study area is located within the community forest area 'Forest of Avon.

A6.1.11.5 Chapter 4, Section 2 refers to Environmental Protection. Policy EP2 refers to flood risk and development. Development which generates surface water run-off or water discharge will not be permitted where it could increase risk of flooding, require protection from flooding, reduce the capacity of the flood plain, impede the flow of flood waters, affect tidal or fluvial defences, alter the water table, increase river channel instability, cause unacceptable silt deposition, prevent maintenance of the watercourse or preclude the solution to existing flooding problems.

A6.1.11.6 Policy EP3 refers to coastal defence works. New coastal defence works or improvements to existing works will be permitted providing that they would not unacceptably affect the Severn Estuary. They will need to meet the minimum standards of 1 in 200 year event with provision for sea level rise over the lifetime of the development.

A6.1.11.7 Part of the Severn Beach/Severnside area is proposed as Green Belt. Paragraph 5.26 states that due to the potential for flooding of the Severn Levels as a possible effect of global warming, the EA has advised the Council against any further releases of land at Severnside for any purpose.

A6.1.11.8 Paragraph 6.37 details proposals for a study, which aims to increase more frequent passenger services from Bristol to Avonmouth and Severn Beach. It also aims to assess passenger services on the existing freight line between Avonmouth and Filton and Rapid Transit on the Bristol-Avonmouth-Filton and Severn Beach Routes.

Severnside

A6.1.11.9 Paragraphs 7.22 to 7.38 outline the proposed future development at Severnside. The Council's principal objective is to ensure a balance between the promotion of the area as an employment resource and the protection and enhancement of the ecological important, fragile and visually prominent coastal zone. Both South Gloucestershire and Bristol City Councils agree that the Avonmouth and Severnside areas should be planned on a comprehensive basis. An agreed Master Plan will be drawn up to oversee the phased development of the area. The council will seek to promote manufacturing and high technology industries.

A6.1.12 Bristol Local Plan 1997

A6.1.12.1 The Local Plan was formally approved in 1997. Following consultation in 2001, a number of alterations were made to the Plan and issued in February 2003. These alterations will not be adopted but will feed into the compilation of the Local Development Framework. The Local Plan has precedence in this instance.

A6.1.12.2 The key objectives of the Plan are as follows:

- To reinforce the vitality and viability of Bristol;
- To promote economic development and regeneration;

- To provide employment, economic, and social opportunities;
- To protect the environment
- To reduce congestion in the city, protect and promote shopping centres, and promote opportunities for local and regional leisure; and
- To maintain and enhance housing areas

A6.1.12.3 Chapter 2, Management of the Environment outlines a range of policies to 'plan for a sustainable city'. It states that a number of areas within the town are at risk from flooding, including parts of Avonmouth.

A6.1.12.4 Chapter 3 refers to the Natural Environment. The following policies would apply to the study area:

- Policy NE1 refers to Open Space. It aims to enhance the existing level of open space provision; sites which are important for nature conservation etc;
- Policy NE2 refers to landscape features, and aims to protect prominent or strategically important landscape features, which make a significant contribution to the landscape;
- Policy NE3 states that development will not be permitted which would involve the loss of or damage to trees and woodlands which are of landscape, amenity or nature conservation value;
- Policy NE4 refers to watercourses and wetlands. It states that development which would cause unacceptable harm to the natural watercourse system or to the extent of the loss of natural flood-plain would not be permitted, unless accompanied by appropriate mitigation measures;
- Policy NE5 refers to Sites of Nature Conservation Interest and their protection. Development which would adversely impact on an SAC or Ramsar Site, SSSI, Sites of Citywide Importance would not be permitted; development which would affect an SSSI subject to conditions which would prevent adverse impact on wildlife habitats etc;
- Policy NE6 refers to the Wildlife Network which will be protected where possible;
- Policy NE8 refers to Protected Species. Development will not be permitted which would adversely impact protected species, unless they include effective mitigation measures;
- Policy NE11 refers to New Development 'Natural Environmental' Considerations. In determining planning applications, account will be taken of the retention and protection of existing natural features and habitats and where appropriate the benefit of the landscape treatment;
- Policy NE12 refers to the creation and enhancement of open space. In determining planning applications, account will be taken of the benefits of creating new or enhancing existing open spaces.;

- Policy NE13 refers to Green Belt 'Boundary'. This outlines the inner boundary of the Green Belt, which follows generally the limits of development; and
- Policy NE14 refers to Green Belt 'Development Control', which aims to the protect the open character of the Green Belt.

A6.1.12.5 Policy ME9 states that 'development subject to flood risk will be required to provide the appropriate defence works at the same time as the development itself'. It further states that 'development which would increase the risk of flooding, or which is likely to cause unacceptable effects arising from surface water run-off, will be required to provide for the appropriate drainage infrastructure works and retention works at the same time as the development itself'.

A6.1.12.6 Chapter 12 highlights Avonmouth as an area for 'Promotion and Regeneration'. This area comprises the residential area of Avonmouth village and the docks and extensive industrial area. The prime objectives of the plan with regard to Avonmouth are as follows:

- To promote economic development, regeneration and maximise investment; and
- To make the most of the existing social, environmental and economic opportunities created by the second Severn crossing, the Channel Tunnel and new investment in the Port of Bristol.

A6.1.12.7 Policy A1 refers to Avonmouth as a 'priority area for major development opportunities'. Policy A2 refers to the provision of 95ha of employment land within this area. Policy A3 proposes increased industrial development in the vicinity of the local port, provided that there is no adverse impact on local residents.

A6.1.12.8 This chapter makes no reference to flood risk, which could adversely impede development in the area.

A6.1.12.9 The Proposals map outlines the land designations within the study area. The majority of the Avonmouth area comprises industrial development, located within a high-risk flood zone (Policy ME9). Other environmental designations, which apply to the area, include SSSIs, Wildlife Network Sites, Citywide Sites, Ramsar Sites and Greenbelt areas.

A6.1.13 First Deposit Proposed Alterations to the Bristol Local Plan February 2003

A6.1.13.1 This outlines the vision for Bristol as "the regional capital of the South West and a successful European city, valuing diversity, offering prosperity and a good and sustainable quality of life for all its citizens". In addition it outlines a Spatial

Framework, which aims to build up a network of accessible centres where local services will be encouraged to develop in the future.

A6.1.13.2 Chapter 12 refers to the Avonmouth area. Section 12.5 refers to environmental protection and improvement and makes reference to PPG25 and RPG10 (Policy RE2), stating that the 'Avonmouth area is at high risk from tidal flooding'. It refers to the EA's view that greenfield land in Avonmouth is at high risk from flooding and that the EA would object to all proposed development on this basis. It states that all new development in the Avonmouth Area should have regard to Policy ME9 (Chapter 2, Management of the Environment), as follows:

1) Development will not be permitted where:
    - It causes a net loss of flood storage capacity;
    - Runoff from development which would result in, or increase the risk of flooding of watercourses, ditches land or property; or
    - Land drainage systems serving the development site are adversely affected; or the land drainage of the site will be inadequate after development.
2) Development will not be permitted within high-risk flood zones, except;
    - Within the substantially developed area of Avonmouth shown on the proposals map. In this area, development of industrial, warehousing and storage, essential transport utilities infrastructure and docks related uses will be permitted, subject to the use of flood resistant forms of construction and appropriate contributions to improvement of flood defences and to arrangements for warning and evacuation; or
    - Within other substantially developed areas shown on the proposals map. In these areas development will be permitted subject to the use of flood resistant forms of construction and appropriate contributions to improvement of flood defences and to arrangements for warning and evacuation.
3) Where new drainage infrastructure is necessary as part of a development, SUDS (Sustainable Urban Drainage Systems) will be sought, subject to their ability to meet technical requirements.
4) Proposals should provide and/or retain access for relevant bodies to maintain drainage infrastructure.

A6.1.13.3 In addition, Para12.5.4A states that the Avonmouth area is highly sensitive ecologically, containing large areas of land designated under both the Birds Directive and the Habitats Directive, SSSIs, SNCIs and Wildlife Network Sites.

A6.1.14 South Gloucestershire Local Plan - Topic Paper to Public Local Inquiry June 2003: TP6 Severnside

A6.1.14.1 This paper explains the planning policy position taken by the Council in respect of land at Severnside and gives a detailed background to the evolution of planning policy pertaining to this area. It refers to objections, which have remained unresolved following consultation on the First and Second Revised Deposit Local Plan.

A6.1.15 Inspectors Report South Gloucestershire Local Plan (November 2004

A6.1.15.1 The Inspectors report recommends that the Local Plan be modified, through the addition of the following policy:

"The council is committed to realising the long-term economic potential of the major strategic location at Severnside, with a view to achieving a comprehensive, integrated and sustainable form of development, which would include the following:

1) a broad range of employment uses, based on the extensive opportunities for B2 and B8 uses;
2) the inclusion of non-employment uses where this complements the employment use, where it accords with the plan's locational strategy and where it helps to achieve a sustainable pattern of development. The provision of the necessary highway infrastructure, to include:
    - An M49 junction;
    - A link road to the M49 junction;
    - A spine road designed to link through the area to the south; and
    - Other necessary local road improvements
3) the provision of a level of public transport that will provide a realistic alternative to the use of the car;
4) the balancing of the promotion of the employment potential of the area with the protection and enhancement of the Coastal Zone's special ecology and landscape, and
5) the implementation of measures to avoid the unacceptable risk of flooding in the area as a whole.

A6.1.15.2 Existing employment land in Severnside is safeguarded for employment purposes under policy E3. Within these areas, employment development will be permitted provided that it would accord with policy E2 and in particular would;

1) have no unacceptable impact upon flooding, the landscape or the area's ecology;
2) not prejudice the long-term development of the area;
3) make a positive contribution to the overall achievement of a sustainable form of development in this area;
4) not harm the amenity of local residents; and
5) not cause harm to the free flow and safety of traffic on the public highway.

A6.1.15.3 No further significant development will be permitted beyond that referred to above until a development strategy is prepared.

A6.1.15.4 During the plan period the council will use all its endeavours to encourage the preparation of a comprehensive strategy for development, infrastructure provision and environmental protection at Severnside for the period beyond 2011. Such a strategy will need to be agreed with Bristol City Council and those other agencies involved with the comprehensive planning of this area.

A6.1.15.5 In addition, the proposals map should be modified to include the definition of the Severnside area, the deletion of the 1957/58 planning permissions, the reduction of the area subject to policy E3 to that of the existing industrial area (and WAP 1 area) and the definition of an area reserved for the future construction of the M49 junction. The extent of the 1957/58 planning permissions should be shown on a figure within the text of the plan

A6.1.15.6 This proposed policy has been accepted by South Gloucestershire Council, except that there is insufficient information to be able to identify an area to be safeguarded for the junction on the M49. This will continue to be shown diagrammatically in the Written Statement (see Figure 6.9 - to be renumbered as 7.6A)

A6.1.16 Avon Biodiversity Action Plan (BAP)

A6.1.16.1 The Avon BAP is the over-arching conservation strategy for the Avon area, which provides a ten-year strategic framework for management and enhancement of biodiversity. The main aims of the Avon BAP are to:

- Provide a strategic overview of nature conservation priorities in Avon;
- Identify habitats and species that are of particular value in Avon, within the national context;
- Highlight threats and issues affecting these ‘priority’ habitats and species and outline objectives to address such threats;
- Encourage a common approach to biodiversity conservation and sharing of best-practice in Avon;

- Encourage education and community action as an integral part of the biodiversity process;
- Promote the importance of Avons biodiversity at local, regional and national levels; and
- Provide a focus for monitoring biodiversity and biodiversity action.

A6.1.16.2 Ecologically, Avon is exceptionally diverse for its size. There are 28 UK BAP priority habitats located within the area. In addition, the area holds 19 of the 27 broad habitat types found in the UK. The area also supports a large number of plant and animal species that are regarded as nationally vulnerable. An audit undertaken in 2003 listed over 1,000 nationally important species, of which 47 were UK BAP species. Furthermore, the area contains a number of designated and legally protected wildlife and geological areas. These include Sites of Special Scientific Interest (SSSIs), National Nature Reserves, Special Protection Areas, candidate Special Areas of Conservation and Areas of Outstanding Natural Beauty. The Severn Estuary and its tributaries is an especially important wetland, which is protected as an SSSI, SPA, pSAC and Ramsar site. The following Habitat Action Plans are of interest within the study area:

Standing Open Water

A6.1.16.3 Standing Open Water in Avon includes natural features over 1 sq.m in size (canals, fish ponds, farm ponds, canals etc), which are important for wintering and breeding birds, invertebrates, water vole and otter. Objectives include the following:

- Maintain and enhance the condition of all standing open water;
- Monitor extent and condition of standing open water;
- Promote creation and restoration of sites such as farm and garden ponds, and ensure they are managed for wildlife;
- Monitor extent and condition of standing open water; and
- Raise awareness and appreciation of the wildlife importance of standing open water.

Watercourses and Floodplain

A6.1.16.4 These include all linear watercourses from source to sea and the whole of the floodplain, which support a diverse range of species including white-clawed crayfish, water voles, brown trout and a rich diversity of invertebrates. Objectives include the following:

- Maintain and enhance the water quality, biodiversity and natural features of all rivers and streams;
- Conduct research and monitoring to improve knowledge and understanding of riverine habitats and species; and

- Provide opportunities for education, access and awareness-raising initiatives at appropriate sites;

Coastal and Floodplain Grazing Marsh

A6.1.16.5 It is defined as seasonally inundated permanent pasture or meadow, within a level area with ditches, which maintain the water levels. As such the ditches in this landscape would be valuable wildlife havens. Objectives include the following:

- Maintain and enhance the quality of the habitat and restore biodiversity interest;
- Monitor condition of existing resource; and
- Raise awareness of the importance of coastal and floodplain grazing marsh.

Estuary

A6.1.16.6 All of the coastal areas of Avon lie within the Severn Estuary, which is one of the largest in Britain. It supports a range of distinctive communities, linked together by coastal processes, a number of which have been identified as UK BAP priority habitats. These include mudflats, maritime cliff and slopes, saltmarsh, coastal and sand dunes and Sabellarla reefs. In addition, the estuary is designated as a SPA under the EC Birds Directive, pSAC under the EC Habitats Directive and a Ramsar site (wetland of international importance) and SSSI. Over 80 species of fish, internationally important wildfowl, wader populations and nationally scarce plant species have been recorded in the area. There is also a wealth of archaeological and historic features located within the area. Current threats include coastal protection works and development in the estuary and hinterlands. Objectives include the following:

- Encourage the use of managed realignment as a viable and attractive option for coastal defence, to permit the creation of further areas of priority habitat in order to offset predicted loss to sea level rise;
- Encourage management of the foreshore and surrounding hinterlands;
- Enhance the quality of the existing saltmarsh in terms of community and species diversity;
- Protect the existing sand dunes and encourage accretion by active management;
- Where possible, ensure that new developments affecting the estuary whether directly or indirectly, do not have an adverse impact on biodiversity. An Environmental Statement should also be submitted with proposals for development, and plans and projects likely to have a significant effect on priority habitats within the Severn Estuary SPA and pSAC will require an appropriate assessment;
- Improve estuarine water quality to ensure that existing priority habitats fulfil ecological and conservation roles;

- Monitor condition and extent of priority habitats in the estuary; and
- Increase awareness, understanding and appreciation of the estuary's biodiversity and its favourable management.

Bristol Biodiversity Action Project

A6.1.16.7 Bristol Biodiversity Action Project has prepared a Species Action Plan for Water Voles. Water voles are mainly confined to lowland areas adjacent to water. Objectives aim to maintain and expand on the current distribution and abundance of the species. This will be undertaken though their management and protection, by incorporating water vole conservation into integrated area management plans and providing information on water vole conservation requirements.

A6.2 Sub-Areas

This section briefly reviews the zoning designations within each of the sub-areas.

A6.2.1 Sub-Area A

A6.2.1.1 Sub-Area A is located within Bristol City Council local plan area. The entire site is designated as an area subject to flood risk. The area is designated as a coastal area, an SSSI, County Site, Open Space and Playing Fields and Recreation Ground. In addition, statutory areas of greenbelt, pedestrian route proposals, a new station and the Severnside rhines are also located within the area.

A6.2.1.2 Hallen Marsh is highlighted as a Regeneration Area in the Bristol Local Plan 1997. Policy A2 'Regeneration Area' states that between 1989 and 2001, up to 95 ha of employment development is proposed within this area. The area will be developed northwards and eastwards of the existing industrial area. The provision of a realigned A403, and its connections to a junction on the M49 will be treated as a priority.

A6.2.1.3 The Proposed Alterations to the Bristol Local Plan 2003 has not de-allocated Hallen Marsh as a regeneration area.

A6.2.2 Sub-Area B – Severnside

A6.2.2.1 This sub-area is zoned 'Major Area with Planning Permission' as per the South Gloucestershire Local Plan 2002. Several 'Major Recreational Routes' (Policy LC12) and linear tracks designated as 'Sites of Regional and Local Nature Conservation Interest and Regionally Important Geological Sites (Policy L9)' pervade this area.

A6.2.2.2 Policy L9 states that development will not be permitted unless the importance of the development outweighs the value of the interests affected. Sites of regional and local nature conservation interest represent the best examples of wildlife habitats, populations or rare species and geological features in the area.

A6.2.2.3 Policy LC12 states that recreational routes will be protected.

A6.3 Environmental Appraisal

A6.3.1.1 A review of the mapping on the Environment Agency website indicated the following:

- Bathing water is assessed as excellent along the Severn Estuary, extending southwards to Bristol;
- There is a dense network of landfill sites in the vicinity of Avonmouth, Redwick and Hallen; and
- Pollution Inventory Sites are located along the length of the A403 at Redwick and Avonmouth.

1) There are a wide range of Sites of Nature Conservation Interest located within the study area. These include SSSIs, SPAs, pSACs, Ramsar sites and locally designated areas such as Citywide Sites, Wildlife Network Sites, Greenbelt, Local Nature Reserves and Areas of Open Space.
2) The most notable includes the Severn Estuary, which is notified as a Site of Special Scientific Interest (SSSI) and is protected under the Wildlife & Countryside Act 1981 (as amended) and the Countryside & Rights of Way Act 2000. It is also designated as a Special Protection Area (SPA) under EC Directive 79/409 on the Conservation of Wild Birds ('the Birds Directive') and a Ramsar site under the Ramsar Convention on the Conservation of Wetlands of Importance.
3) The Estuary is also a possible Special Area of Conservation (pSAC) under European Directive 92/43/EEC on the Conservation of Natural Habitats and Wild Fauna and Flora ('the Habitats Directive 1992'), implemented in Britain by the Conservation (Natural Habitats & c.) Regulations 1994 ('the Habitat Regulations'). Any present and future planning proposals need to meet the requirements of these pieces of national and international legislation.
4) The estuary is located at the mouth of the River Severn, River Wye and River Avon. Its immense tidal range (second highest in the world) and classic funnel shape make it unique in Britain and very rare worldwide. The intertidal zone of mudflats, sandbanks, rocky platform and saltmarsh is one of the largest and most important in Britain. Local fauna includes internationally important populations of waterfowl, migratory fish and important invertebrate populations.

A6.3.1.2 The Forest of Avon is a mixture of green spaces in and around Bristol. In 1995 the Forest of Avon Plan was approved by the Government and a revised Forest Plan was published in 2001. This is a non-statutory plan, but is treated as a material consideration in determining proposals within the area. The Plan aims to create a "multi-purpose forest including farmland, meadows, lakes and waterways with a woodland environment for recreation and education, timber production and the provision of wildlife habitats. The ultimate aim is to ensure that woodland will occupy at least 30% of the Forest area, while 20% of the area would also be available for quiet countryside recreation based on existing public rights of way". Plantations and moors located within the study area are as follows:

- Lower Knole Farm is a new woodland, which extends to 67 ha, comprising of native broadleaves and conifers. It is located to the west of Almondsbury.
- Wheat Hill Farm is a broadleaved woodland, which extends to 8 ha.
- The Lawrence Weston Moor is located east of the M5 and northeast of Shirehampton. It is an ancient landscape of wet meadows, ponds and willow trees.
- Avonmouth Sewage Treatment Works is a National Nature Reserve designated by The Wildlife Trust and located within the vicinity of the industrial areas to the north of Avonmouth. It attracts large numbers of ducks, waders and other water birds. Three man-made lagoons and a pool provide feeding and nesting areas for birds. Rough tussocky grassland provides a refuge for voles and other small mammals.

Scheduled Ancient Monuments

A6.3.1.3 The Avonmouth Levels is an area of high archaeological sensitivity and potential. Recent work has identified the survival, over a wide area, of a prehistoric landscape comprising probably seasonal settlements of late Bronze Age to early Iron Age date, palaeochannels (the forerunners of our present rhine system) which probably connected these settlements and indications that the levels may have been settled and utilised from at least the Neolithic. There are also a number of now disappeared farm sites from the medieval period onwards, including the recently investigated Moorend Farm dating from the 11th century and the extensive moated site at Rockingham Farm (where there were also indications of a preceding Roman settlement).

There are two Scheduled Ancient Monuments on the Avonmouth Levels, the Mere Bank (SAM No 27988), an east-west bank with flanking ditches dating probably to the 12th century and forming part of the reclamation scheme instigated by the bishop of Worcester. The other Scheduled Monument is an anti-aircraft battery, west of Rockingham Farm (SAM No 28885), operational from 1940 until the end of World War Two (Figure 6.2 – Scheduled Ancient Monuments (SAM)

A6.3.1.4).

A6.4 Socio-Economic Appraisal

A6.4.1 Introduction

A6.4.1.1 The following summary gives an indication of the socio-economic characteristics of the following Wards located within the study area:

Bristol City Council

A6.4.1.2 This area has been divided into Super Output Areas (SOA), which allows a greater level of detail and analysis of available data. Bristol comprises of 252 SOA's, each with an average of 1,500 people. There are 8 SOA's located within the Avonmouth ward. Avonmouth is not ranked in the most deprived 10% of SOA's nationally in terms of Index of Multiple Deprivation. However, 5 out of the 8 SOA's are in the worst 10% in terms of Education, Skills and Training.

A6.4.1.3 There were a total of 12,177 persons in the Avonmouth Ward as per the 2001 census.

A6.4.1.4 As at 2004, there were a total of 12,700 jobs in the Avonmouth Ward, which compares with an average of 6,597 within all other wards in Bristol. The majority of people aged 16-74 were employed in semi-routine and routine occupations. There is a higher number of people who are economically inactive (2,743) compared to an average of 2,634. 30% of households have no cars or vans, compared to an average of 29%. 74% of jobs are in the service industry, whilst 19% comprise of part-time employment. 24% of residents work outside of Bristol. 62% of households are owner-occupied (average 61%), whilst 29% are rented from the city council (average 19%).

South Gloucestershire

A6.4.1.5 The total population of South Gloucestershire as per the 2001 census was 245,641. The following wards are located with the study area:

- Almondsbury;
- Pilning and Severn Beach; and
- Severn.

Almondsbury

A6.4.1.6 The population of Almondsbury (2001) was 3,703. 68% of people aged between 16-74 were economically active, with 21.7% employed in lower managerial and professional occupations. 71.8 % of people drove a car/van to work. 60.6% lived in detached accommodation and 57.9% of households own 2 or more vehicles. 41.7% owns their accommodation outright, whilst 43.7% are owner occupied with a mortgage.

Pilning and Severn Beach

A6.4.1.7 The total population of this area was 3,442 (2001). There were 1,915 economically active people aged between 16-74, 1,274 of which were in full-time employment. The majority of people (520) were in low managerial and professional occupations and 326 were in semi-routine occupations. 1,354 people drove a car/van to work. Furthermore, there were 1,404 households located within the study area, 735 of which owned their own dwelling (with a mortgage) with 449 owning their dwelling outright.

Severn

A6.4.1.8 The population of Severn was 3,537 (2001), 1,819 of which were economically active. 33.5% of people aged 16-74 were educated to degree level. A total of 598 people were employed in lower managerial /professional occupations. The majority of people (1,194) drove a car/van to work, with the majority of households (853) owning 2 or more cars/vans. There was a total of 1,350 households with 570 owned outright and 548 owned with a mortgage.

Revision Status and Schedule of Changes

Section Revision Status

Section 6 – Planning, Socio-Economic and Environment Appraisal has not been updated for the Phase 4 (November 2010) release of the SFRA. Section 6.1 – Revision Status has been added.

All technical revisions of the SFRA January 2007 release for Section 6 – Planning, Socio-Economic and Environment Appraisal are outlined below:

- Literature and information presented in this section has **not** been updated as part of the SFRA January 2007 release. The status and findings of key documents reviewed may not reflect the most recent versions.

Schedule of Changes – Latest release only

Section numbering amended to reflect the introduction of a new section 6.1.

Section 7. Strategic Flood Risk Assessment

7.1. Revision Status

This section was updated during the Phase 4 (November 2010) revision of the SFRA to take account of the latest (2010) hydraulic model results and reflect current guidance contained in PPS25 as appropriate.

7.2. Introduction to Strategic Flood Risk Assessment

7.2.1.1 This section describes the results of the hydraulic modelling simulations carried out to assist in defining the flood zones, actual risk and residual risk categories. To assist in the understanding of these results in the broader SFRA process, Appendix A7 provides guidance on the SFRA process and other associated issues (for example the definition, identification and quantification of the magnitude of the flooding hazards).

7.2.1.2 It should be noted that this section of the SFRA was produced assuming that the existing flood defences are maintained at their current crest levels over the next 100 years, and are not improved over time thus the level of protection will gradually be reduced as a consequence of the increase risk posed by sea level rise (as a consequence of climate change).

7.2.1.3 Each part of the assessment was based on specific assumptions and uncertainties. These are discussed in relation to the expected impacts on the presented results.

7.2.1.4 Finally, the implications of these results on the SFRA process are discussed.

7.3. Hydraulic Modelling to Define Flood Zones

7.3.1 Simulations to Define Zones

7.3.1.1 A number of simulations using the 2D/1D hydraulic model were carried out aimed at defining the Flood Zones. The boundaries that separate the respective zones are defined in Appendix A7.2. With the exception of the functional floodplain (Flood Zone 3b), the zones are defined for a condition where there are no formal flood defences present. Flood zones presented in Table D.1 of PPS 25 are:

- Zone 1 Low Probability

  This zone comprises land assessed as having a less than 1 in 1000 annual probability of river or sea flooding in any year (<0.1%).

- Zone 2 Medium Probability

  This zone comprises land assessed as having between 1 in 100 and 1 in 1000 annual probability of river flooding (1% - 0.1%) or between 1 in 200 and 1 in 1000 annual probability of sea flooding (0.5% - 0.1%) in any year.

- Zone 3a High Probability

  This zone comprises land assessed as having a 1 in 100 or greater annual probability of river flooding (>1%) or 1 in 200 or greater annual probability of flooding from the sea (>0.5%) in any year.

- Zone 3b Functional Floodplain

  This zone comprises land where water has to flow or be stored in times of flood. PPS25 states that the identification of the Functional Floodplain should take account of local circumstances and not be defined solely on rigid probability parameters. But land which would flood with an annual probability of 1 in 20 (5% AEP) or greater in any given year or is designated to flood in an extreme (0.1%) flood, should provide a starting point for consideration. The impact of flood defences is considered when defining flood zone 3b.

7.3.1.2 The following criteria were used in the analysis:

7.3.1.3 Zone 1 *(Low probability)* is defined as being on higher ground than the areas defined by Zones 2 and 3. Hence, no flood modelling was required to define this zone.

7.3.1.4 Zone 2 *(Medium probability)* is defined by producing a peak flood envelope of the following flood scenarios using a geometry representing the undefended case for the tidal and the defended case for the fluvial:

Tidal

- 1 in 1,000 year return period surge and tide for the critical scenario (maximum overtopping volume) at each wave overtopping section with 1 in 2 year return period fluvial inflows;
- 1 in 1,000 year return period surge and tide for the maximum extreme water level with a significant wave height at each wave overtopping section with 1 in 2 year return period fluvial inflows;
- 1 in 1,000 year return period maximum surge and tide with no significant wave with 1 in 2 year return period fluvial inflows;

Fluvial

- 1 in 2 year return period surge and tide for the critical scenario at each wave overtopping section with 1 in 1,000 year return period fluvial inflows;

- 1 in 2 year return period maximum surge and tide with no significant wave with 1 in 1,000 year return period fluvial inflows;

7.3.1.5 Zone 3a *(High Probability)* has been defined by producing a peak flood envelope of the following flood scenarios using a geometry representing the undefended case for the tidal and the defended case for the fluvial:

Tidal

- 1 in 200 year return period surge and tide for the critical scenario at each wave overtopping section with 1 in 2 year return period fluvial inflows;
- 1 in 200 year return period surge and tide for the maximum extreme water level with a significant wave height at each wave overtopping section with 1 in 2 year return period fluvial inflows;
- 1 in 200 year return period maximum surge and tide with no significant wave with 1 in 2 year return period fluvial inflows;

Fluvial

- 1 in 2 year return period surge and tide for the critical scenario at each wave overtopping section with 1 in 100 year return period fluvial inflows;
- 1 in 2 year return period maximum surge and tide with no significant wave with 1 in 100 year return period fluvial inflows;

7.3.1.6 Zone 3b *(Functional floodplain)* has been defined by producing a peak flood envelope of the following flood scenarios using a geometry representing the defended case:

- 1 in 20 year return period surge and tide for the critical scenario at each wave overtopping section with 1 in 20 year return period fluvial inflows;
- 1 in 20 year return period surge and tide for the maximum extreme water level with a significant wave height at each wave overtopping section with 1 in 20 year return period fluvial inflows;
- 1 in 20 year return period maximum surge and tide with no significant wave with 1 in 20 year return period fluvial inflows;

7.3.2 Assumptions in Simulations

7.3.2.1 The main assumptions in the modelling simulations are:

- The ground levels in the 2D model are also based on LiDAR data with accuracies of between ±150mm and ±250mm (on hard surfaces);
- The estimations of surge and tidal water levels, including allowances for climate change, have inherent assumptions that are not fully documented in this report; and

- The 2D/1D model's representation of the fluvial flood behaviour may be slightly compromised by the inability to properly represent the interaction with groundwater flows. This will have only a minor influence on practical results for larger return period events, which are primarily dominated by tidal/surge/wave effects. However, it is possible that the site is affected more frequently by less severe flooding generated by a combination of groundwater and fluvial sources.

7.3.3 Results of Flood Zone Definition

7.3.3.1 Figure 7.1 – SFRA Flood Zones

7.3.3.2 shows the flood zones derived from simulations using the 2D/1D flood model. Figure 7.2 – Environment Agency Flood Zones

7.3.3.3 shows the Flood Zones 2 and 3 previously derived by the EA. A comparison of the two figures shows that there are generally only minor differences between the two sets of zones (Flood Zone 3b is not derived by the EA). This is primarily due to low elevations of the area above sea level (i.e. generally below the 200 year tide/surge level) and the steep edges of the floodplain. The EA Flood Zones are more extensive in the southern part of the study area, indicating that more detailed local modelling may be needed to fully define the risks in this area.

7.3.3.4 A summary of Zone 2 and the flood behaviour used to derive this zone is as follows:

- Zone 2 covers the majority of the study area and almost all of the area in the northern portion of the study area. Developed areas around Avonmouth village and the adjacent industrial area are not shown to be inundated;
- With the exception of some areas around Avomnmouth, this study's definition of Zone 2 is not substantially different from the EA Zone 2. This is primarily due to the relatively simplistic nature of the flood mechanisms that dictate the ultimate flood inundation area. The major differences between the two zones relate to the areas of existing development, which are not as inundated in the simulations carried out for this study. This could be the result of LiDAR accuracy and the differing modelling approaches used to define the zones. Further detailed assessment of this area is recommended as the reasons for the differences are not immediately apparent;
- The tidal/surge dominated simulations (for instance, 1 in 1,000 year return period surge with 1 in 2 year return period fluvial inflows) completely dominate the envelope over the fluvial dominated simulations (the 1 in 2 year surge/tide with a 1 in 1,000 year return period fluvial inflows).
- The dynamic behaviour of this event can be described in three stages corresponding to the three tidal peaks. These are:

- The first tidal peak (lower than the second and equal to the third) results in significant inundation of the study area due to the absence of any flood defences. The speed of the flood wave associated with this first peak is very quick with the eastern edge of the study area inundated in approximately two hours. The southern area is not as badly inundated as the northern two-thirds of the study area. This is primarily due to the higher natural ground behind the flood defences in this area and the higher density of buildings;
- The second tidal peak is the biggest of the three peaks. The highest tide/surge levels also correspond to the highest wave overtopping inflows. This peak occurs when there is already a considerable depth of water over most of the floodplain. Hence, the conveyance of flow across the floodplain is considerably quicker than the first peak. The peak flood depths and peak flood hazards occur during this peak. The flood depths are sufficiently deep after this peak that a significant volume of water flows back out to the Severn Estuary during the recession of this peak (prior to the third peak); and
- The third tidal peak (lower than the second and equal to the first) raises depths slightly but not to the levels reached during the second tidal peak.

7.3.3.5 A similar extent of the study area for the Avonmouth / Severnside SFRA lies within the high probability flood zone (Zone 3a) where the annual probability of flooding is greater than 1% for fluvial events and greater than 0.5% for tidal events (See Figure 7.1 – SFRA Flood Zones

7.3.3.6). A summary of Zone 3 and the flood behaviour used to derive this zone can be described as follows:

- With the exception of some areas around Avomnmouth, this study's definition of Zone 3a is not substantially different from the EA Zone 3. This is primarily due to the relatively simplistic nature of the flood mechanisms that dictate the ultimate flood inundation area. The major differences between the two zones relate to the areas of existing development, which are not as inundated in the simulations carried out for this study. This could be the result of LiDAR accuracy and the differing modelling approaches used to define the zones. Further detailed assessment of this area is recommended as the reasons for the differences are not immediately apparent;
- The tidal/surge simulations (for instance, 1 in 200 year return period surge and with 1 in 2 year return period fluvial inflows) dominate the envelope and not the fluvial dominated simulations (the 1 in 2 year return period surge and extreme tide with 1 in 100 year return period fluvial inflows).
- The flood level difference between the 1 in 1,000 year return period tide/surge case (which dominates Zone 2) and the 1 in 200 year return period tide/surge case (which dominates Zone 3a) is about 0.3m;

- The dynamic behaviour of this event is very similar to that described above for Zone 2. However, the tidal/surge profile is slightly lower. This also results in lower inflows from wave overtopping;

7.3.3.7 The functional floodplain (Flood Zone 3b) is much less extensive than zones 2 and 3a. In contrast with the other two zones this zone is fluvially dominated with areas to the east of Avonmouth, around Marsh Common and west of Almondsbury showing the most inundation (see Figure 7.1 – SFRA Flood Zones

7.3.3.8). A summary of Zone 3 and the flood behaviour used to derive this zone can be described as follows:

7.3.4 Appropriate Planning Response

7.3.4.1 PPS 25 Table D3 sets out the appropriate planning response to development in the flood zones; the guidance makes clear that site-specific flood risk assessments will be an integral part of planning decisions on development proposals, allowing each proposal to be considered on its merits. A final decision and appropriate planning response will ultimately be based on case specific assessment by planning and drainage authorities. Further guidance is provided in the accompanying Summary Report.

7.4. Hydraulic Modelling to Define Actual Risk

7.4.1 Simulations to Define Actual Risk

7.4.1.1 A number of simulations using the 2D/1D hydraulic model were carried out aimed at defining the actual and residual risk characteristics of the study area.

7.4.1.2 Actual risk was assessed by considering the results of the following scenarios:

Tidal

- 1 in 200 year return period surge and extreme tide for the critical scenario at each wave overtopping section with 1 in 2 year return period fluvial inflows (present day, 2010, and future 2110);
- 1 in 200 year return period surge and extreme tide for the maximum extreme water level with a significant wave height at each wave overtopping section with 1 in 2 year return period fluvial inflows (present day, 2010, and future 2110);
- 1 in 200 year return period maximum surge and extreme tide with no significant wave with 1 in 2 year return period fluvial inflows (present day, 2010, and future 2110);

Fluvial

- 1 in 2 year return period surge and extreme tide for the critical scenario at each wave overtopping section with 1 in 100 year return period fluvial inflows (present day 2010, and future 2110);
- 1 in 2 year return period maximum surge and extreme tide with no significant wave height with 1 in 100 year return period fluvial inflows (present day 2010, and future 2110);

7.4.2 Assumptions in Simulations

7.4.2.1 These simulations included similar assumptions to those for the zone definition (as previously discussed). Additional assumptions include:

- The APBmer (2005) report indicates that the maximum extreme water level for a given return period and offshore wave height of zero is predicted. In reality, this would be unlikely, because meteorological conditions required to cause extreme levels would involve wave action. The wave heights used in the 2007 update to the SFRA were taken forward for Phase 4 (combined with the updated still tide levels) as updated still tide level / wave height joint probability was not available);
- The size of the 2D grid (20m x 20m for tidally dominated events) will have a very minor influence over the extent of inundation but a more marked influence on the distribution of velocity and flood hazard ratings;
- These actual flood defences which are not expected to maintain their integrity, described in Figure 5.8 – Flood Defences Assumed to be Removed, are not included in the analyses and have been assumed to provide no protection from flooding.

7.4.3 Results of Actual Risk Definition

7.4.3.1 The peak flood depths of the flood events tested above are presented in Figure 7.19 – Actual Risk: Peak Flood Depths, Current Case (present day) and Figure 7.3 (future), and the peak flood hazard based on the DEFRA Flood Risks to People guidance are presented in Figure 7.20 – Actual Risk: Peak Flood Hazard (DEFRA), Current Case (present day) and Figure 7.4 (future). The flood hazard rating is a measure of the force of the flood water and the hazard flooding poses to people and property. The purpose of these contours is to define those areas or "hazard categories" that would be considered unsafe (to some degree) during a flood event. The DEFRA Flood Risks to People guidance is summarised in Appendix A7.3.

7.4.3.2 The main results of the actual risk assessment are:

- As was the case for the derivation of Zones 2 and 3a, the tidal/surge simulations dominate the flood extent of these actual risk areas;

- The dynamic behaviour of this event can be described in three stages corresponding to the three tidal peaks:
    - The first tidal peak (lower than the second and equal to the third) results in only minor inundation of the study area due to small wave overtopping inflows and the protection of the flood defences, most noticeable to the north of the M4. The inundated area after this first peak remains local to the tidal defence to the south of the M4;
    - The second tidal peak is the biggest of the three peaks. The highest tide/surge levels also correspond to the highest wave overtopping inflows. Due to these tidal/surge and wave inflows the entire area is completely inundated, with depths significantly large west of the M49 and north of the M4. and;
    - The third tidal peak (lower than the second and equal to the first) raises depths slightly but not the peaks reached during the second tidal peak.
- Another important consideration in the definition of actual risk is the speed of inundation. In order to illustrate this parameter in a spatial manner, Figure 7.5 shows the areas inundated at various time intervals during the 1 in 200 year return period surge and tide for all wave combinations with 1 in 2 year return period fluvial inflows event (2110). Inundation patterns at various times in this event are presented. The times are in hours with the peak of the surge/tide and the peak of the fluvial runoff occurring 43.0 hours into the event. This figure shows that some areas will be inundated with a warning time (based purely on approaching areas of inundation) in the order of a few hours. The speed of inundation for this event will need to be recognised in the definition of the actual flood risk to this area;
- In defining actual risk, the simulation of the 1 in 2 year return period tide/surge/wave combined with a 1 in 100 year return period fluvial event resulted in fluvial based inundation but also significant inundation from the 1 in 2 year return period tide/surge/wave. These results do not match the observed flooding behaviour of the study area during fluvial dominated events as the degree of inundation from tide/surge/wave is far less than that being simulated in the 2D/1D flood model. The principal reason for this as discussed previously, is the allowance made for climate change and sea level rise over the period to 2110, which results in 1 in 2 year extreme surge levels greater than present day (2010) 1 in 1,000 year extreme surge levels;

7.4.4 Implications of Actual Risk on Potential Land Use within Study Area

7.4.4.1 The definition of the actual risk within the study area will need to be considered in land use planning and development applications. The implications of the results discussed previously are that the majority of the study area falls within Zone 3a. Whilst the present day actual risk is reasonably low (Low hazard / Danger for some) across the majority of the study area, this increases dramatically in the future. The majority of land to the west of the M49 and north of the M4 has an actual risk with the following flooding characteristics:

- Depths greater than 1m (for instance, all yellow, orange and red areas on Figure 7.3); and
- Flood hazard rating of "danger to most" to "danger to all" (for instance, all areas on Figure 7.4 that are shaded orange and red).

7.4.4.2 This would imply that, in the absence of a strategic solution to the flooding issues of the area, the majority of the study area would probably be considered unsuitable for development using a sequential risk-based approach.

7.5. Hydraulic Modelling to Define Residual Risk

7.5.1.1 In recognition that engineered flood reduction measures cannot eliminate flood risk there is a need to be aware of the residual risk generated by an event more severe than that for which particular flood defences have been designed to provide protection. Accordingly a series of "sensitivity" analyses have been undertaken to examine the implications.

7.5.1.2 Residual risk was assessed by considering the results of the following two scenarios using a geometry representing the defended case (without the defences assumed to be sub-standard as discussed in Section 5.6.1):

Tidal

- 1 in 1,000 year return period surge and extreme tide for the critical scenario at each wave overtopping section with 1 in 2 year return period fluvial inflows;
- 1 in 1,000 year return period surge and extreme tide for the maximum extreme water level with a significant wave height at each wave overtopping section with 1 in 2 year return period fluvial inflows;
- 1 in 1,000 year return period maximum surge and tide with no significant wave with 1 in 2 year return period fluvial inflows;

7.5.1.3 The peak flood depths of these two events are presented in Figure 7.15 and the peak flood hazards are presented in Figure 7.16.

7.5.1.4 As for the derivation of Zones 2 and 3, the tidal/surge simulations dominated the flood extent of these residual risk areas. In general, the dynamic flooding behaviour is similar to that of the actual risk (dominated by the 1 in 200 year return period surge/tide/waves) but slightly more severe.

7.5.2 Breach Modelling to Define Residual Risk

7.5.2.1 The definition of the residual risk considered the results of six (6) breach scenarios. Each breach location (as identified in Section 4) was assessed to define which future tide/surge dominated event would just fail to overtop the un-breached section of defence. The 2D/1D model was then simulated with this event (without any wave overtopping inflows) to provide the perceived worst case of breach behaviour.

7.5.2.2 The breaches represent a risk for which the frequency cannot be easily estimated. The consequences of the breach are thus the important factor that contribute materially to decisions on land use. The analyses are thus a means of identifying the extent of the potential hazard posed by breaches.

7.5.2.3 Figure 7.6 to Figure 7.11 show the contours of flood hazard (based on the DEFRA guidance) in the vicinity of each breach location. The flood hazard rating is a measure of the force of the flood water and the hazard flooding poses to people and property. The purpose of these contours is to define those areas “hazard categories” that would be considered unsafe (to some degree) in the event of a breach.

7.5.2.4 Appendix A7.3 presents a summary of the DEFRA Flood Risks to People guidance. With these flood hazard categories in mind, these maps provide an indication of the bandwidth behind the defences that may be subjected to “Danger to All” flooding in the event of a breach in the vicinity.

7.5.2.5 A bandwidth for high hazard areas inside the defences was also derived and is presented in Figure 7.12. The bandwidth represents the areas that are adversely affected by defence breach where high hazard and fast inundation (and thus little warning time) can be expected and has been derived using the model results to define areas that are inundated through defence breach or overtopping within 1.5 hours.

7.5.3 M49 Culvert Blockage Modelling to Define Residual Risk

7.5.3.1 As further input to the definition of residual risk, the effects of possible blockages in some culverts under the M49 were investigated. Five locations were identified by the Environment Agency and LSDB for consideration of culvert blockage.

7.5.3.2 Simulations were carried out for the future 1 in 1,000 year and 1 in 100 year return period fluvial scenarios (both with coincident 2 year tide / surges and no waves). These simulations indicated that the blockage of these culverts would have little or no influence on flood levels in the vicinity of the blockages.

7.5.3.3 Figure 7.13 and Figure 7.14 show the peak depths for these two simulations (for instance, with blocked culverts). These resulting depths should be used in consideration of actual risk for these areas in the vicinity of the possibly blocked culverts.

7.6. Conclusions of Strategic Flood Risk Assessment

7.6.1.1 The main conclusions on the Strategic Flood Risk Assessment of the Avonmouth area are:

- Flood Zones have beenredfined using the 2D/1D model. The events with large tide/surge/wave overtopping components dominated the definition of the flood zones as well as the definition of actual flood risks. The fluvial dominated events did not result in any significant areas of inundation;
- Zones 2 and 3a cover almost all of the study area with the exception of some land around Avonmouth and the adjacent industrial areas. Flood zone 3b is considerably smaller, as it is dominated by fluvial flooding;
- Flooding behaviour under six breach scenarios tested helped to define a band-width of potential high hazard areas resulting from breaching;
- The actual risk defined in this study indicates that the majority of the area to the west and north of the M49 and M4 motorways would have high hazard levels associated with deep water and some areas of high flood hazard (danger to all) in the future;
- The residual risk, defined by consideration of a 1 in 1,000 year return period tide/surge/wave event (and a minor fluvial event), dominated over the simulation of a 1 in 1,000 year return period fluvial event;

7.6.1.2 The implications of this strategic flood risk assessment are that, in the absence of a strategic solution to the flooding issues of the area, the majority of the study area would probably be considered unsuitable for development using a sequential risk-based approach. Strategic solutions are considered in Section 4 and Section 8 of this SFRA.

Mapping and Figures

Figure 7.14 – M49 Culvert Blockage Impacts (100 Year Fluvial and 2 Year Tide Future Case)

Figure 7.15 – Residual Risk: Peak Flood Depths, Future Case

Figure 7.16 – Residual Risk: Peak Flood Hazard (DEFRA), Future Case

Figure 7.17 - Not Used

Figure 7.18 - Not Used

Figure 7.19 – Actual Risk: Peak Flood Depths, Current Case

Figure 7.20 – Actual Risk: Peak Flood Hazard (DEFRA), Current Case

Figure 7.21 – Residual Risk: Peak Flood Depths, Current Case

Figure 7.22 – Residual Risk: Peak Flood Hazard (DEFRA), Current Case

Section 7 Appendices

A7.1 Uncertainty

A7.1.1.1 It is conventional to consider risk as the product of the frequency and magnitude of the hazard and the severity of the consequences. The major hazards in the study area being the vulnerability of the land to high ground water levels and the high surge tide and wave heights in the Severn Estuary.

A7.1.1.2 When assessing risk the impact of the uncertainties associated with the predictions of the hazard and the consequences should be recognised and understood so that the best possible information is made available for the decision making process and when necessary information updated so that the "best available" data is used.

Probability of Hazard

A7.1.1.3 Following a review of the available baseline information it has been possible to identify the following principal elements that contribute to the uncertainty in the quantification of the hazard.

- The prediction of the surge tide levels has been made using the best available data but tide gauge records will extend into the future and it is possible that there will be a need to amend the statistically generated extreme value predictions as more data comes available;
- The wave height predictions are based on empirical data and the predicted heights have a significant influence on the volume of overtopping and hence the inundation in the study area; and
- The impact of global warming has a significant influence on the predicted surge tide levels. Any future change to these factors will affect the predicted outcomes.
- PPS 25 advocates a precautionary, risk based sequential approach when assessing flooding and it is proposed that the strategy addresses the inherent uncertainties and where necessary seeks to institute measures for their reduction in the future. In keeping with the guidance a prudent approach has been adopted and "lack of full scientific certainty" has not been used as a reason for neglecting the potential impact of such factors.

Consequences

A7.1.1.4 In accordance with the guidance given in PPS25 the approach to the assessment addresses the consequences of inundation for designated scenarios. By adopting an approach based on computer modelling of the hydraulic processes it is possible to examine the predictions for the specific scenarios described in the guidance. The definition of Flood Zones is in accordance with advice given in PPS25 and is complemented by the preparation of plans identifying 'actual and residual risk'.

A7.1.1.5 Changes of land use within the Zones and risk areas will affect the consequences and thus there will be a need to adjust the analyses to match changes in land use. Land use decisions that are not in accordance with the agreed risk based parameters will result in a change to the consequences.

Generic Risks and Uncertainties

A7.1.1.6 Other future uncertainties that will potentially affect the estimate of flood risk in the study area include:

- The implementation of the relevant CFMP(s);
- General economic conditions;
- Improved data from other technical studies (for example, Severn Estuary Flood Risk Management Strategy); and

A7.1.1.7 A reasonable response is to use the best available data at each stage of the planning process and prepare proposals that are respectively precautionary in accordance with the advice in PPS 25 and flexible with respect to uncertainty.

A7.1.1.8 Underlying the strategic approach is the identification of the need to collect additional data in circumstances where the uncertainty associated with the "best available" data is influencing the outcome of the results given in the assessment. By collecting such additional data it will be possible to refine the estimates and reduce the reliance on the "precautionary" approach.

A7.1.1.9 At this juncture the key data sets that need enhancement are ground water levels and flow data.

A7.2 The Identification of Flood Zones and Flood Risk Categories

A7.2.1.1 In keeping with the guidance in PPS25 there is a need to adopt the following three-tier approach to the sequential examination of flood risk:

Stage 1: To investigate the extent of the Flood Zones as described in PPS25;

Stage 2: To assess the actual level of flood risk taking account of defences & other flood risk management infrastructure;

Stage 3: To examine the residual risk posed by an event more severe than that for which particular flood defences have been designed to provide protection and / or failure of flood defences and other infrastructure.

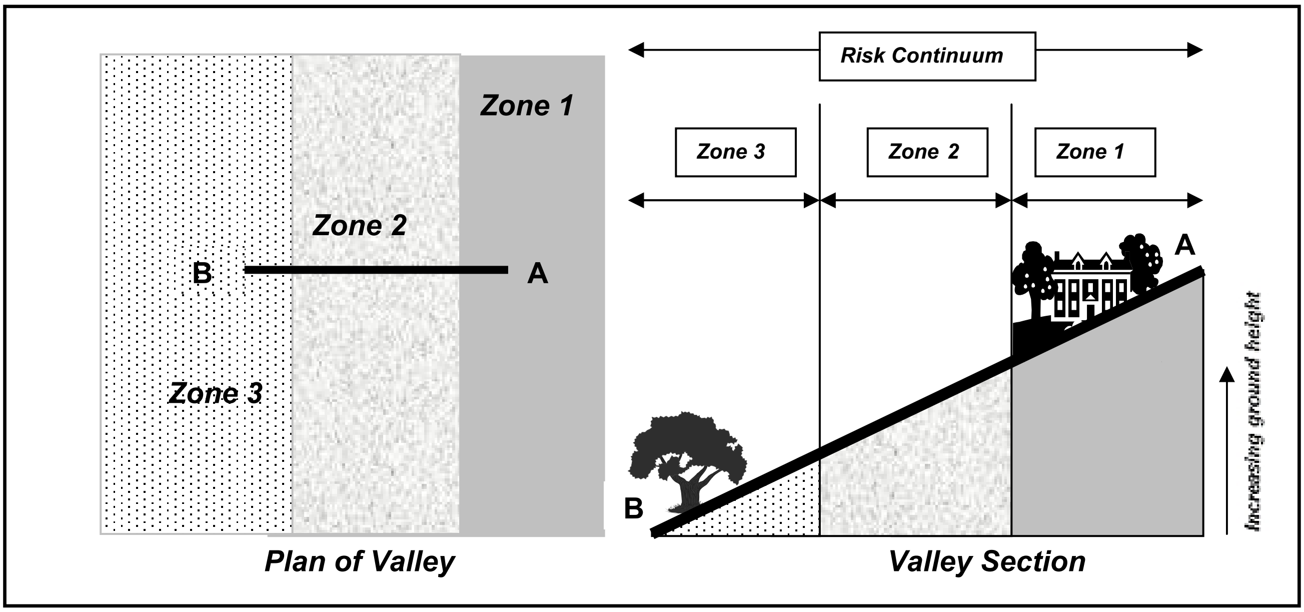
A7.2.1.2 All current and subsequent planning applications in the study area should make reference to the results from the Strategic Flood Risk Assessment. As stated earlier in this document there will be a need to update the Strategic Flood Risk Assessment such that it takes account of all the available information at the time particular planning decisions are taken.

Stage 1 - Flood Zones

A7.2.1.3 Table D1 of PPS25 describes how the Flood Zones should be defined. It is important to recognise that the Zones do not describe an actual level of flood risk since they are derived on the basis that there are no flood defences. For the purpose of the study this assessment assumes that all flood walls and fixed defences are removed. The Flood Zone maps do not give a representation of actual flood risk but can be used to inform a risk-based search sequence.

A7.2.1.4 The Flood Zones, as described in Figure A7.23 – Flood Zones, have been derived so as to identify areas affected by both fluvial and tidal flood hazards.

Figure A7.23 – Flood Zones



A7.2.1.5 The boundaries separating the Flood Zones are defined by the water level associated with a defined probability of occurrence.

Stage 2 – Actual Flood Risk Assessment

A7.2.1.6 Local Planning Authorities are advised to give appropriate weight to information on flood-risk and how it might be affected by climate change in preparing development plans and considering individual proposals for development. The sequential risk-based approach is based on the premise that land use decisions are based on the actual risk and should take account of:

1) The area at risk from flooding;
2) The probability of it occurring, both now and over time;

3) The extent and standard of existing defences and their effectiveness over time;
4) The likely depth of flooding;
5) The rates of flow likely to be involved;
6) The likelihood of impacts to and from other areas, properties and habitats;
7) The effects of climate change; and
8) The nature and currently expected lifetime of the development proposed and the extent to which it is designed to deal with flood risk.

A7.2.1.7 The SFRA provides information on the flood risk within the study area. The area at risk from flooding is based on the Flood Zones. The actual risk is assessed on a sequential basis that includes a qualitative assessment of the performance capability of the existing flood defences. This necessarily results in a "scenario-based" approach that illustrates the consequences of selected events but cannot assign specific probabilities to them.

A7.2.1.8 Nevertheless, the sequential "scenario-based" approach does give an indication of the likely consequences of specific circumstances and enables judgements to be made using a precautionary approach.

A7.2.1.9 The probability of flooding, both now and over time, has been assessed using the relevant probabilities of flows and tidal water levels ,where necessary adjusted to allow for future trends driven by potential global warming impacts.

A7.3 Defra Flood Risks to People (2006)

A7.3.1.1 A Defra Flood and Coastal Defence R&D Programme, "Flood Risks to People – The Flood Risks to People Methodology, FD2321/TR1" and the "Framework and Guidance for Assessing and Managing Flood Risk for New Development (FD2320/TR2)" was completed by HR Wallingford for the Environment Agency. The reports outlined the methodology for Flood Risks to People, which is based on a multi-criteria assessment of factors that affect Flood Hazard, the chance of people in the floodplain being exposed to the hazard, and the likely consequence of those (people) affect to respond to flooding.

A7.3.1.2 The Flood Risks to People study developed a relationship between flooding depth and velocity to predicted flood hazard. Figure A7.24 presents the combinations of flood depths and velocity with corresponding flood hazard rating and summarises the ranges for classifying the degree of flood hazard, along with the hazard rating formula.

HR	Depth of flooding - d (m)												
	DF = 0.5				DF = 1								
Velocity v (m/s)	0.05	0.10	0.20	0.25	0.30	0.40	0.50	0.60	0.80	1.00	1.50	2.00	2.50
0.0	0.03 + 0.5 = 0.53	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.13 + 0.5 = 0.63	0.15 + 1.0 = 1.15	0.20 + 1.0 = 1.20	0.25 + 1.0 = 1.25	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.75 + 1.0 = 1.75	1.00 + 1.0 = 2.00	1.25 + 1.0 = 2.25
0.1	0.03 + 0.5 = 0.53	0.06 + 0.5 = 0.56	0.12 + 0.5 = 0.62	0.15 + 0.5 = 0.65	0.18 + 1.0 = 1.18	0.24 + 1.0 = 1.24	0.30 + 1.0 = 1.30	0.36 + 1.0 = 1.36	0.48 + 1.0 = 1.48	0.60 + 1.0 = 1.60	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.55
0.3	0.04 + 0.5 = 0.54	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.19 + 0.5 = 0.69	0.23 + 1.0 = 1.23	0.30 + 1.0 = 1.30	0.38 + 1.0 = 1.38	0.45 + 1.0 = 1.45	0.60 + 1.0 = 1.60	0.75 + 1.0 = 1.75	1.13 + 1.0 = 2.13	1.50 + 1.0 = 2.50	1.88 + 1.0 = 2.88
0.5	0.05 + 0.5 = 0.55	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.25 + 0.5 = 0.75	0.30 + 1.0 = 1.30	0.40 + 1.0 = 1.40	0.50 + 1.0 = 1.50	0.60 + 1.0 = 1.60	0.80 + 1.0 = 1.80	1.00 + 1.0 = 2.00	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	2.50 + 1.0 = 3.50
1.0	0.08 + 0.5 = 0.58	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.38 + 0.5 = 0.88	0.45 + 1.0 = 1.45	0.60 + 1.0 = 1.60	0.75 + 1.0 = 1.75	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.50	2.25 + 1.0 = 3.25	3.00 + 1.0 = 4.00	3.75 + 1.0 = 4.75
1.5	0.10 + 0.5 = 0.60	0.20 + 0.5 = 0.70	0.40 + 0.5 = 0.90	0.50 + 0.5 = 1.00	0.60 + 1.0 = 1.60	0.80 + 1.0 = 1.80	1.00 + 1.0 = 2.00	1.20 + 1.0 = 2.20	1.60 + 1.0 = 2.60	2.00 + 1.0 = 3.00	3.00 + 1.0 = 4.00	4.00 + 1.0 = 5.00	5.00 + 1.0 = 6.00
2.0	0.13 + 0.5 = 0.63	0.25 + 0.5 = 0.75	0.50 + 0.5 = 1.00	0.63 + 0.5 = 1.13	0.75 + 1.0 = 1.75	1.00 + 1.0 = 2.00	1.25 + 1.0 = 2.25	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	3.50	4.75	6.00	7.25
2.5	0.15 + 0.5 = 0.65	0.30 + 0.5 = 0.80	0.60 + 0.5 = 1.10	0.75 + 0.5 = 1.25	0.90 + 1.0 = 1.90	1.20 + 1.0 = 2.20	1.50 + 1.0 = 2.50	1.80 + 1.0 = 2.80	3.40	4.00	5.50	7.00	8.50
3.0	0.18 + 0.5 = 0.68	0.35 + 0.5 = 0.85	0.70 + 0.5 = 1.20	0.88 + 0.5 = 1.38	1.05 + 1.0 = 2.05	1.40 + 1.0 = 2.40	1.75 + 1.0 = 2.75	3.10	3.80	4.50	6.25	8.00	9.75
3.5	0.20 + 0.5 = 0.70	0.40 + 0.5 = 0.90	0.80 + 0.5 = 1.30	1.00 + 0.5 = 1.50	1.20 + 1.0 = 2.20	1.60 + 1.0 = 2.60	3.00	3.40	4.20	5.00	7.00	9.00	11.00
4.0	0.23 + 0.5 = 0.73	0.45 + 0.5 = 0.95	0.90 + 0.5 = 1.40	1.13 + 0.5 = 1.63	1.35 + 1.0 = 2.35	1.80 + 1.0 = 2.80	3.25	3.70	4.60	5.50	7.75	10.00	12.25
4.5	0.25 + 0.5 = 0.75	0.50 + 0.5 = 1.00	1.00 + 0.5 = 1.50	1.25 + 0.5 = 1.75	1.50 + 1.0 = 2.50	2.00 + 1.0 = 3.00	3.50	4.00	5.00	6.00	8.50	11.00	13.50
5.0	0.28 + 0.5 = 0.78	0.60 + 0.5 = 1.10	1.10 + 0.5 = 1.60	1.38 + 0.5 = 1.88	1.65 + 1.0 = 2.65	3.20	3.75	4.30	5.40	6.50	9.25	12.00	14.75

Flood Hazard Rating (HR)	Colour Code	Hazard to People Classification
Less than 0.75		Very low hazard - Caution
0.75 to 1.25		Danger for some – includes children, the elderly and the infirm
1.25 to 2.0		Danger for most – includes the general public
More than 2.0		Danger for all – includes the emergency services

Figure A7.24 – Defra Flood Hazard Rating

Revision Status and Schedule of Changes

Section Revision Status

All technical revisions of the SFRA November 2010 release for Section 7 – Strategic Flood Risk Assessment are outlined below:

- Updated Strategic Flood Risk Assessment and SFRA, based on Phase 4 (2010) hydraulic modelling for the years 2010 and 2110.
- Removed Strategic Flood Risk Assessment for Sub Areas from January 2007 release, as directed by SFRA Management Group.
- Additional model runs and results presented for present day (2010) conditions.
- Additional runs and results presented for Flood Zone 3b (functional floodplain). Flood Zone definitions updated to in accordance with PPS25 guidance.
- Updated relevant DEFRA Flood Risk to People Flood Hazard.
- Updated the relevenat text in Section 7 and the appendices to reflect introduction of PPS25 which superseded PPG25 in December 2006.

Schedule of Changes – Latest release only

Changes have been throughout this section of the report and appendices therefore a detailed schedule of changes is not appropriate for this release of the SFRA.

Section 8. Strategic Mitigation Assessment

8.1. Revision Status

8.1.1.1 This is new section introduced in the November 2010 release of the SFRA.

8.2. Strategic Mitigation Assessment

8.2.1.1 Although the Avonmouth / Severnside area is offered some protection from flooding by defences, and defence improvements are recommended to increase the standard of protection now and in the future taking account of climate change, a residual risk of tidal flooding will still be present due to overtopping or failure of defence systems. As discussed in section 4.5 even if defences are raised to the target crest level of 10.74mAOD used in the defence assessment flood risk could still be posed by wave overtopping. A thorugh assessment is needed to establish the appropriate defence crest level, taking into account future flood risk arising from extreme tide levels and wave overtopping. Although much less significant to the area, the fluvial flood risk from the rhine network must also be considered for existing and future development in the area.

8.2.1.2 It is therefore important to consider measures to mitigate this residual flood risk (fluvial, tidal – defence overtopping and / or breach) to keep existing development safe for people during times of flood, reduce damages and protect against flooding and associated pollution linked with the storage of hazardous substances.

8.2.1.3 Mitigation measures also need to be considered where, after the application of the sequential test, further development of areas within flood zones 3 and 2 is still necessary.

8.2.1.4 An assessment of options to reduce flood risk to the Avonmouth / Severnside area, including raising of defences has been undertaken. The assessment has been split into two parts, an initial assessment to look at a wide range of options and identify preferable options, and then a more detailed multi criteria assessment of the preferred options to produce a list of the options which are most likely to be successful.

8.2.1.5 For the purposes of this assessment the Avonmouth / Severnside area has been split into 'strategic zones'. These areas were defined according to similar characteristics taking account of information on flooding mechanisms, current land use, future development and key infrastructure. Eight strategic zones have been defined, these are shown in Figure 8.1.

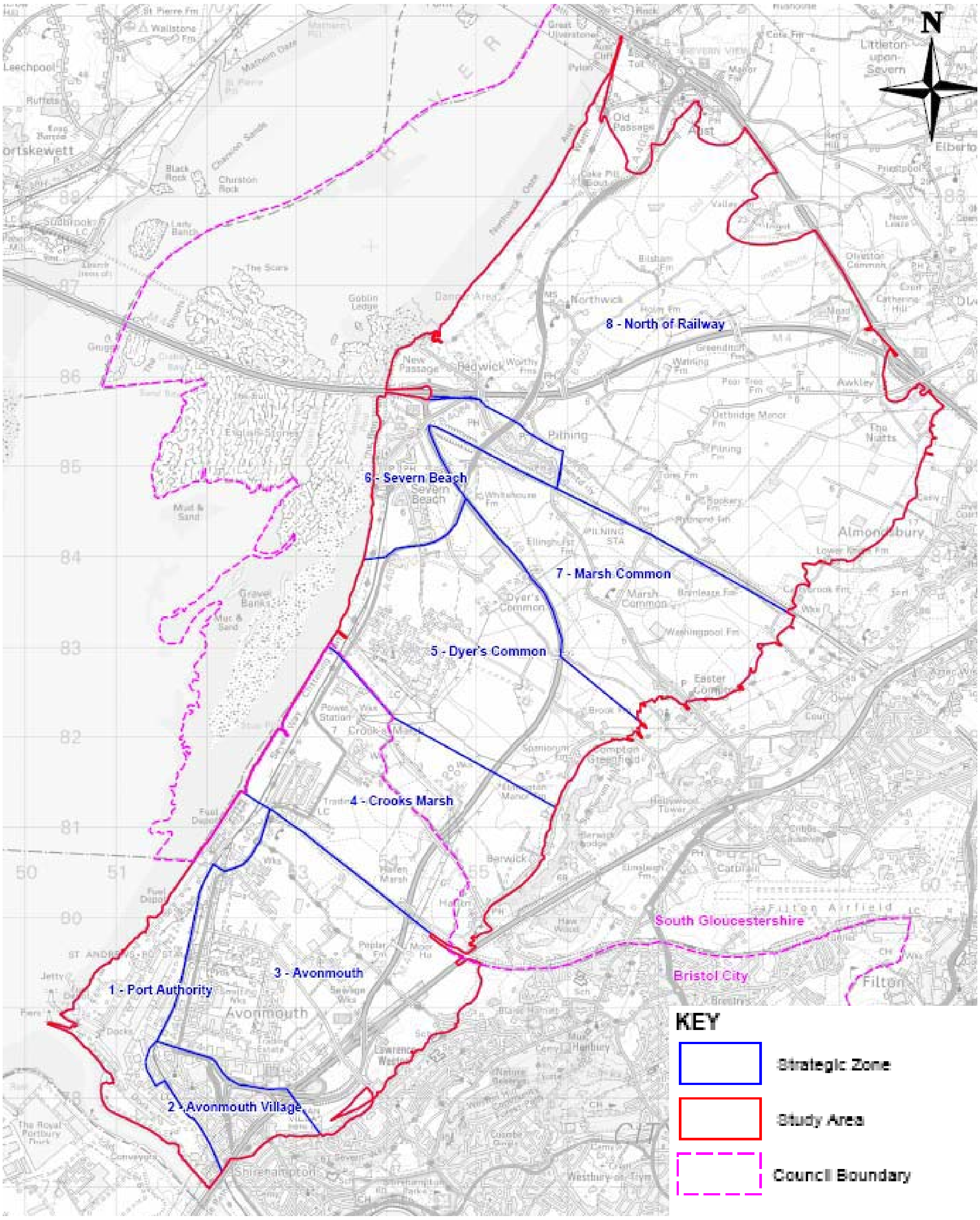


Figure 8.1 – Strategic Zones

8.3. Initial assessment

8.3.1.1 The list of strategic flood risk management measures developed for the CFMPs, SMP and the TSS processes along with the principles of Defra's FCDPAG has been used as the basis for the initial identification of potential strategic flood risk mitigation measures. The list covers a range of both structural and non-structural solutions, including soft engineering and flood incident management. Options may reduce the risk of an event or reduce the damages incurred when an event happens.

8.3.1.2 The approach taken in identifying options included:

- consideration of the 'do nothing' and 'do minimal' scenarios, taking account of existing Flood Risk Management.
- Flood Risk Management options considered in previous studies, including CFMP, SMP and TSS policies and actions.
- Flood Risk Management options which may be technically feasible but have not been considered in previous studies to manage flood risk.

8.3.2 Do nothing scenario

8.3.2.1 The appraisal of potential FRM options is undertaken with reference to a baseline situation. FCDPAG recommends that the baseline is the ‘do nothing’ scenario.

8.3.2.2 The existing FRM infrastructure in the Avonmouth / Severnside area was described in Section 4 of this report. The whole area is protected from tidal flooding by Environment Agency (formal) and privately owned (defacto) raised defences and the network of rhines is managed by the Lower Severn Internal Drainage Board to manage fluvial flood risk. Currently FRM activities therefore centre on maintenance and upkeep of these defence systems.

8.3.2.3 A 'do nothing' scenario in the strictest sense is therefore likely to involve the cessation of current maintenance and upkeep of rhines, raised defences and associated infrastructure. This scenario is likely to result in an increase in flooding due to:

- <u>Increased siltation</u> - reducing rhine channel capacity and increased blockages of structures;
- <u>Failure of raised defences and control structures</u> - the condition of defences and control structures will decline and the structures will eventually fail. The impact of failure would be significant and damaging for the whole of the Avonmouth and Severnside area.
- <u>Climate change</u> – extreme tide levels are expected to increase by up to 14.5 mm per year in a 100year time horizon.

8.3.2.4 As well as 'hard' flood defences, flood warning and incident management are currently undertaken in the Avonmouth / Severnside area. These activities can play an important role in reducing the potential consequences to people and in some instances properties (should individual property level flood defence options be employed). The social implications of cessation of this flood risk management option should be included in the 'do nothing' scenario.

8.3.2.5 Given the scale of tidal flooding anticipated in the future, improvements and maintenance of the defences are considered a minimum requirement for the area to remain viable. A reduction in this maintenance as well as other existing FRM activities such as Flood Warning is unlikely given the objectives and actions identified in the Severn Estuary Shoreline Management Plan, Severn Tidal Strategy and Severn Tidal tributaries and Bristol Avon CFMPs.

8.3.2.6 A more realistic baseline may be to define the 'do nothing' scenario as involving continued maintenance (i.e. ‘do minimal’ scenario).

8.3.3 Do minimal scenarios

8.3.3.1 With raised defences and managed rhines offering flood protection, a 'do minimal' scenario in the Avonmouth / Severnside area is likely to involve:

- continued maintenance of defences, rhines and flood risk management infrastructure such as sluice gates to keep them in working order;
- emergency repair and/or replacement of FRM infrastructure;
- channel maintenance works as required;
- ongoing flood warning and flood incident management; and
- opportunist improvements to the existing standard of protection of flood risk management infrastructure.

8.3.3.2 A 'do minimal' scenario is still likely to lead to an increase in flooding due to the predicted impacts of climate change. If new development is located in areas that are expected to be affected by inundation in the future then the flood risk will be increased.

8.3.4 Do something options

8.3.4.1 FCDPAG recommends that a full range of options be considered in the early stages of the analysis. In addition to different types of FRM features, a range of 'standards of protection' should also be considered for raised defences in combination with other options (such as flood warning and flood resilience). More detailed studies should consider the optimum 'standard of protection' provided by defences and FRM measures.

8.3.4.2 The options that are technically feasible in each of the strategic zones have been considered. These options are listed in Table 8.1.

Table 8.1 Strategic mitigation measures for initial assessment in each Strategic Zone

Strategic Mitigation Measures for Initial Assessment
Improve existing defences to increase standard of protection and to keep pace with climate change
Change of use – Policy measures to discourage highly vulnerable / more vulnerable (where feasible) development and essential infrastructure.
Strategic land raising
Local scale land raising*
New / improved access routes
Flood resilient design and individual property level flood resilience (flood boards / flood proofing / voids / stilts)*
Flood incident management and flood warning* *(NB – Flood warning may be of limited value for a defence breach situation where inundation may be rapid).*
Improvements to the rhine network

* These are not normally considered 'strategic' flood mitigation measures and instead would normally be considered site-specific mitigation. However they have been included in this assessment as accepted strategic measures may not be feasible in all locations. These site specific mitigation measures may be recommended across a large area of Avonmouth / Severnside, alongside or instead of other measures, and are therefore strategic in terms of geographical coverage.

8.3.4.3 The outcomes of this initial assessment and a short list of options to be taken forward for further assessment for each strategic zone are discussed in 8.4 to 8.11 below.

8.4. Strategic Zone 1: Bristol Port Company (Employment)

8.4.1 Description of the Current Problem

8.4.1.1 Strategic Zone 1 (SZ1) includes over 7km of coastline and thus has potential to be highly vulnerable to tidal flooding. The rhine network in this zone is rather limited and as such, fluvial flooding poses little threat.

8.4.1.2 During a 1 in 200yr tidal flood event, model results show considerable inundation in areas north and east of the Royal Edward Docks. The majority of the flooding shown in this zone is categorised as posing danger to some or most. A significant proportion of this flood risk is a result of the overtopping of tidal defence sections G-J. Model results also show danger to some to the west of Avonmouth dock; this is due to the overtopping of defence section L-N. The majority of roads and access routes are inundated; the strategic access route into SZ1 is via the M5.

8.4.1.3 SZ1 includes 3 culverted outfalls for the following Rhines: Mere Bank, Salt and Kings Weston. It also contains a short section (~0.1km) of open channel leading to the Salt Rhine outfall in the north of the zone.

8.4.1.4 Model results show that for a 1 in 100 year fluvial event, SZ1 remains unaffected with the exception of some very localised flooding in the car park north west of Victoria Road (hazard rating: danger for some).

8.4.1.5 With climate change, tidal flooding is considerably more severe, posing danger to most of SZ1. The risk of fluvial flooding is also expected to worsen with climate change.

8.4.1.6 Defences have a high nominal standard of protection however concerns over condition and resilience suggest these current defences cannot be relied upon.

8.4.2 Potential Development

8.4.2.1 Development associated with the Bristol Port Company would most likely be in relation to expansion of the port and potential employment uses. The port district is spatially limited in where it can develop and consequently a Deep Sea Terminal has been proposed. The majority of the seaward terminal expansion is within SZ1 however part of the site falls outside the SFRA study area.

8.4.2.2 SZ1 is in Flood Zone 3a; according to PPS25, Buildings used for “general industry; storage and distribution” are appropriate in this zone, following application of the sequential test.

8.4.2.3 SZ1 also contains potential developments to the Avonmouth Industrial Area. Whether these are permitted under the current flood zone categorization depends on the nature of the sites.

8.4.2.4 The nature of the development may be classified as a combination of Less Vulnerable and Essential Infrastructure. The Exception Test may be required.

8.4.3 Mitigation Requirements

8.4.3.1 Strategic mitigation measures should seek to achieve the following key objectives:

- Safe and reasonable operation and occupation of development on a daily basis;
- Safe access & egress in the event of failure or a breach in the defences;
- Safe refuge, as floods (especially through breach) may occur rapidly with little warning;
- Reduction in damages associated with flooding (as a minimum seek to minimise any extra damages through new development)
- Protection against flooding and associated pollution / contamination linked with storage of any hazardous substances.

8.4.4 Potential Mitigation Solutions

Impact of flooding to development

8.4.4.1 Potential mitigation solutions identified include:

- Improvements to defences

In order to reduce the risk of SZ1 being inundated during a 1 in 200yr tidal flood event, taking account of climate change, tidal defence sections G-P would need to be raised to approximately 10.7mAOD. These improvements are estimated to cost £7.09m and would provide protection to SZ1 and SZ3. The optimum defence crest level, taking into account risks due to wave overtopping would need to be defined through detailed studies.

Although current defence heights may be above the minimum requirement of 0.5% (1 in 200 years), with climate change taken into account this would reduce to less than the accepted standard. The future standard of protection of adjacent defence sections is anticipated to be significantly less. The defences in this area are also of uncertain quality and therefore may be at higher risk of breach.

Given the scale of flooding anticipated in the future as a result of climate change, improvements to the defences are considered a minimum requirement for the docks to remain viable. Nevertheless, development remains vulnerable to breach / failure of defences and therefore residual flood risk management measures should be considered.

- Change of use

Current land use within SZ1 includes the Bristol Port Company and Avonmouth industrial area. A change in land use would have significant implications for the economy and prosperity of the Avonmouth / Severnside area and is not considered an appropriate strategic measure at this stage for the life of the LDF.

- Land raising

Large scale land raising within SZ1 is not considered an appropriate strategic measure, due to operational requirements and the level of existing development within the zone. Localised land raising should be considered for new developments, especially any development that may involve hazardous substances as the most reliable flood protection measure.

- New / improved access routes

Provision of new / improved access routes into SZ1 should be considered as existing access routes are anticipated to be inundated during a tidal flood / breach event. The primary access route into SZ1 is via the M5, which remains dry, therefore a strategic access route linking with the M5 is considered appropriate. A primary safe access route through SZ1 will aid evacuation during a flood event.

- Property resilience / resistance measures

Constraints on new & existing development mean that raised ground levels may not always be possible. Property level flood resilience and resistance measures may help to reduce the impact of flooding on development. Whilst this could be a strategic measure, implemented through policy, in practice it will be implemented on a local scale.

- Flood warning / flood event management

Effective flood warning and event management will be a key component of development and occupation of SZ1 in the long term. Flood risk management plans, developed on an individual development and zone-wide approach should be included in the strategic approach.

- Improvements to the rhine network

The rhine network in SZ1 is concentrated in the north of the zone; increasing its capacity is unlikely to affect flooding around Victoria Road (southern extent). It is recommended that land raising and compensatory flood storage, where possible, are used to reduce the fluvial flood risk in this area.

Strategic mitigation solutions recommended for further investigation:

- **Defence improvements**
- **Local scale land raising**
- **New / improved access routes**
- **Property resilience / resistance measures**
- **Flood warning / event management**

Impact of development / mitigation solutions on flooding elsewhere

8.4.4.2 As the dominant flood risk affecting the zone is tidal, direct from the Avon & Severn new development and mitigation measures are less likely to affect other areas. A raised access route could potentially act as a barrier to flooding; this could have a detrimental effect seaward of the road and potentially beneficial to the landward side. The impact of land raising (for both tidal and fluvial flooding) should be considered on a local scale. Similarly the impact of increased runoff from developments needs to be considered, although this is unlikely to be a key consideration as drainage is generally direct to the Severn & Avon.

8.4.4.3 No strategic solutions are considered necessary to address impact of development on flood risk elsewhere. The impact of land raising should be considered on a local scale.

8.4.5 Links with other Strategies & Plans

8.4.5.1 CFMP Policy 4: Take further action to reduce flood risk

8.4.5.2 SMP Policy: Hold the Line (short term). Unknown at this stage whether SoP will be maintained or defence height maintained (to be determined through SEFRMS).

8.4.5.3 The SMP policy indicates there is an existing commitment to maintain defences. However improvements required for sustainable development in SZ1 may be over and above that provided through SMP policy.

8.4.5.4 The CFMP does not identify specific actions relevant to the strategic options identified above.

8.4.5.5 Strategic mitigation measures suggested are in line with current / anticipated policy, however may need additional commitment to that implemented in line with the CFMP / SMP policies and actions.

8.4.6 Scope for Developer Contributions

8.4.6.1 The Bristol Port Company is not generally required to contribute to tidal defence improvements as much of the development within the Port is classed as “permitted development”, which does not need planning permission. In addition, development may also be consented through other regimes – eg a Harbour Revision Order. Consequently, only a limited range of Port related developments are expected to make Section 106 contributions to improved flood risk management measures. Consequently developer contributions for the raising of flood defences or other strategic flood risk management measures in SZ1 is limited to the Avonmouth Industrial Area and Pipeline Sites and those developing in SZ3. The scope for developer contributions is discussed in more detail in Section 4.

8.5. Strategic Zone 2: Avonmouth Village (Residential)

8.5.1 Description of the Current Problem

8.5.1.1 Strategic Zone 2 (SZ2) does not include any coastline and is considerably less vulnerable to tidal flooding than the neighbouring SZ1. The rhine network in this zone is limited to only one culvert which runs underneath Avonmouth Road on the eastern side of the zone; fluvial flooding poses marginal threat.

8.5.1.2 During a 1 in 200yr tidal flood event, model results show small pockets of inundation around St Andrews Gate Roundabout. The tidal flood water passes into SZ2 from SZ3, consequently any reduction in tidal flood risk in SZ3 is likely to reduce the risk in SZ2.

8.5.1.3 Model results show that for a 1 in100 year fluvial event, approximately 25% of the zone is inundated. The following areas have been shown to pose “danger to some”:

- South West of Portway roundabout (up to railway line)
- Warehouses North of St Brendans Way
- Avonmouth Road
- Napier Road
- Jutland Road

8.5.1.4 With climate change, tidal flooding is considerably more severe, posing danger to most of SZ2. The risk of fluvial flooding is also expected to worsen with climate change.

8.5.2 Potential Development

8.5.2.1 SZ2 is already tightly developed and as such further development is restricted to windfall sites. Areas bordering the residential quarters are developed industrial sites. Residential development and various change of use planning applications are considered likely.

8.5.2.2 The following residential developments are not permitted in the current flood zone (3a), unless the requirements of the Exception Test are satisfied:

- Basement dwellings

- Caravans, mobile homes and park homes intended for permanent residential use
- Residential institutions such as residential care homes, children's homes, social services homes, prisons and hostels.
- Buildings used for: dwelling houses; student halls of residence; drinking establishments; nightclubs; and hotels.
- Sites used for holiday or short-let caravans and camping

8.5.2.3 There are also areas of functional flood plain (zone 3b) where all development, except water compatible development and essential infrastructure, should not be permitted.

8.5.2.4 SZ2 also contains potential developments to the Avonmouth Industrial Area. Whether these are permitted under the current flood zone categorization depends on the nature of the sites. According to PPS25, Buildings used for "general industry; storage and distribution" are permissible in Flood Zone 3a, subject to the sequential test.

8.5.2.5 The nature of development is likely to be a combination of More Vulnerable, Less Vulnerable and Essential Infrastructure.

8.5.3 Mitigation Requirements

8.5.3.1 Strategic mitigation measures should seek to achieve the following key objectives:

- Safe & reasonable occupancy of homes and businesses on a daily basis;
- Safe access & egress in the event of failure or a breach in the defences;
- Safe refuge, as floods (especially through breach) may occur rapidly with little warning;
- Reduction in damages associated with flooding (as a minimum seek to minimise any extra damages through new development)
- Protection against flooding and associated pollution / contamination linked with storage of any hazardous substances.

8.5.4 Potential Mitigation Solutions

Impact of flooding to development

8.5.4.1 Potential mitigation solutions identified include:

- Improvements to defences

In order to reduce the risk of SZ2 being inundated during a 1 in 200yr tidal flood event, tidal defence sections G-P would need to be raised to approximately 10.7mAOD. These improvements are estimated to cost £7.09m and would also provide protection to SZ1 and SZ3. . The optimum defence crest level, taking into account risks due to wave overtopping would need to be defined through detailed studies.

Although current defence heights may be above the minimum requirement of 0.5% (1 in 200 years), with climate change taken into account this would reduce to less than the accepted standard. The future standard of protection of adjacent defence sections is anticipated to be significantly less. The defences in this area are also of uncertain quality and therefore may be at higher risk of breach.

Given the scale of flooding anticipated in the future as a result of climate change, improvements to the defences are considered a minimum requirement for Avonmouth village to remain viable. Nevertheless, development remains vulnerable to breach / failure of defences and therefore residual flood risk management measures should be considered.

- Change of use

Policy measures to encourage gradual replacement of existing residential development with less vulnerable business and industrial uses could be considered. This is likely to be a very long-term approach, that will meet considerable resistance from the public, therefore is not considered an appropriate strategic measure at this stage for the life of the LDF. Policy measures to discourage highly vulnerable development and essential infrastructure could be considered.

- Land raising

Large scale land raising within SZ2 is not considered an appropriate strategic measure, due to the level of existing development within the zone. Localised land raising should be considered for new developments, especially any particularly vulnerable development.

- New / improved access routes

Provision of new / improved access routes into SZ2 should be considered as existing access routes are anticipated to be inundated during a tidal flood / breach event. The primary access route into SZ2 is via the M5, which remains dry, therefore a strategic access route linking with the M5 is considered appropriate. A primary safe access route through SZ2 will aid evacuation during a flood event.

- Property resilience / resistance measures

Constraints on new & existing development mean that raised ground levels may not always be possible. Property level flood resilience and resistance measures may help to reduce the impact of flooding on development. Whilst this could be a strategic measure, implemented through policy, in practice it will be implemented on a local scale.

- Flood warning / flood event management

Effective flood warning and event management will be a key component of development and occupation of SZ2 in the long term. Flood risk management plans, developed on an individual development and zone-wide approach should be included in the strategic approach.

- Improvements to the rhine network

The rhine network is limited to only one culvert on the eastern side and therefore increasing the capacity is likely to provide minimal benefits across the zone. Land raising and compensatory flood storage is recommended to reduce the fluvial flood risk in this SZ.

Strategic mitigation solutions recommended for further investigation:

- **Defence improvements**
- **Change of use (Policy measures to discourage highly vulnerable development and essential infrastructure)**
- **Recommendation of local scale land raising**
- **New / improved access routes**
- **Property resilience / resistance measures**
- **Flood warning / event management**

Impact of development / mitigation solutions on flooding elsewhere

8.5.4.2 Fluvial flooding is an important source of flooding in this zone. The impact of land raising (for both tidal and fluvial flooding) should be considered on a local scale. Similarly the impact of increased runoff from developments. Implementation of sustainable drainage measures and improvements to the existing drainage and rhine networks through SWMPs should be considered.

8.5.4.3 No strategic solutions are considered necessary to address the impact of development on flood risk elsewhere.

8.5.5 Links with other Strategies & Plans

8.5.5.1 CFMP Policy 4: Take further action to reduce flood risk

8.5.5.2 SMP Policy: Hold the Line (short term). Unknown at this stage whether SoP will be maintained or defence height maintained (to be determined through SEFRMS).

8.5.5.3 The SMP policy indicates there is an existing commitment to maintain defences. However improvements required for sustainable development in SZ2 may be over and above that provided through SMP policy.

8.5.5.4 The CFMP does not identify specific actions relevant to the strategic options identified above.

8.5.5.5 Strategic mitigation measures suggested are in line with current / anticipated policy however may need additional commitment to that implemented in line with the CFMP / SMP policies and actions.

8.5.6 Scope for Developer Contributions

8.5.6.1 The small-scale nature of development in this zone suggests that scope for developer contributions to strategic schemes is limited. The scope for developer contributions is discussed in more detail in Section 4.

8.6. Strategic Zone 3: Avonmouth (Employment)

8.6.1 Description of the Current Problem

8.6.1.1 Strategic Zone 3 (SZ3) is at risk of both fluvial and tidal flooding mechanisms. While the zone itself does not include any coastline, tidal flood water enters the zone through the neighbouring SZ1. The zone includes a complex rhine network with ~14km of open rhines and ~8km of culverted channels; fluvial flooding poses some threat.

8.6.1.2 The current flood hazard results indicate that ~50% of the zone as a Danger for Some. There are small regions shown in the model as a Danger for Most; these are concentrated around the Works south of Cabot Park and immediately south of Rockingham Roundabout. This is due to the overtopping of sea defence section G-H.

8.6.1.3 Model results show that for a 1 in100 year fluvial event, there is considerable flooding of fields to the north and south of Ballast Lane (in the south east of the zone). In addition to this, the following areas have been shown to pose “danger to some”:

- Warehouses along Second Way
- Junction of Third Way and A403
- Works along Severn Road
- Flooding between Lawrence Weston Road and Poplar Way

8.6.1.4 With climate change, tidal flooding is anticipated to inundate the zone, with the exception of isolated pockets of high ground. The risk of fluvial flooding is also expected to worsen with climate change.

8.6.2 Potential Development

8.6.2.1 SZ3 includes a number of proposed developments including waste sites, industry and employment. General development is restricted by the railway embankment to the north and the docks to the west.

8.6.2.2 Three sites within SZ3 have been identified for Waste Management;

- DS05 (6.6ha)
- DS13 (23.3ha)
- DS06 (46.2ha)

8.6.2.3 With the exception of landfill and hazardous waste facilities, waste treatment sites are permitted in flood zone 3a. Should the sites listed above be for hazardous waste, they are classed as more vulnerable and must pass the exception test to be permissible in flood zone 3a.

8.6.2.4 SZ3 also contains potential developments to the Avonmouth Industrial Area. Whether these are permitted under the current flood zone categorization depends on the nature of the sites. According to PPS25, Buildings used for “general industry; storage and distribution” are permissible in Flood Zone 3a. There is a significant area of functional floodplain (zone 3b) in SZ3, all development except water compatible and essential infrastructure should not be permitted in zone 3b.

8.6.2.5 Development in SZ3 is likely to be predominantly Less vulnerable.

8.6.3 Mitigation Requirements

8.6.3.1 Strategic mitigation measures should seek to achieve the following key objectives:

- Safe & reasonable occupancy and operation of homes, businesses and industry on a daily basis;
- Safe access & egress in the event of failure or a breach in the defences or a fluvial flood event;
- Safe refuge, as floods (especially through breach) may occur rapidly with little warning;
- Reduction in damages associated with flooding (as a minimum seek to minimise any extra damages through new development)
- Protection against flooding and associated pollution / contamination linked with storage of any hazardous substances.

8.6.4 Potential Mitigation Solutions

Impact of flooding to development

8.6.4.1 Potential mitigation solutions identified include:

- Improvements to defences
  In order to reduce the risk of SZ3 being inundated during a 1 in 200yr tidal flood event, tidal defence sections G-P would need to be raised to approximately 10.7mAOD. These improvements are estimated to cost £7.09m and would provide protection to SZ1 and SZ3. The optimum defence crest level, taking into account risks due to wave overtopping would need to be defined through detailed studies.

  Although current defence heights may be above the minimum requirement of 0.5% (1 in 200 years), with climate change taken into account this would reduce to less than the accepted standard. The defences in this area are also of uncertain quality and therefore may be at higher risk of breach.

  Given the scale of flooding anticipated in the future as a result of climate change, improvements to the defences are considered a minimum requirement for SZ3. Nevertheless, development remains vulnerable to breach / failure of defences and therefore residual flood risk management measures should be considered.

- Change of use
  Current land use within SZ3 includes employment, waste sites and Avonmouth industrial area. A change in land use would have significant implications for the economy and prosperity of the Avonmouth / Severnside area and is not considered an appropriate strategic measure at this stage for the life of the LDF.

- Land raising (tidal flood risk)
  Land raising in this zone for new developments could reduce the flood risk however care must be taken to ensure islands are not created and that escape routes are included. Compensatory floodplain storage may be required in areas liable to fluvial flooding dependent on the overall IDB strategy. The provision of compensatory flood storage for tidal flooding is unlikely to be achieved due to the lack of sufficient areas of higher ground that could be used. The impacts of land raising without compensation storage will therefore need to be assessed.

- New / improved access routes
  Provision of new / improved access routes into SZ3 should be considered as existing access routes are anticipated to be inundated during a tidal flood / breach event. The primary road access route into SZ3 is via the M49, which remains dry, therefore a strategic access route linking with the M49 is considered appropriate. Access routes linking with the raised railway line could also be considered. A primary safe access route through SZ3 will aid evacuation during a flood event.

- Property resilience / resistance measures
  Constraints on new & existing development mean that raised ground levels may not always be possible. Property level flood resilience and resistance measures may help to reduce the impact of flooding on development. Whilst this could be a strategic measure, implemented through policy, in practice it will be implemented on a local scale.

- Flood warning / flood event management

Effective flood warning and event management will be a key component of development and occupation of SZ3 in the long term. Flood risk management plans, developed on an individual development and zone-wide approach should be included in the strategic approach.

- Improvements to the rhine network
  Flooding is concentrated around the rhine network and it is expected that increasing the capacity of the rhines would significantly reduce flood risk. In addition to widening the rhines there is potential to lower fields around Kings Weston Lane to increase storage capacity.

Strategic mitigation solutions recommended for further investigation:

- **Defence improvements**
- **Strategic land raising**
- **New / improved access routes**
- **Property resilience / resistance measures**
- **Flood warning / event management**
- **Improvements to the rhine network**

Impact of development / mitigation solutions on flooding elsewhere

8.6.4.2 Strategic level compensation storage for land raising is unlikely to be achieved as discussed above. The impact of strategic land raising on flooding elsewhere should be considered.

8.6.4.3 Fluvial flooding is an important source of flooding in this zone. The impact of land raising for fluvial flooding should be considered on a local scale. Similarly the impact of increased runoff from developments. Implementation of sustainable drainage measures and improvements to the existing drainage and rhine networks through SWMPs should be considered.

Strategic scale rhine improvements and storage provision could be considered for this zone.

8.6.5 Links with other Strategies & Plans

8.6.5.1 CFMP Policy 4: Take further action to reduce flood risk

8.6.5.2 SMP Policy: Hold the Line (short term). Unknown at this stage whether SoP will be maintained or defence height maintained (to be determined through SEFRMS).

8.6.5.3 The SMP policy indicates there is an existing commitment to maintain defences. However improvements required for sustainable development in SZ3 may be over and above that provided through SMP policy.

8.6.5.4 The CFMP included an action to “Carry out multi-agency review of flood risk management led by the Environment Agency and involving South Gloucester Council and the Internal Drainage Board”

8.6.5.5 Strategic mitigation measures suggested are in line with current / anticipated policy, however may need additional commitment to that implemented in line with the CFMP / SMP policies and actions.

8.6.6 Scope for Developer Contributions

8.6.6.1 There is scope for developer contributions towards strategic measures in this zone. Developments are likely to be of a reasonable scale, with direct benefits from defence and rhine network improvements. The scope for developer contributions is discussed in more detail in Section 4.

8.7. Strategic Zone 4: Crooks Marsh (Employment)

8.7.1 Description of the Problem

8.7.1.1 Strategic Zone 4 (SZ4) is predominantly at risk of tidal flooding with only a few small pockets of inundation during a 1 in 100yr fluvial event (although this increases with climate change). The zone includes approximately 2km of coastal defences the majority of which are shown to be overtopped during a 1 in 200yr tidal event.

8.7.1.2 During a 1 in 200yr tidal flood event, model results show ~80% of the zone as a Danger for some or most. The low lying area just south of Crooks Marsh Power Station poses a Danger for all. Defence Sections E-G are over topped during the modelled 1 in 200yr tidal flood event.

8.7.1.3 For a 1 in 100yr fluvial event, model results show localised flooding around the rhine network. Results show fluvial flood water as a danger for some around Minor's farm and Red Splot Gout

8.7.1.4 With climate change, tidal flooding is anticipated to inundate the zone, with the exception of isolated pockets of high ground. Fluvial flooding is also more extensive when climate change effects are included.

8.7.2 Potential Development

8.7.2.1 SZ4 includes part of the larger undeveloped area, formerly owned by ICI, which benefits from an extant planning permission for industrial development dating from the late 1950s. There are also sites that have been identified in the Joint Waste Core Strategy within this area. Improvements in the road network are detailed in the local plan and include a new spine road and link road from the M49.

8.7.2.2 Two sites within SZ4 have been identified for Waste Management;

- DS07 (11.1ha)
- DS15 (3.3ha)

8.7.2.3 With the exception of landfill and hazardous waste facilities, waste treatment sites are permitted in flood zone 3a. Should the sites listed above be for hazardous waste, they are classed as more vulnerable and must pass the exception test to be permissible in flood zone 3a. SZ4 includes a reasonably large area of functional floodplain (zone 3b). All development, except water compatible evelopment and essential infrastructure should not be permitted in flood zone 3b.

8.7.2.4 SZ4 also contains potential developments to the Avonmouth Industrial Area. Whether these are permitted under the current flood zone categorization depends on the nature of the sites. According to PPS25, buildings used for "general industry; storage and distribution" are permissible in Flood Zone 3a.

8.7.2.5 New development in this strategic zone is generally anticipated to be Less Vulnerable. The existing works and power station may be highly vulnerable and essential infrastructure respectively, and therefore subject to the Exception test.

8.7.3 Mitigation Requirements

8.7.3.1 Strategic mitigation measures should seek to achieve the following key objectives:

- Safe & reasonable operation of development on a daily basis;
- Safe access & egress in the event of failure or a breach in the defences or a fluvial flood event;
- Safe refuge, as floods (especially through breach) may occur rapidly with little warning;
- Reduction in damages associated with flooding (as a minimum seek to minimise any extra damages through new development)
- Protection against flooding and associated pollution / contamination linked with storage of any hazardous substances.
- Maintained operation of critical infrastructure during a flood

8.7.4 Potential Mitigation Solutions

Impact of flooding to development

8.7.4.1 Potential mitigation solutions identified include:

- Improvements to defences

In order to reduce the risk of SZ4 being inundated during a 1 in 200yr tidal flood event, tidal defence sections E-G would need to be raised to approximately 10.7mAOD. These improvements are estimated to cost £2.46m. The optimum defence crest level, taking into account risks due to wave overtopping would need to be defined through detailed studies.

Although current defence heights may be above the minimum requirement of 0.5% (1 in 200 years), with climate change taken into account this would reduce to less than the accepted standard. The defences in this area are also of uncertain quality and therefore may be at higher risk of breach.

Given the scale of flooding anticipated in the future as a result of climate change, improvements to the defences are considered a minimum requirement for SZ4. Nevertheless, development remains vulnerable to breach / failure of defences and therefore residual flood risk management measures should be considered.

- Change of use

Current land use within SZ4 includes industry, waste sites and essential infrastructure. A change in land use would have significant implications for the economy and prosperity of the Avonmouth / Severnside area and is not considered an appropriate strategic measure at this stage for the life of the LDF.

- Land raising

Land raising in this zone for new developments could reduce the flood risk however care must be taken to ensure islands are not created and that escape routes are included. Compensatory floodplain storage may be required in areas liable to fluvial flooding dependent on the overall IDB strategy. The provision of compensatory flood storage for tidal flooding is unlikely to be achieved due to the lack of sufficient areas of higher ground that could be used. The impacts of land raising without compensation storage will therefore need to be assessed.

- New / improved access routes

Provision of new / improved access routes into SZ4 should be considered as existing access routes are anticipated to be at least partially inundated during a tidal flood / breach event. Several access roads lead into the SZ, improvements should be considered to provide an integrated access network through the zone to aid evacuation during a flood event.

- Property resilience / resistance measures

Constraints on existing development mean that raised ground levels may not always be possible. If not already adequately defended, specific defence measures for the critical parts of the chemical works and power station should be considered.

- Flood warning / flood event management

Effective flood warning and event management will be a key component of development and occupation of SZ4 in the long term. Flood risk management plans, developed on an individual development and zone-wide approach should be included in the strategic approach.

- Improvements to the rhine network

Fluvial flooding in SZ4 is concentrated around the rhine network. As such it is expected that increasing the capacity of the rhines would significantly reduce flood risk. There are approximately 16km of open rhines in this zone (and ~0.8km of culverts).

Strategic mitigation solutions recommended for further investigation:

- **Defence improvements**
- **Strategic Land raising**
- **New / improved access routes**
- **Property resilience / resistance measures (localised defence schemes)**
- **Flood warning / event management**
- **Improvements to the rhine network**

Impact of development / mitigation solutions on flooding elsewhere

8.7.4.2 Strategic level compensation storage for land raising is unlikely to be achieved as discussed above. The impact of strategic land raising on flooding elsewhere should be considered.

8.7.4.3 Fluvial flooding is an important source of flooding in this zone. The impact of land raising for fluvial flooding should be considered. Similarly the impact of increased runoff from developments. Implementation of sustainable drainage measures and improvements to the existing drainage and rhine networks through SWMPs should be considered.

Strategic scale rhine improvements and storage provision could be considered for this zone.

8.7.5 Links with other Strategies & Plans

8.7.5.1 CFMP Policy 4: Take further action to reduce flood risk

8.7.5.2 SMP Policy: Hold the Line (short term). Unknown at this stage whether SoP will be maintained or defence height maintained (to be determined through SEFRMS).

8.7.5.3 The SMP policy indicates there is an existing commitment to maintain defences. However improvements required for sustainable development in SZ4 may be over and above that provided through SMP policy.

8.7.5.4 The CFMP included an action to “Carry out multi-agency review of flood risk management led by the Environment Agency and involving South Gloucestershire Council and the Internal Drainage Board”

8.7.5.5 Strategic mitigation measures suggested are in line with current / anticipated policy, however may need additional commitment to that implemented in line with the CFMP / SMP policies and actions.

8.7.6 Scope for Developer Contributions

8.7.6.1 There is scope for developer contributions towards strategic measures in this zone. Developments are likely to be of a reasonable scale, with direct benefits from defence and rhine network improvements. The scope for developer contributions is discussed in more detail in Section 4.

8.8. Strategic Zone 5: Dyer's Common / ICI site

8.8.1 Description of the Problem

8.8.1.1 Strategic Zone 5 (SZ5) is predominantly at risk of tidal flooding with only a few small pockets of inundation during a 1 in 100yr fluvial event (although this increases with climate change). The zone includes approximately 1km of coastal defences the majority of which are shown to be overtopped during a 1 in 200yr tidal event.

8.8.1.2 During a 1 in 200yr tidal flood event, model results show ~80% of the zone as a Danger for some or most. Defence Sections E-F are overtopped during the modelled 1 in 200yr tidal flood event. SZ5 is also at risk from tidal flooding as a result of the overtopping of defence section B-C.

8.8.1.3 For a 1 in 100yr fluvial event, model results show localised flooding round the rhine network. Results show fluvial flood water as a danger for some in the following areas:

- Central Avenue
- Fields around Green Pool Lane and Impool Gout
- Fields around Shipman's Gout
- Fields North of Ashton Gout

8.8.1.4 With climate change, tidal flooding is anticipated to inundate the zone, with the exception of isolated pockets of high ground. Fluvial flooding is also more extensive when climate change effects are included.

8.8.2 Potential Development

8.8.2.1 SZ5 comprises the former ICI chemical works site, a warehousing and distribution park and a large undeveloped area, formerly owned by ICI, which benefits from an extant planning permission for industrial development dating from the late

1950s. Improvements in the road network are detailed in the local plan and include a new spine road and link road from the M49.

8.8.2.2 A 12.8ha site (SG39) within SZ5 has been identified for Waste Management.

8.8.2.3 With the exception of landfill and hazardous waste facilities, waste treatment sites are permitted in flood zone 3a. Should the site listed above be for hazardous waste, it will be considered more vulnerable and must pass the exception test to be permissible in flood zone 3a.

8.8.2.4 New development in this SZ is generally anticipated to be Less Vulnerable. The existing chemical works and power station may be highly vulnerable and essential infrastructure respectively, and therefore subject to the Exception test.

8.8.3 Mitigation Requirements

8.8.3.1 Strategic mitigation measures should seek to achieve the following key objectives:

- Safe & reasonable operation of development on a daily basis;
- Safe access & egress in the event of failure or a breach in the defences or a fluvial flood event;
- Safe refuge, as floods (especially through breach) may occur rapidly with little warning;
- Reduction in damages associated with flooding (as a minimum seek to minimise any extra damages through new development)
- Protection against flooding and associated pollution / contamination linked with storage of any hazardous substances.
- Maintained operation of critical infrastructure during a flood

8.8.4 Potential Mitigation Solutions

Impact of flooding to development

8.8.4.1 Potential mitigation solutions identified include:

- Improvements to defences
  In order to reduce the risk of SZ5 being inundated during a 1 in 200yr tidal flood event, tidal defence sections B-F would need to be raised to approximately 10.7mAOD. These improvements are estimated to cost £7.42m. The optimum defence crest level, taking into account risks due to wave overtopping would need to be defined through detailed studies.

  Although current defence heights may be above the minimum requirement of 0.5% (1 in 200 years), with climate change taken into account this would reduce to less than the accepted standard. The defences in this area are also of uncertain quality and therefore may be at higher risk of breach.

Given the scale of flooding anticipated in the future as a result of climate change, improvements to the defences are considered a minimum requirement for SZ5. Nevertheless, development remains vulnerable to breach / failure of defences and therefore residual flood risk management measures should be considered.

- Change of use
  Current land use within SZ5 includes industry, waste sites and essential infrastructure. A change in land use would have significant implications for the economy and prosperity of the Avonmouth / Severnside area and is not considered an appropriate strategic measure at this stage for the life of the LDF.

- Land raising
  Land raising in this zone for new developments could reduce the flood risk however care must be taken to ensure islands are not created and that escape routes are included. Compensatory floodplain storage may be required in areas liable to fluvial flooding dependent on the overall IDB strategy. The provision of compensatory flood storage for tidal flooding is unlikely to be achieved due to the lack of sufficient areas of higher ground that could be used. The impacts of land raising without compensation storage will therefore need to be assessed.

- New / improved access routes
  Provision of new / improved access routes into SZ5 should be considered as existing access routes are anticipated to be at least partially inundated during a tidal flood / breach event. Several access roads lead into the SZ, improvements should be considered to provide an integrated access network through the zone to aid evacuation during a flood event.

- Property resilience / resistance measures
  Constraints on existing development mean that raised ground levels may not always be possible. If not already adequately defended, specific defence measures for the critical parts of the chemical works and power station should be considered.

- Flood warning / flood event management
  Effective flood warning and event management will be a key component of development and occupation of SZ5 in the long term. Flood risk management plans, developed on an individual development and zone-wide approach should be included in the strategic approach.

- Improvements to the rhine network
  Fluvial flooding in SZ5 is concentrated around the rhine network. As such it is expected that increasing the capacity of the rhines would significantly reduce flood risk. There are approximately 15km of open rhines in this zone (and ~0.9km of

culverts). It should be noted that the zone contains new developments which have already increased the rhine capacity around Dyers Common.

In addition to rhine widening, the fields around Green Pool Lane and Impool Gout could potentially be lowered to increase storage.

Strategic mitigation solutions recommended for further investigation:

- **Defence improvements**
- **Strategic land raising**
- **New / improved access routes**
- **Property resilience / resistance measures (localised defence schemes)**
- **Flood warning / event management**
- **Improvements to the rhine network**

Impact of development / mitigation solutions on flooding elsewhere

8.8.4.2 Strategic level compensation storage for land raising is unlikely to be achieved as discussed in 8.8.4.1 above. The impact of strategic land raising on flooding elsewhere should be considered.

8.8.4.3 Fluvial flooding is an important source of flooding in this zone. The impact of land raising for fluvial flooding should be considered. Similarly the impact of increased runoff from developments. Implementation of sustainable drainage measures and improvements to the existing drainage and rhine networks through SWMPs should be considered.

Strategic scale rhine improvements and storage provision could be considered for this zone.

8.8.5 Links with other Strategies & Plans

8.8.5.1 CFMP Policy 4: Take further action to reduce flood risk

8.8.5.2 SMP Policy: Hold the Line (short term). Unknown at this stage whether SoP will be maintained or defence height maintained (to be determined through SEFRMS).

8.8.5.3 The SMP policy indicates there is an existing commitment to maintain defences. However improvements required for sustainable development in SZ5 may be over and above that provided through SMP policy.

8.8.5.4 The CFMP included an action to “Carry out multi-agency review of flood risk management led by the Environment Agency and involving South Gloucestershire Council and the Internal Drainage Board”

8.8.5.5 Strategic mitigation measures suggested are in line with current / anticipated policy, however may need additional commitment to that implemented in line with the CFMP / SMP policies and actions.

8.8.6 Scope for Developer Contributions

8.8.6.1 There is scope for developer contributions towards strategic measures in this zone. Developments are likely to be of a reasonable scale, with direct benefits from defence and rhine network improvements. The scope for developer contributions is discussed in more detail in Section 4.

8.9. Strategic Zone 6: Severn Beach (Residential/Employment)

8.9.1 Description of the Current Problem

8.9.1.1 Strategic Zone 6 (SZ6) is low lying and vulnerable to tidal flooding. The zone includes almost 2km of coastal defences (defence sections B-D), the majority of which are shown to be overtopped during a 1 in 200yr tidal event.

8.9.1.2 During a 1 in 200yr tidal flood event, model results show ~90% of the zone to be inundated and a Danger to most. The eastern part of the zone (east of the A403) is only partially flooded showing danger to some.

8.9.1.3 Although SZ6 contains over 3km of rhines, model results show no inundation during a 1 in 100 year fluvial event.

8.9.1.4 Climate change effects are anticipated to increase the severity of both fluvial and tidal flooding in this zone.

8.9.2 Potential Development

8.9.2.1 The type of development that is likely in Severn Beach and Pilning is for commercial and residential purposes. There is likely to be new development and development enquiries made in this area. Large scale development is not anticipated.

8.9.2.2 Development is likely to be a mixture of more and less vulnerable.

8.9.3 Mitigation Requirements

8.9.3.1 Strategic mitigation measures should seek to achieve the following key objectives:

- Safe & reasonable occupancy of homes and businesses on a daily basis;
- Safe access & egress in the event of failure or a breach in the defences;

- Safe refuge, as floods (especially through breach) may occur rapidly with little warning;
- Reduction in damages associated with flooding (as a minimum seek to minimise any extra damages through new development)

8.9.4 Potential Mitigation Solutions

Impact of flooding to development

8.9.4.1 Potential mitigation solutions identified include:

- Improvements to defences

The raising of sea defence sections B-D to approximately 10.7mAOD is estimated to cost £5.22 million. This would provide additional protection to SZ6 and reduce the risk of overtopping for a 1 in 200yr tidal event. The optimum defence crest level, taking into account risks due to wave overtopping would need to be defined through detailed studies.

Figure 4.3 shows that current defence heights are below the minimum requirement of 0.5% (1 in 200 years), with climate change taken into account this would reduce to much less than the accepted standard.

Given the scale of flooding anticipated in the future as a result of climate change, improvements to the defences are considered a minimum requirement for Severn Beach to remain viable. Nevertheless, development remains vulnerable to breach / failure of defences and therefore residual flood risk management measures should be considered.

- Change of use

Policy measures to encourage gradual replacement of existing residential development with less vulnerable business and industrial uses could be considered. This is likely to be a very long-term approach, that will meet considerable resistance from the public, therefore is not considered an appropriate strategic measure at this stage for the life of the LDF. Policy measures to discourage highly vulnerable development and essential infrastructure could be considered.

- Land raising

Large scale land raising within SZ6 is not considered an appropriate strategic measure, due to the level of existing development within the zone. Localised land raising should be considered for new developments, especially any particularly vulnerable development. Compensatory floodplain storage may be required in areas liable to fluvial flooding dependent on the overall IDB strategy.

- New / improved access routes

Provision of new / improved access routes into SZ6 should be considered as existing access routes are anticipated to be inundated during a tidal flood / breach event. The primary access route into SZ6 is via the A403 and B4064, which are themselves likely to be partially inundated. Strategic access routes linking with the M49 is considered appropriate. A primary safe access route through SZ6 will aid evacuation during a flood event.

- Property resilience / resistance measures

Constraints on new & existing development mean that raised ground levels may not always be possible. Property level flood resilience and resistance measures may help to reduce the impact of flooding on development. Whilst this could be a strategic measure, implemented through policy, in practice it will be implemented on a local scale.

- Flood warning / flood event management

Effective flood warning and event management will be a key component of development and occupation of SZ6 in the long term. Flood risk management plans, developed on an individual development and zone-wide approach should be included in the strategic approach.

- Improvements to the rhine network

Significant fluvial flooding is anticipated in the future with climate change effects. Improvements to the rhine / drainage network may reduce fluvial flooding.

Strategic mitigation solutions recommended for further investigation:

- **Defence improvements**
- **Change of use (Policy measures to discourage highly vulnerable development and essential infrastructure)**
- **Local scale land raising**
- **New / improved access routes**
- **Property resilience / resistance measures**
- **Flood warning / event management**
- **Improvements to the rhine network**

Impact of development / mitigation solutions on flooding elsewhere

8.9.4.2 Fluvial flooding is an important source of flooding in this zone. The impact of land raising (for both tidal and fluvial flooding) should be considered on a local scale. Similarly the impact of increased runoff from developments. Implementation of sustainable drainage measures and improvements to the existing drainage and rhine networks through SWMPs should be considered.

8.9.4.3 No strategic solutions are considered necessary to address impact of development on flood risk elsewhere.

8.9.5 Links with other Strategies & Plans

8.9.5.1 CFMP Policy 4: Take further action to reduce flood risk

8.9.5.2 SMP Policy: Hold the Line (short term). Unknown at this stage whether SoP will be maintained or defence height maintained (to be determined through SEFRMS).

8.9.5.3 The SMP policy indicates there is an existing commitment to maintain defences. However improvements required for sustainable development in SZ6 may be over and above that provided through SMP policy.

8.9.5.4 The CFMP included an action to “Carry out multi-agency review of flood risk management led by the Environment Agency and involving South Gloucestershire Council and the Internal Drainage Board”

8.9.5.5 Strategic mitigation measures suggested are in line with current / anticipated policy, however may need additional commitment to that implemented in line with the CFMP / SMP policies and actions.

8.9.6 Scope for Developer Contributions

8.9.6.1 The small-scale nature of development in this zone suggests that scope for developer contributions to strategic schemes is limited. The scope for developer contributions is discussed in more detail in Section 4.

8.10. Strategic Zone 7: Marsh Commons (Residential/Employment)

8.10.1 Description of the Current Problem

8.10.1.1 The predominant flood mechanism in Strategic Zone 7 (SZ7) is tidal defence overtopping (defence section B-D). There are small areas of localised fluvial flooding around the rhines on the western side of the B4055.

8.10.1.2 Model results from the 1 in 200yr tidal event show total inundation to the west of the B4055 (the east side of the road remains largely unaffected). The flood water covers approximately 70% of the zone and creates a danger for some.

8.10.1.3 There are a number of rhines in this zone which sum to approximately 3.6km of open channels. Flooding from these rhines during a 1 in 100yr fluvial event pose small pockets of danger for some in the following areas:

- Fields between Whitehouse and Ellinghurst Farms
- Fields East of Dyers Common

8.10.1.4 Fluvial and tidal flooding in this zone is anticipated to increase with the effects of climate change; however remains largely confined to land west of the B4055.

8.10.2 Potential Development

8.10.2.1 SZ7 includes land formerly owned by ICI and there is an extant planning permission for industrial development. Residential properties and building associated with agricultural and employment purposes are likely to form the main type of future development in SZ7. Whether these are permitted under the current flood zone categorisation depends on the nature of the sites. Buildings used for "general industry; storage and distribution" are permissible in Flood Zone 3a, subject to the sequential test. There area some areas of functional floodplain (zone 3b) in SZ7. Only water compatible development and essential infrastructure should be permitted in this zone.

8.10.2.2 New development in this zone is anticipated to largely comprise Less Vulnerable development.

8.10.3 Mitigation Requirements

8.10.3.1 Strategic mitigation measures should seek to achieve the following key objectives:

- Safe & reasonable operation of business and industry on a daily basis;
- Safe access & egress in the event of failure or a breach in the defences or fluvial flood;
- Safe refuge, as floods (especially through breach) may occur rapidly with little warning;
- Reduction in damages associated with flooding (as a minimum seek to minimise any extra damages through new development)

8.10.4 Potential Mitigation Solutions

Impact of flooding to development

8.10.4.1 Potential mitigation solutions identified include:

- Improvements to defences

In order to reduce the risk of SZ7 being inundated during a 1 in 200yr tidal flood event, tidal defence sections B-D would need to be raised to approximately 10.7mAOD. These improvements are estimated to cost £5.22m. The optimum defence crest level, taking into account risks due to wave overtopping would need to be defined through detailed studies.

The M49, although not preventing tidal flooding, acts as a barrier and reduces the impact east of the M49. Without improvements to the defences future tidal flooding in this SZ is significant, however it is possible that it could be managed through strategic 'in-zone' measures, rather than improvements to defences.

- Change of use

Current land use within SZ7 includes residential, agricultural, employment and industry, A change in land use would have significant implications for the economy and prosperity of the Avonmouth / Severnside area and is not considered an appropriate strategic measure at this stage for the life of the LDF.

- Land raising

Land raising in this zone for new developments could reduce the flood risk however care must be taken to ensure islands are not created and that escape routes are included. Compensatory floodplain storage may be required in areas liable to fluvial flooding dependent on the overall IDB strategy. The provision of compensatory flood storage for tidal flooding is unlikely to be achieved due to the lack of sufficient areas of higher ground that could be used. The impacts of land raising without compensation storage will therefore need to be assessed.

- New / improved access routes

Provision of new / improved access routes into SZ7 should be considered. Although existing access routes are largely flood-free, they border the zone. Access routes into the zone, alongside new development, should be considered to aid evacuation during a flood event.

- Property resilience / resistance measures

As SZ7 is largely undeveloped reliance on property level flood resilience / resistance is not considered an appropriate strategic measure.

- Flood warning / flood event management

Effective flood warning and event management will be a key component of development and occupation of SZ7 in the long term. Flood risk management plans, developed on an individual development and zone-wide approach should be included in the strategic approach.

- Improvements to the rhine network

Significant fluvial flooding is anticipated in the future with climate change effects. Improvements to the rhine network may reduce fluvial flooding. There is potential for rhine widening along the B4055.

Strategic mitigation solutions recommended for further investigation:

- **Defence improvements**
- **Strategic Land raising (tidal flood risk)**
- **New / improved access routes**
- **Flood warning / event management**
- **Improvements to the rhine network**

Impact of development / mitigation solutions on flooding elsewhere

8.10.4.2 Strategic level compensation storage for land raising is unlikely to be achieved as discussed above. The impact of strategic land raising on flooding elsewhere should be considered.

8.10.4.3 Fluvial flooding is an important source of flooding in this zone. The impact of land raising on fluvial flooding should be considered on a local scale. Similarly the impact of increased runoff from developments. Implementation of sustainable drainage measures and improvements to the existing rhine network should be considered.

Strategic scale rhine improvements and storage provision could be considered for this zone.

8.10.5 Links with other Strategies & Plans

8.10.5.1 CFMP Policy 4: Take further action to reduce flood risk

8.10.5.2 SMP Policy: Hold the Line (short term). It is unknown at this stage whether SoP will be maintained or defence height maintained (to be determined through SEFRMS).

8.10.5.3 The SMP policy indicates there is an existing commitment to maintain defences. However improvements required for sustainable development in SZ7 may be over and above that provided through SMP policy.

8.10.5.4 The CFMP included an action to "Carry out multi-agency review of flood risk management led by the Environment Agency and involving South Gloucestershire Council and the Internal Drainage Board"

8.10.5.5 Strategic mitigation measures suggested are in line with current / anticipated policy, however may need additional commitment to that implemented in line with the CFMP / SMP policies and actions.

8.10.6 Scope for Developer Contributions

8.10.6.1 There may be scope for developer contributions towards strategic measures in this zone. However this will depend on the scale of developments coming forward. The scope for developer contributions is discussed in more detail in section 4.

8.11. Strategic Zone 8: North of railway

8.11.1 Description of the Current Problem

8.11.1.1 The predominant flood mechanism in Strategic Zone 8 (SZ8) is tidal defence overtopping (defence section A-C). There is a small area of localised fluvial flooding around the Ingst Rhine, close to the M48.

8.11.1.2 Model results from the 1 in 200yr tidal event show total inundation to the north of the M4 (the motorway serves as a barrier reducing the risk south of the M4). The flood water covers approximately 80% of the zone; creating a danger for all/most in the north and some in the south.

8.11.1.3 There are a number of rhines in this zone which sum to approximately 29km of open channels and 1km of culverts. Flooding from these rhines during a 1 in 100yr fluvial event pose small pockets of danger for some in the following areas:

- The Ingst Rhine
- The Niatts

8.11.1.4 Fluvial and tidal flooding in this zone is anticipated to increase with the effects of climate change; however remains largely confined to land north of the M4.

8.11.2 Potential Development

8.11.2.1 Residential properties and building associated with agricultural and employment purposes are likely to form the main type of future development in SZ8. Whether these are permitted under the current flood zone categorization depends on the nature of the sites. Buildings used for “general industry; storage and distribution” are permissible in Flood Zone 3a subject to the sequential test.

8.11.2.2 New development in this zone is anticipated to largely comprise Less Vulnerable development.

8.11.3 Mitigation Requirements

8.11.3.1 Strategic mitigation measures should seek to achieve the following key objectives:

- Safe & reasonable operation of business and industry on a daily basis;
- Safe access & egress in the event of failure or a breach in the defences or fluvial flood;
- Safe refuge, as floods (especially through breach) may occur rapidly with little warning;
- Reduction in damages associated with flooding (as a minimum seek to minimise any extra damages through new development)

8.11.4 Potential Mitigation Solutions

Impact of flooding to development

8.11.4.1 Potential mitigation solutions identified include:

- Improvements to defences

In order to reduce the risk of SZ8 being inundated during a 1 in 200yr tidal flood event, tidal defence sections A-C would need to be raised to approximately 10.7mAOD. These improvements are estimated to cost £6.71m. The optimum defence crest level, taking into account risks due to wave overtopping would need to be defined through detailed studies.

The M4, although not preventing tidal flooding, acts as a barrier and reduces the impact south of the M4. Without improvements to the defences future tidal flooding in this SZ is significant, however it is possible that it could be managed through strategic measures within the zone measures, rather than improvements to defences.

- Change of use

Policy measures to encourage gradual replacement of existing residential development with less vulnerable business and industrial uses could be considered. This is likely to be a very long-term approach, that will meet considerable resistance from the public, therefore is not considered an appropriate strategic measure at this stage for the life of the LDF. Policy measures to discourage highly vulnerable development and essential infrastructure could be considered.

- Land raising

Large scale land raising within SZ8 is not considered an appropriate strategic measure, due to the small scale of future development anticipated within the zone. Localised land raising should be considered for new developments, especially any particularly vulnerable development. Compensatory floodplain storage may be required in areas liable to fluvial flooding dependent on the overall IDB strategy.

- New / improved access routes

Provision of new / improved access routes into SZ8 should be considered. Although the main access routes that cross the zone are largely flood-free, there is no safe access onto these routes within the zone. Access routes into the zone should be considered to aid evacuation during a flood event.

- Property resilience / resistance measures

As SZ8 is largely undeveloped reliance on property level flood resilience / resistance is not considered an appropriate strategic measure.

- Flood warning / flood event management

Effective flood warning and event management will be a key component of development and occupation of SZ8 in the long term. Flood risk management plans, developed on an individual development and zone-wide approach should be included in the strategic approach.

- Improvements to the rhine network

Fluvial flooding is confined to small pockets within SZ8 and this is anticipated to increase in the future with climate change effects, Improvements to the rhine network may reduce fluvial flooding, however as the majority of the flood risk in SZ8 is tidal improvements to the rhine network will have only a small impact on the reduction on overall flood risk.

Strategic mitigation solutions recommended for further investigation:

- **Defence improvements**
- **Change of use (Policy measures to discourage highly vulnerable development and essential infrastructure)**
- **Local scale land raising**
- **New / improved access routes**
- **Flood warning / event management**
- **Improvements to the rhine network**

Impact of development / mitigation solutions on flooding elsewhere

8.11.4.2 The impact of land raising (for both tidal and fluvial flooding) should be considered on a local scale. Similarly the impact of increased runoff from developments. Implementation of sustainable drainage measures and improvements to the existing drainage and rhine networks through SWMPs should be considered.

8.11.4.3 No strategic solutions are considered necessary to address the impact of development on flood risk elsewhere.

8.11.5 Links with other Strategies & Plans

8.11.5.1 CFMP Policy 3: Generally managing flood risk effectively

8.11.5.2 SMP Policy: Hold the Line (short term). It is unknown at this stage whether SoP will be maintained or defence height maintained (to be determined through SEFRMS).

8.11.5.3 The SMP policy indicates there is an existing commitment to maintain defences. However improvements required for sustainable development in SZ8 may be over and above that provided through SMP policy.

8.11.5.4 The SMP includes a commitment to maintain existing defences at their current physical levels, but also recognises that this will effectively allow flood risk to increase over time with the effects of climate change. The increase in flood risk should be minimised by encouraging third parties to reduce the risks posed by their activities. Opportunities will be taken to restore the natural storage of flood water on undeveloped floodplains to reduce dependence on raised defences.

8.11.5.5 Strategic mitigation measures suggested are in line with current / anticipated SMP policy, however require additional commitment to that outlined within the CFMP policies and actions.

8.11.6 Scope for Developer Contributions

8.11.6.1 Although small scale development may take place in this zone may take place it is expected that there is limited scope for developer contributions to strategic measures. The scope for developer contributions is discussed in more detail in Section 4.

8.12. Mitigation measures to be taken forward for multi criteria assessment

Table 8.2 summarises the outcomes of the initial assessment and forms the list of mitigation measures to be taken forward for multi criteria assessment.

Table 8.2 Mitigation measures to be taken forward for multi criteria assessment

Flood Risk Management Measure	SZ1	SZ2	SZ3	SZ4	SZ5	SZ6	SZ7	SZ8
Improvements to defences to increase SoP and keep pace with climate change	✓	✓	✓	✓	✓	✓	✓	✓
Change of use*		✓				✓		✓
Strategic land raising			✓	✓	✓		✓	
Recommendation of local scale land raising	✓	✓	✓	✓	✓	✓	✓	✓
New / improved access routes	✓	✓	✓	✓	✓	✓	✓	✓
Property resilience / resistance measures^	✓	✓	✓	✓**	✓**	✓		
Flood warning / flood event management	✓	✓	✓	✓	✓	✓	✓	✓
Improvements to the Rhine network (local & stretgic)			✓***	✓***	✓	✓	✓***	✓

*Policy measures to discourage highly vulnerable development and essential infrastructure
** Possibly to include local flood defence schemes
***Including strategic rhine improvements and storage to reduce fluvial flooding
^ Thorough assessment of the feasibility of these options will be needed on a site-specific level taking into account local flood depths & velocities and the vulnerability of the proposed land use

8.13. Multi Criteria Assessment

The list of mitigation measures for further assessment identified through the initial assessment described above were taken forward for multi criteria assessment. For each measure in each zone consideration was given to the following criteria:

- Technical feasibility
    - Effectiveness in reducing future flood risk
    - Residual risk
    - Adverse offsite impacts
- Environmental / Social

  - Potential benefits / opportunities
  - Potential impacts / constraints / mitigation
- Costs
  - Construction costs
  - Ongoing maintenance requirements
  - Funding considerations
- Deliverability
  - Location risks (physical constraints, land purchase)
  - Planning constraints / consents

8.13.1.1 The multi criteria assessment was based on the mitigation of residual flood risks, it is assumed that defences will remain in place and that improvements are made to increase crest heights to the minimum 10.74mAOD. Flood depths from the defended, future case (taking account of climate change) 200 year tidal and 2 year fluvial and the defended, future case (taking account of climate change) 100 year fluvial and 2 year tidal events were used in the assessment.

8.14. Outcomes of multi criteria assessment

8.14.1.1 Table 8.3 summarises the result of the multi criteria assessment for each strategic zone. The detailed multi criteria assessment tables are shown in Appendix 8.1

Table 8.3 Summary of outcomes of multi criteria assessment
(colours indicate relative suitability: Green = recommended for detailed consideration & likely to provide suitable mitigation, Orange = recommended for further consideration however may prove to be unsuitable or difficult to implement)

Flood Risk Management Measure	SZ1	SZ2	SZ3	SZ4	SZ5	SZ6	SZ7	SZ8
Improvements to defences to increase SoP and keep pace with climate change	✓	✓	✓	✓	✓	✓	✓	✓
Change of use*		✓				✓		✓
Strategic land raising			✓	✓	✓		✓	
Recommendation of local scale land raising	✓	✓	✓	✓	✓	✓	✓	✓
New / improved access routes	✓	✓	✓	✓	✓	✓	✓	✓
Property resillience / resistance measures^	✓	✓	✓	✓**	✓**	✓		
Flood warning / flood event management	✓	✓	✓	✓	✓	✓	✓	✓
Improvements to the Rhine network (local / strategic)			✓***	✓***	✓	✓	✓***	✓

*Policy measures to discourage highly vulnerable development and essential infrastructure
** Local flood defence schemes
***Including strategic rhine improvements and storage to reduce fluvial flooding
^ Thorough assessment of the feasibility of these options will be needed on a site-specific level taking into account local flood depths & velocities and the vulnerability of the prposed land use

8.14.1.2 The impacts of strategic-scale land raising on flooding elsewhere were calculated using a cumulative approach for each strategic zone, following a similar approach to that described in the PPS25 Practice Guide. Details of the impact assessment are provided in Appendix A8.2.

8.14.1.3 Residual flood risks for the combined defended 200 year tidal with 2 year fluvial and the 100 year fluvial with 2 year tide consist of wave overtopping and defence breach. The residual risk as a result of a breach in tidal defences is considerably greater than the residual risk posed through wave overtopping alone. A mitigation measure may therefore be effective in reducing flood risk associated with wave overtopping but not effective in reducing the risk associated with defence breach.

8.14.1.4 A breach in the tidal defences would lead to significant flooding within the Avonmouth / Severndside area. In a breach situation flood incident management and emergency preparedness will be key to reducing risk to life and property. It is therefore imperative that Flood Incident Management Plans are developed on an individual development and a zone wide basis and that occupants of properties within the Avonmouth / Severnside area are well prepared and know how to respond in a defence breach situation.

8.14.2 The effectiveness and feasibility of residual flood risk mitigation options and their impacts on flooding elsewhere needs more detailed investigation, particularly the flood risk associated with wave overtopping taking account of joint probability and the impact of land raising and raised access routes on flooding to existing development and property. This should be undertaken in cionjunction with the preparation of a delivery plan to establish how the required infrastructure may be pahsed and delivered.

8.14.3 Strategic Zone 1

8.14.3.1 Improvements to flood defences are considered essential for strategic zone 1 to remain viable given the scale of future flooding due to climate change.

8.14.3.2 Local scale land raising could provide a reduction in flood risk for wave overtopping but due to predicted flood depths and constraints posed by surrounding development, this would not be a practical solution to reducing flood risk during a breach situation.

8.14.3.3 New / improved access routes could provide flood free access routes during wave overtopping but again this may become impractical during defence breach events due to the flood depth involved and access route elevation required in relation to surrounding development. The impacts of raising access routes to remain usable during a breach situation on flooding elsewhere would need to be carefully considered. These impacts may be able to be mitigated through careful design.

8.14.3.4 Property resilience / resistance measures could feasibly provide a reduction in flood risk from wave overtopping but due to the flood depths involved this measure would not be effective in reducing risk in a defence breach situation.

8.14.3.5 Flood warning and flood incident management will be key in reducing the residual risks posed to life and property by wave overtopping and particularly in defence breach situations where safe access / egress may not be feasible.

8.14.4 Strategic Zone 2

8.14.4.1 Improvements to flood defences are considered essential for strategic zone 2 to remain viable given the scale of future flooding due to climate change.

8.14.4.2 Policy measures to discourage highly vulnerable development and essential infrastructure should be considered to reduce future flood consequences.

8.14.4.3 Local scale land raising could provide some benefit against wave overtopping, however this may be difficult to implement due to surrounding development constraints. Local scale land raising would not be a practical solution to reducing flood risk during a breach situation due to predicted flood depths and constraints posed by surrounding development.

8.14.4.4 New / improved access routes could provide flood free access routes during wave overtopping but again this may become impractical during defence breach events due to the flood depths involved and access route elevations required in relation to surrounding development. The impacts of raising access routes to remain usable during a breach situation on flooding elsewhere would need to be carefully considered. These impacts may be able to be mitigated through careful design.

8.14.4.5 Property resilience / resistance measures would be appropriate to provide a reduction in flood risk from wave overtopping but as in strategic zone 1 due to the flood depths involved this measure would not be effective in reducing flood risk in a defence breach situation.

8.14.4.6 Flood warning and flood incident management will be key in reducing the residual risks posed to life and property by wave overtopping of the defences and particularly in defence breach situations where safe access / egress may not be feasible.

8.14.5 Strategic Zone 3

8.14.5.1 Improvements to flood defences are considered essential for strategic zone 3 to remain viable given the scale of future flooding due to climate change.

8.14.5.2 Strategic land raising could provide a reduction in flood risk during wave overtopping, although it would be difficult to provide sufficient compensation storage and the impacts to flooding elsewhere could be unacceptable unless development is limited. Alternative means of raising development levels, such as voids or stilts may be necessary to enable the full development however the design feasibility of such measures would need to be thoroughly assessed. This may pose a challenge to developers to meet safety requirements. Further investigation into the impacts of strategic land raising would be required to fully assess the feasibility of this measure. Land raising may not be a practical solution to reducing flood risk during a breach situation due to predicted flood depths and constraints posed by surrounding development.

8.14.5.3 New / improved access routes could provide flood free access routes during wave overtopping but again this may become impractical during defence breach events due to the flood depths involved and access route elevations required in relation to surrounding development. The impacts of raising access routes to remain usable during a breach situation on flooding elsewhere would need to be carefully considered. These impacts may be able to be mitigated through careful design.

8.14.5.4 Property resillience measures could provide benefit to isolated properties during a wave overtopping event. Due to the flood depths involved this measure would not be effective in reducing flood risk in a defence breach situation.

8.14.5.5 Flood warning and flood incident management will be key in reducing the residual risks posed to life and property by wave overtopping of the defences and particularly in defence breach situations where safe access / egress may not be feasible.

8.14.5.6 Improvements to the rhine network and provision of strategic fuvial flood storage areas could reduce fluvial flood risk in strategic zone 3. Further investigation is required into the feasibility of the provision of fluvial flood storage.

8.14.6 Strategic Zone 4

8.14.6.1 Improvements to flood defences are considered essential for strategic zone 4 to remain viable given the scale of future flooding due to climate change.

8.14.6.2 Strategic land raising could provide a reduction in flood risk during wave overtopping, although it would be difficult to provide sufficient compensation storage. The impacts to flooding elsewhere could be unacceptable although it is anticpated that a reasonable level of development could proceed before this became too much of a concern. Further investigation into the impacts of strategic land raising would be required to fully assess the feasibility of this measure.Land raising may not be a practical solution to reducing flood risk during a breach situation due to predicted flood depths and constraints posed by surrounding development.

8.14.6.3 New improved access routes would be essential for safe access and egress to strategic zones 4 and 5 during wave overtopping and breach events. The impacts of raising access routes to remain usable during a breach situation on flooding elsewhere would need to be carefully considered. These impacts may be able to be mitigated through careful design and consideration may need to be given to the use of stilts rather than raised road embankments.

8.14.6.4 The depths of flooding expected, even for wave overtopping only, would be too great for ‘off the shelf’ flood resistance measures to be effective. Flood resilience measures may be effective in isolated areas. Bespoke flood resistance measures would be required at the power station site to eliminate residual flood risk from wave overtopping and defence breach.

8.14.6.5 Flood warning and flood incident management will be key in reducing the residual risks posed to life and property by wave overtopping of the defences and particularly in defence breach situations where safe access / egress may not be feasible.

8.14.6.6 Improvements to the rhine network and provision of strategic fuvial flood storage areas could reduce fluvial flood risk in strategic zone 3. Further investigation is required into the feasibility of the provision of fluvial flood storage.

8.14.7 Strategic Zone 5

8.14.7.1 Improvements to flood defences are considered essential for strategic zone 5 to remain viable given the scale of future flooding due to climate change.

8.14.7.2 Strategic land raising in zone 5, even to reduce flood risk during wave overtopping events only, becomes difficult due to the flood depths involved. It would be extremely difficult to provide sufficient compensation storage and the impacts to flooding elsewhere are likely to be unacceptable. Further investigation into the impacts of strategic land raising would be required to fully assess the feasibility of this measure. Land raising may not be a practical solution to reducing flood risk during a breach situation due to predicted flood depths and constraints posed by surrounding development.

8.14.7.3 New improved access routes would be essential for safe access and egress to strategic zones 4 and 5 to during wave overtopping and breach events. The impacts of raising access routes to remain usable during a breach situation on flooding elsewhere would need to be carefully considered. These impacts may be able to be mitigated through careful design and consideration may need to be given to the use of stilts rather than raised road embankments.

8.14.7.4 The depths of flooding expected, even for wave overtopping only, would be too great for ‘off the shelf’ flood resistance measures to be effective. Flood resilience measures may be effective in isolated areas. Bespoke flood resistance measures would be required at the chemical works site to eliminate residual flood risk from waver overtopping and defence breach.

8.14.7.5 Flood warning and flood incident management will be key in reducing the residual risks posed to life and property by wave overtopping of the defences and particularly in defence breach situations where safe access / egress may not be feasible.

8.14.7.6 Improvements to the rhine network would be effective in reducing fluvial flood risk.

8.14.8 Strategic Zone 6

8.14.8.1 Improvements to flood defences are considered essential for strategic zone 6 to remain viable given the scale of future flooding due to climate change.

8.14.8.2 Policy measures to discourage highly vulnerable development and essential infrastructure should be considered to reduce future flood consequences.

8.14.8.3 Local scale land raising may be impractical, even during events that only involve wave overtopping due to the high flood depths involved. The feasibility of this measure would require further investigation.

8.14.8.4 New / improved access routes would need to be considered in conjunction with zones 5 and 8 and could provide flood free access routes during wave overtopping but this may become impractical during defence breach events due to the flood depths involved and access route elevations required in relation to surrounding development. Further investigation is required into the feasibility of this measure. The impacts of raising access routes to remain usable during a breach situation on flooding elsewhere would need to be carefully considered. These impacts may be able to be mitigated through careful design.

8.14.8.5 The depths of flooding expected, even for wave overtopping only, would be too great for 'off the shelf' flood resistance measures to be effective. Flood resilience measures may be effective, due to the flood depths involved the feasibility of this measure would need further investigation.

8.14.8.6 Flood warning and flood incident management will be key in reducing the residual risks posed to life and property by wave overtopping of the defences and particularly in defence breach situations where safe access / egress may not be feasible.

8.14.8.7 Improvements to the rhine network could be effective in reducing fluvial flood risk. The feasibility and effectiveness of drainage network improvements would require further investigation.

8.14.9 Strategic Zone 7

8.14.9.1 The M49, although not preventing tidal flooding, acts as a barrier and reduces the impact east of the M49. Without improvements to the defences future tidal flooding in this SZ is significant, however it is possible that it could be managed through strategic measures within the zone, rather than improvements to defences in adjacent zones.

8.14.9.2 Strategic land raising could reduce the risk of flooding, and due to the lower flood depths predicted within strategic zone 7 a reasonable level of development may be able to take place before impacts elsewhere become too great. Current development pressures may not justify strategic land raising at this stage of the LDF. Further investigation into the impacts of strategic land raising would be required should this measure be considered in the future.

8.14.9.3 New / Improved access routes would only be required on a small scale if further development were to take place within the areas at risk of flooding within zone 7.

8.14.9.4 Flood warning and flood incident management will be key in reducing the residual risks posed to life and property by wave overtopping of the defences and particularly in defence breach situations where safe access / egress may not be feasible.

8.14.9.5 Improvements to the rhine network and provision of strategic fluvial flood storage areas could reduce fluvial flood risk, however the scale of fluvial flooding is small therefore benefits would be minimal.

8.14.10 Strategic Zone 8

8.14.10.1 In order to reduce the risk of SZ8 being inundated during a 1 in 200yr tidal flood event, tidal defence sections B-D would need to be raised to 10.74mAOD.

8.14.10.2 The M49, although not preventing tidal flooding, acts as a barrier and reduces the impact east of the M49. Without improvements to the defences future tidal flooding in this SZ is significant, however it is possible that it could be managed through strategic measures within the zone, rather than improvements to defences.

8.14.10.3 Policy measures to discourage highly vulnerable development and essential infrastructure should be considered to reduce future flood consequences.

8.14.10.4 Local land raising could reduce flood risk in an overtopping event, however this measure would not be practical to reduce flood risk in a defence breach situation due to the flood depths involved. The impacts of local land raising to reduce flood risk in overtopping events only on flood risk elsewhere are likely to be small as land use within strategic zone 8 is generally low vulnerability.

8.14.10.5 New / improved access routes would need to be considered in conjunction with zones 5 and 6 and could provide flood free access routes during wave overtopping but this may become impractical and non cost beneficial during defence breach events due to the flood depths involved and access route elevations required in relation to surrounding development. The impacts of raising access routes to remain usable during wave overtopping or a breach situation on flooding elsewhere would need to be carefully considered. These impacts may be able to be mitigated through careful design.

8.14.10.6 Flood warning and flood incident management will be key in reducing the residual risks posed to life and property by wave overtopping of the defences and particularly in defence breach situations where safe access / egress may not be feasible.

8.14.10.7 Improvements to the rhine network could be effective in reducing fluvial flood risk. The feasibility and effectiveness of drainage network improvements would require further investigation.

Mapping and Figures

Figure 8.1 Avonmouth / Severnside Strategic Zones

Section 8 Appendices

A8.1 Multi Criteria Assessment

Please note this document should be referred to in conjunction with Section 8 of the SFRA.

Multi Criteria Assessment

A8.2 Impact Assessment

A8.2.1.1 A component of the assessment of the strategic mitigation measures identified is their potential to affect the level of flood risk to existing land and properties. Guidance in PPS25 states that development should seek to reduce flood risk overall, and not increase flood risk elsewhere, particularly where development is subject to application of the Exception Test.

A8.2.1.2 Following the initial assessment the measures shown in Table A8.2.1 were taken forward to more detailed review.

Table A8.2.1. Strategic Mitigation Measures Assessed

Mitigation Measure	Relevant Zones	Potential to impact 3rd parties
Defence improvements	ALL	Defence improvements will reduce tidal flood risk to the entire zone (including existing properties & infrastructure) therefore no impact assessment required.
Change of use – policy measures to discourage highly vulnerable / more vulnerable development and essential infrastructure	2, 6, 8,	No impact on existing property & infrastructure therefore no impact assessment required.
Strategic land raising to reduce flood risk	3,4, 5, 7	Potential to impact 3rd parties through reduction in floodplain storage & conveyance. **Impact assessment required.**
Localised land raising to reduce flood risk including compensation storage where possible	1, 2, 3, 8	Potential to impact 3rd parties unless carefully managed. Impacts & mitigation will be specific to each individual development. Not appropriate to complete a strategic impact assessment.
New / improved access routes	ALL	Potential to impact 3rd parties through reduction in flood flow conveyance & storage. May be beneficial to existing properties / infrastructure on the landward side of the road. May increase flood risk on the seaward side of the road. **Impact assessment required.**

Mitigation Measure	Relevant Zones	Potential to impact 3rd parties
Flood resilient design (voids / stilts) and individual property level flood resilience (flood boards / flood proofing)	1, 2, 3, 4, 5, 6	No impact on existing property & infrastructure. No impact assessment required.
Flood incident management and flood warning	ALL	No impact on existing property & infrastructure. No impact assessment required.
Improvements to rhine network	3, 4, 5, 6, 7, 8	Improvements to rhine network will include additional storage and flow capacity. It is expected that these will be designed maintain runoff in the rhine system without flooding. Detailed design will need to ensure that improvements do not increase risk to existing properties but it is not considered appropriate for a strategic impact assessment.

A8.2.1.3 As shown above the mitigation measures requiring a strategic impact assessment are:

- Strategic land raising – impact of reduction in flood storage (fluvial flooding and tidal flooding from defence overtopping); and
- New / improved access routes – impact of reduction in flood storage & flood conveyance.

A8.2.1.4 As there is considerable uncertainty regarding the location and scale of development that may come forward, a simplified impact assessment methodology was considered appropriate for the SFRA which follows the approach described in PPS25 Practice Guide examples[8]. The approach recommends that in defended areas the cumulative impact of land raising (and therefore loss of flood storage) is assessed for each flood cell, to provide an indication of the increase in flood depths that may occur across the remainder of the cell as a result of the reduction in storage.

[8] PPS25 Practice Guide, CLG, December 2009 – Box: Example 1, page 66.

A8.2.1.5 For the SFRA, the assessment has been completed for each of the strategic zones. The zones were defined on the basis of potential development (scale & type), flooding characteristics and key hydraulic features (e.g. embankments) which define flood cells. Due to the scale of flooding for tidal events in Avonmouth / Severnside there is some interaction between zones, however they are considered sufficiently well defined for the purposes of this assessment. The full effects of the measures identified and interaction between the zones should be assessed in more detailed studies for example through hydraulic modelling.

A8.2.1.6 New raised access routes on embankments can lead to a loss of flood storage in themselves but also act as a barrier, preventing floodwaters extending beyond the road. The impact assessment has considered this by assuming that the floodplain on the landward side of the embankment is not available for flood storage. The adverse effects of the embankments can be mitigated by placing roads on viaducts although in many cases this may be prohibitively expensive. In reality it is likely that flood culverts would be provided to allow for transfer of floodwater under the embankment. However unless these are large & provided at frequent intervals, the volume passing through the embankment may be substantially less than the existing situation, particularly for tidal flooding. Therefore assuming that these culverts are not provided is considered an appropriately conservative approach for the SFRA. The impacts of raised access routes would be most apparent for tidal flooding as there may be scope to address any impact on fluvial flooding through changes to alignment.

A8.2.1.7 The impact assessment has considered the following scenarios:

- Impact on tidal flood risk from overtopping of defences assuming that defences are not improved in line with the recommendations of the defence assessment. Whilst unlikely, this scenario represents the scale of flooding that could occur either if the defences are not improved or there is a substantial failure of the defences. The impacts have been considered for the future 200 year tidal event. The impacts for a wave overtopping only scenario may be significantly less than are shown here.

- Impact on fluvial flood risk from the rhine network. This has been completed for land raising where fluvial flooding is an important source of flooding within the zone, and where, based on the information available, it is expected that development may take place within fluvial flood risk areas. The impacts have been assessed for the future 100 year fluvial event.

A8.2.1.8 Table A8.2.2 shows the potential development and anticipated flood depths in each of the zones which has been used as the basis for the impact assessment. Table A8.2.3. shows the impact of land raising on flood depths across the remainder of the zone for four development scenarios (25%, 50%, 75% and 100% of potential development takes place).

Table A8.2.2. Information used for impact assessment (where strategic land raising has been identified)

Strategic Zone	**Zone Area (km^2)**	**Potential Development**		**Average Flood Depth**		
				Tidal	**Fluvial**	
			Area (ha)	**200 yr CC**	**100 yr CC**	**% of zone subject to fluvial flooding**
Zone 4 - Crook's Marsh	5.6	Waste Sites	14	1.5	0.25	60%
		Avonmouth industrial area	60			
		Build out of ICI	20			
		Total	**94**			
Zone 5 - Dyer's Common	5.8	ICI consent	350	1.25	0.25	40%
		Waste sites	13			
		Total	**363**			
Zone 7 - Marsh Common (west of B4055)	2.5	Build out of ICI	100	0.6	0.3	30%
		Total	**100**			

Table A8.2.3 Impact of strategic scale land raising

Strategic Zone		**Impact of land raising through reduction in flood storage**															
		25%				**50%**				**75%**				**100%**			
		Development Area (ha)	Loss of flood storage (m^3)	Increase in flood depth (m)	Increase in flood depth (%)	Development Area (ha)	Loss of flood storage (m^3)	Increase in flood depth (m)	Increase in flood depth (%)	Development Area (ha)	Loss of flood storage (m^3)	Increase in flood depth (m)	Increase in flood depth (%)	Development Area (ha)	Loss of flood storage (m^3)	Increase in flood depth (m)	Increase in flood depth (%)
Zone 3 - Avonmouth	Tidal	84.8	1271250	0.21	13.8	169.5	2542500	0.48	32.0	254.3	3813750	0.86	57.0	339.0	5085000	1.41	93.9
	Fluvial	84.8	63562.5	0.04	13.8	169.5	127125	0.10	32.0	254.3	190687.5	0.17	57.0	339.0	254250	0.28	93.9
Zone 4 - Crook's Marsh	Tidal	23.5	352500	0.07	4.4	47	705000	0.14	9.2	70.5	1057500	0.22	14.4	94	1410000	0.30	20.2
	Fluvial	23.5	35250	0.01	4.4	47	70500	0.02	9.2	70.5	105750	0.04	14.4	94	141000	0.05	20.2
Zone 5 - Dyer's Common	Tidal	90.8	1134375	0.23	18.5	181.5	2268750	0.57	45.5	272.3	3403125	1.11	88.5	363.0	4537500	2.09	167.3
	Fluvial	90.8	90750	0.05	18.5	181.5	181500	0.11	45.5	272.3	272250	0.22	88.5	363.0	363000	0.42	167.3
Zone 7 - Marsh Common (west of B4055)	Tidal	25.0	150000	0.07	11.1	50.0	300000	0.15	25.0	75.0	450000	0.26	42.9	100.0	600000	0.40	66.7
	Fluvial	25.0	18750	0.03	11.1	50.0	37500	0.06	25.0	75.0	56250	0.11	42.9	100.0	75000	0.17	66.7

* Fluvial flooding only affects a part of each zone, therefore the impact calculations have assumed that an equivalent proportion of development is located in the fluvial risk area, and that the impact is felt only in the current risk area (e.g. if 40% of the zone is subject to fluvial flooding, the development area (to be raised) and the zone area used in the calculation are both 40% of the actual value).

A8.2.1.9 The findings of the assessment shown in Table A8.2.3 indicate that:

Fluvial flooding:

A8.2.1.10 The impact of land raising on fluvial flooding elsewhere in the zone is less significant in strategic zone 4. With the level of development assumed, the maximum average increase in flood depth is approximately 50mm, which may be able to be addressed on a site specific basis, through rhine improvements, design and localised compensatory storage.

A8.2.1.11 If the majority of development is realised in zones 3 (Avonmouth), 5 (Dyer's Common) and 7 (Marsh Common – west of B4055) land raising could impact on fluvial flood risk elsewhere in the zone. If land raising is not adequately mitigated, the average increase in flood depth is shown to exceed 100mm for the 50% development scenario in zone 5 and 75% development scenario for zones 3 and 7. Improvements to the rhine network may assist in the mitigation of this effect, as would compensatory storage in those locations where this is possible. Although not preferable it may be necessary to consider voids / stilts as an alternative means of raising development levels without reducing flood storage. This may pose a challenge to developers to meet safety requirements.

Tidal flooding:

A8.2.1.12 Within zone 4 (Crooks Marsh) it may be possible to realise approximately 50% of the potential development (47ha) through land raising before the loss of flood storage has a significant impact on land within the remainder of the zone on a strategic scale (there will be localised impacts). Existing development is limited, but does include a power station therefore the impacts could be notable. Although not preferable it may be necessary to consider voids / stilts as an alternative means of raising development levels without reducing flood storage. This may pose a challenge to developers to meet safety requirements.

A8.2.1.13 Within zone 3 (Avonmouth) and 5 (Dyer's Common) the scale of potential development is such that it could have a significant impact on flood depths elsewhere in the zone. There is a reasonable level of development already in the zones therefore although not preferable it may be necessary to consider voids / stilts as an alternative means of raising development levels without reducing flood storage or the scale of development may be limited. This may pose a challenge to developers to meet safety requirements.

A8.2.1.14 Within zone 7 (Marsh Common) the majority of potential development may be able to be realised before land raising has a significant impact on flood depths in the remainder of the zone (on a zone-wide scale). The average increase in flood depth is shown to exceed 100mm for 75% development / 75ha where alternative measures or restrictions on development are expected to be necessary.

A8.2.1.15 It should be noted that the assessment has considered the strategic or wide-scale impacts of land raising on flood risk elsewhere. In all cases measures may have an impact on a local scale that would need to be assessed and addressed through site specific assessments.

A8.2.1.16 Table A8.2.4 shows the potential impact of raised access routes on flood depths if these were to prevent tidal flooding to large areas of the strategic zones. In all cases the potential impact on existing property and infrastructure could be significant, and at a level which is unlikely to be acceptable. The possible impacts of new or improved transport infrastructure on 3rd parties will need to be carefully considered and if possible mitigated through design. This could perhaps be achieved through the provision of flood culverts or viaduct structures. Where engineering or cost constraints are prohibitive, it may not be possible to provide a safe means of egress during a large tidal flood event. The effectiveness of flood warning and appropriate emergency plans, including refuge areas, will therefore be crucial.

Table A8.2.4. Impact assessment for provision of raised access routes

Strategic Zone		Details of potential strategic access route	Area removed from flood storage (km^2)	Average flood depth where storage is lost	Loss of flood storage (m^3)	Increase in flood depth (m)	Average flood depth in zone where impact is felt (m)	% increase in flood depth
Zone 1 – Bristol Port Company		Strategic access route would likely connect with M5 to improve access to north and south of zone. It is less likely that the road would lead to a significant reduction of storage in Z1, however may prevent tidal floodwaters passing through to zones 2 & 3. The impact assessment assumes that all tidal flood storage in zones 2 & 3 is lost and flooding is contained in Zone 1	8.2	1.25	10250000	3.80	1.25	304
Zone 2 - Avonmouth village		Zone 2 is on the landward side of likely strategic access routes therefore provision of new or raised access routes would possibly lead to a reduction in tidal flooding in this zone. The impact on zone 1 is assessed above.	-	-	-	-	-	-
Zone 3 - Avonmouth		New / improved strategic access routes would likely be located on the western border of the zone or potentially connect the M5 in the south-east with the A403 in the north-west corner. A raised access route along the western boundary may lead to an increase in flood depths in zone 1 (assessed above). A raised access route crossing the zone may lead to an increase in flood depths on the seaward side of the zone. The assessment assumes loss of storage in the eastern half of the zone which is contained in the western half.	3.5	1.5	5250000	1.5	1.5	100
Zone 4 - Crook's Marsh		A new / improved strategic access route could link with existing raised infrastructure (M49, A403, railway). The assessment assumed that a raised access route is provided across the zone, preventing tidal flooding on the landward side and that all tidal flooding is contained in the zone.	2.8	0.8	2240000	0.8	1	80
Zone 5 - Dyer's Common		A new / improved strategic access route could link with existing raised infrastructure (M49, A403). The assessment assumed that a raised access route is provided across the zone, preventing tidal flooding on the landward side and that all tidal flooding is contained in the zone.	2.9	1	2900000	1	1	100
Zone 6 - Severn Beach		A strategic access route may involve improvements to the existing B4064 which crosses the zone. The assessment assumed that this road is raised, preventing tidal flooding on the landward side.	1.25	1.2	1500000	2	1	200
Zone 7 - Marsh Common		An improved access route could be provided to improve connectivity between the M49 and B4055. The assessment assumed a new route is provided close to Dyers Common, preventing tidal flooding on the landward side and assumes floodwaters are contained in the zone betwen the M49 and B4055.	1.3	0.5	650000	0.59	0.5	118
Zone 8 - North of railway	N of M4	A strategic access route may involve improvements to the existing A403 which crosses the zone. The assessment assumed that this road is raised, preventing tidal flooding on the landward side.	5.8	1.5	8700000	3.14	2.5	126
	S of M4	A strategic access route may follow the route of existing local roads between Awkley and Pilning station. The assessment assumed that this road is raised, preventing tidal flooding on the landward side.	3.6	0.5	1800000	0.43	0.35	122

Revision Status and Schedule of Changes

Section Revision Status

This is a new section for the November 2010 relase of the SFRA. It replaces the previous Section 8 – Flood Risk Matrix, which is now included in the Summary Report.

Schedule of Changes – Latest release only

Section 9. Management of the SFRA

9.1.1.1 It is recommended that an organisation (or person within) is nominated to be the model 'gate keeper' who steers the model development – i.e. a Model Data Manager. The Environment Agency plays an integral role in an effective Continuous Model Improvement Protocol since that organisation generally has most involvement and knowledge of local modelling commissions for various purposes, which include Flood Risk Mapping, Catchment Flood Management Plans, Flood Management Strategies, Defence Feasibility, Improvements, and Flood Risk Assessments.

9.1.1.2 It is recommended that the Model Data Manager makes regular contact (say every three months) with various EA Department Team Leaders to ensure that he is aware of any new modelling. Once new modelling commissions are identified, then a Quality Assurance procedure will need to be undertaken to ensure that the data sets of the commission are suitable to be merged into the SFRA model. It is envisaged that the largest amount of data potentially under consideration will come from Flood Risk Assessments. A suitably qualified organisation / person will need to perform the Quality Assurance exercise.

9.1.1.3 The actual protocols and measures to manage, maintain and operate the SFRA and models will be co-ordinated by LSDB. All systems should be developed in conjunction with the "User Group" so that systems match user needs and are compatible with management protocols of the Drainage Board. Careful consideration will need to be given to issues of use of data by third parties, licences, copyright assignments and cost of upkeep. The "User Group" will be responsible for monitoring, managing and maintaining the SFRA documentation in accordance with arising data needs and policy changes.

9.1.1.4 The SFRA is a 'live' document. As new data becomes available, particularly improved model data through the process described above, the users of the SFRA should identify whether an update to the information contained in the SFRA is required. Further guidance is provided in the Summary Report.

Section 10. References

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