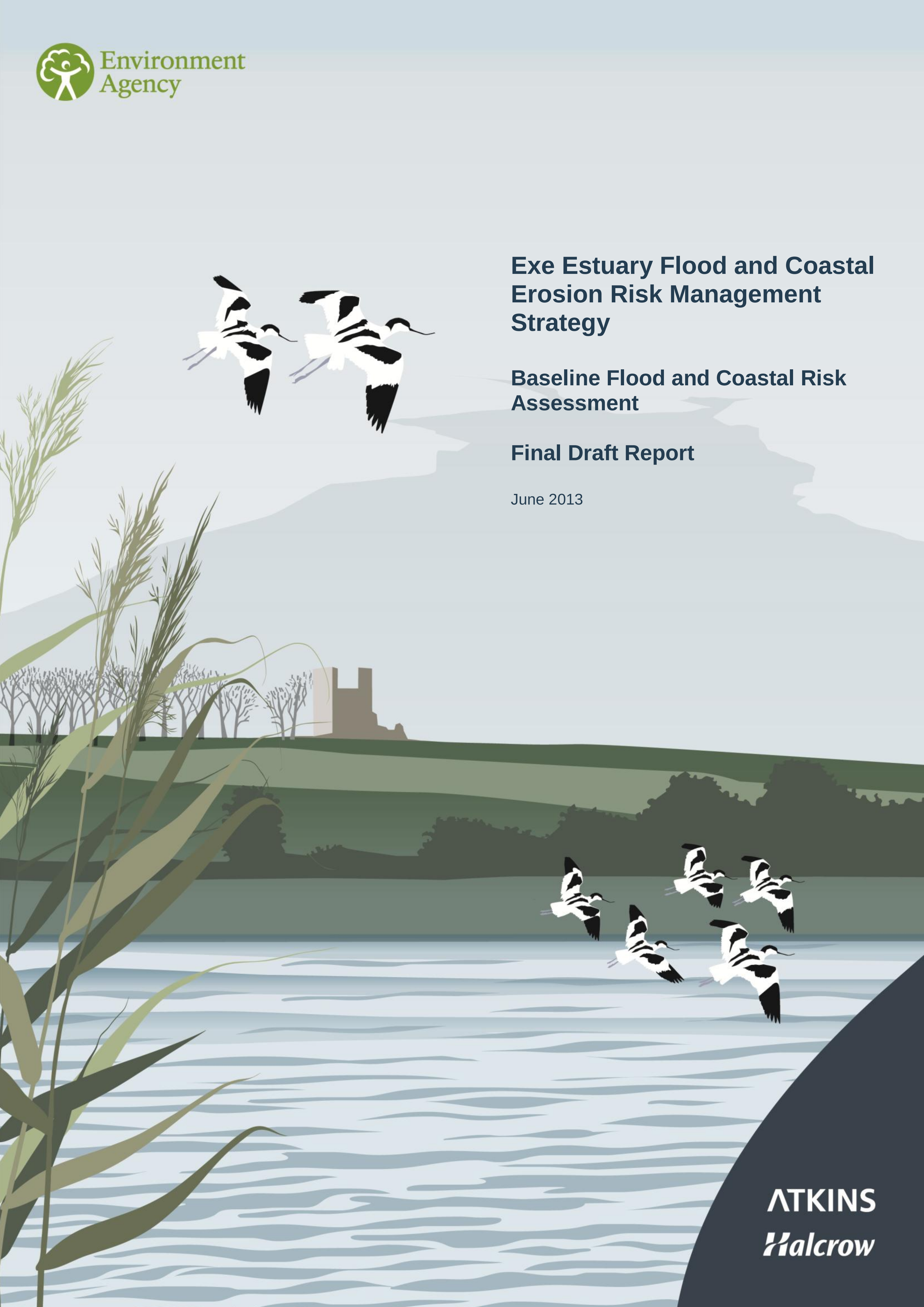
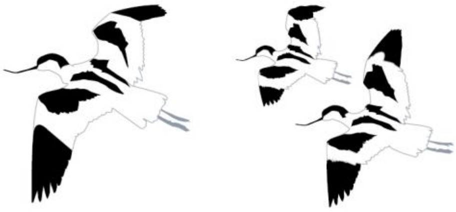


Exe Estuary Flood and Coastal Erosion Risk Management Strategy

Baseline Flood and Coastal Risk Assessment

Final Draft Report

June 2013



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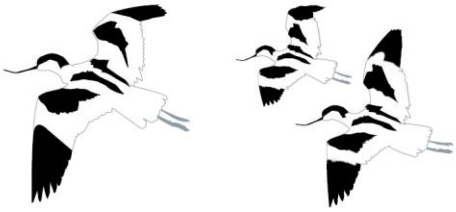

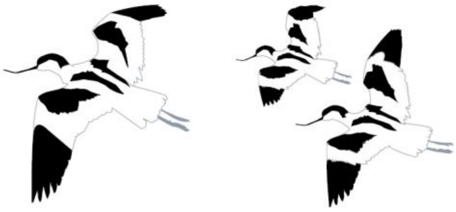

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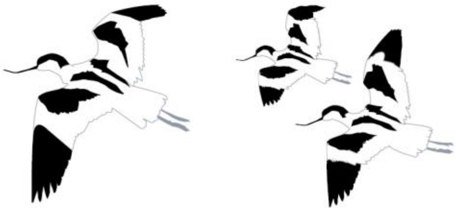

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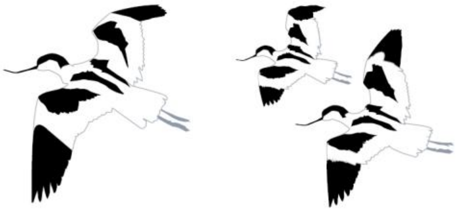

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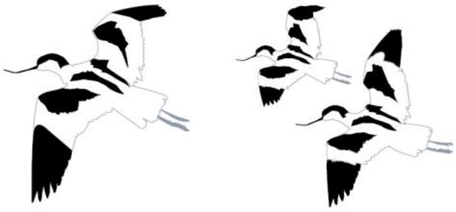


Executive Summary

In January 2010 the Environment Agency commissioned a strategic study for the Exe Estuary to examine the current and future flood and coastal risks as well as potential loss of habitat, and select strategic options to manage these future risks. This report defines the current and future flood risks in the Exe Estuary, focussing on both the Do Nothing and Do Minimum scenarios. The report will form a technical appendix to the business case for submission to the Environment Agency's Large Projects Review Group (LPRG).

Flood and coastal risk is predicted to increase significantly over the 100 year timescale due to both structural degradation of assets and the impacts of climate change. With no intervention (the Do Nothing scenario), the majority of Flood and Coastal Risk Management assets around the Exe Estuary are predicted to have lost their structural integrity by 2060. This would result in Present Value damages of £655 Million. If FCRM assets are maintained (the Do Minimum scenario), the majority of FCRM assets would still lose much of their FCRM function by 2110 due to sea level rise, with the result that Present Value damages would be £367 Million. For both scenarios, the majority of the damages are related to the areas of Exmouth and Starcross.

Two key issues for the strategy are how the Dawlish Warren sand spit at the estuary mouth will evolve into the future, and how the railways on the east and west banks of the estuary will be managed. Both of these issues affect flood risk and related economic damages within the estuary. Our findings are that the Present Value benefit of Dawlish Warren being maintained is most likely around £92 Million, with the majority of this economic benefit coming from the area of Starcross. The Present Value benefit of maintaining the railway embankments is less clear, and is strongly dependent on continued damages incurred due to railway repair and compensation payments.

The key conclusion and recommendation is that the predicted consequences of the current and future flood risk would result in large scale change of the man-made and natural environment within the Exe Estuary and its floodplains. This provides a sound case for further progression to developing and assessing FCRM options to manage flood and coastal risk, and habitats, over the next 100 years.

1. Introduction

1.1 Brief

In January 2010 the Atkins-Halcrow Alliance (AHA) was commissioned by the Environment Agency to undertake the Exe Estuary Flood and Coastal Erosion Risk Management (FCRM) Strategy and Exeter Flood Risk Management (FRM) PAR. AHA's proposed approach to these studies is shown diagrammatically in Figure 1.1. This consists of five main stages:

1. Initial review of available information, identification of gaps, and confirmation or otherwise of the originally proposed project tasks.
2. Definition of the baseline (Do Nothing and Do Minimum) flood risks and consequences, including technical, environmental and socio-economic assessments. This report covers this stage.
3. Development, assessment and selection of strategic options.
4. Public facing scheme/strategy documents.
5. Project/Strategic Appraisal Report to be submitted to Large Projects Review Group (LPRG).

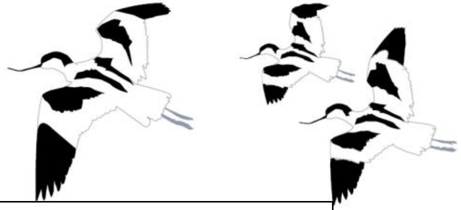
1.2 Purpose

This report describes the work carried out to develop the baseline scenario for the Exe Estuary FCRM Strategy, and will form a technical appendix to the business case for submission to the Environment Agency's Large Projects Review Group (LPRG). The purpose of this is to set out the baseline against which all other Strategic Options can be assessed. This report describes the baseline scenario development with the following structure:

- Section 1: setting of the purpose and context of this work stage.
- Section 2: description of the in-estuary physical processes, including impacts of climate change.
- Section 3: description of the performance of the existing FCRM assets and the consequent inundation.
- Section 4: description of the socio-economic damages associated with the baseline scenario.
- Section 5: conclusions and recommendations drawn from the preceding work, particularly in relation to strategic concerns.

1.3 FCERM Appraisal Context

The recent Flood and Coastal Erosion Risk Management Appraisal Guidance (FCERM-AG) (Defra, 2010) sets out the process of appraising projects, consisting of five stages with further sub-stages. The Devon and Cornwall Area Appraisal Package will produce reports to document the FCERM-AG stages findings, as shown in Table 1.1. This report contributes to Stage 3 (Type of Project and Baseline).



FCERM-AG Stages	Exeter PAR Reporting	Exe Estuary FCRM Strategy Reporting
Stage 1: Understand and define the project 1A. Identify problem and key issues 1B. Establish appraisal period 1C. Set the boundaries	Project Plan and Proposal Data Review and Gaps Analysis	
Stage 2: Set the objectives 2A. Primary objectives 2B: Secondary objectives	User Requirement Survey EIA/SEA Scoping Report	
Stage 3: Type of project and baseline 3A. Identify type of project required 3B. Define the baseline	Baseline Flood Consequence Assessment	Baseline Flood and Coastal Risk Assessment Habitat Delivery Plan
Stage 4: Identify, develop and short-list options 4A. Identify a wide range of options 4B. Develop a short list of options	Options Assessment Report Environmental Impact Assessment Public Scheme Brochure	Options Assessment Report Strategic Environmental Assessment Public Strategy Brochure
Stage 5: Describe, quantify and value costs and benefits 5A. Describe, quantify and value costs 5B. Describe, quantify and value benefits 5C. Discounting		
Stage 6: Compare and select the preferred option		
Stage 7: Complete appraisal report	Project Appraisal Report	Strategic Appraisal Report
Stage 8: Feeding back from project appraisal	Out of scope	

Table 1.1 – Linkage between FCERM-AG stages and reporting.

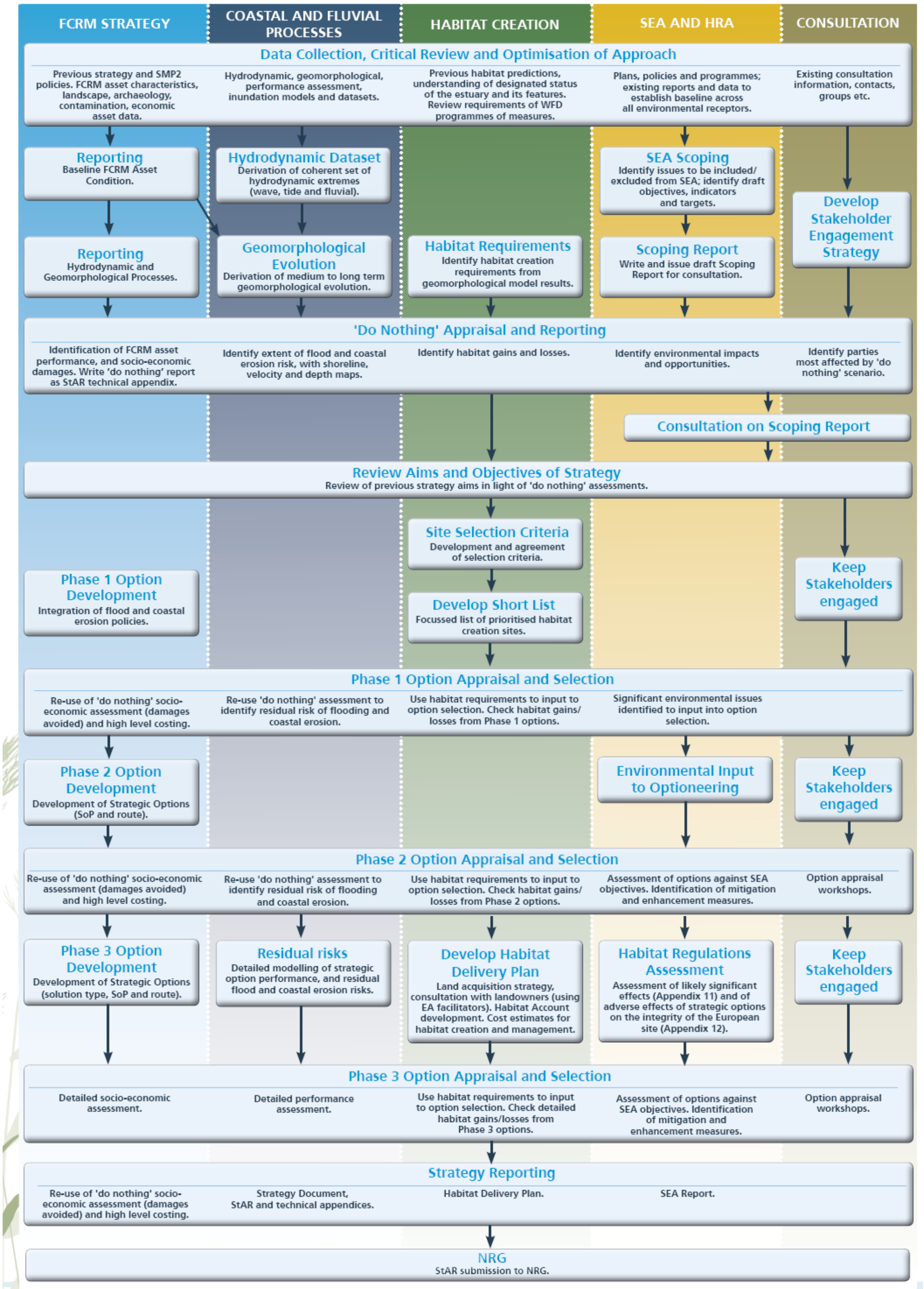


Figure 1.1 – Generic Approach.

1.4 Description of Study Area

1.4.1 Study Boundaries

The initial study area was based on the more extensive of either the 10m contour or a 1km buffer from the shoreline and river bank. The study area for the Exe Estuary FCRM Strategy is given in Figure 1.2. The coastal limits of the study area are Straight Point to Holcombe, and the fluvial limits are St. James Weir on the River Exe and the weir near Clyst St. Mary on the River Clyst.

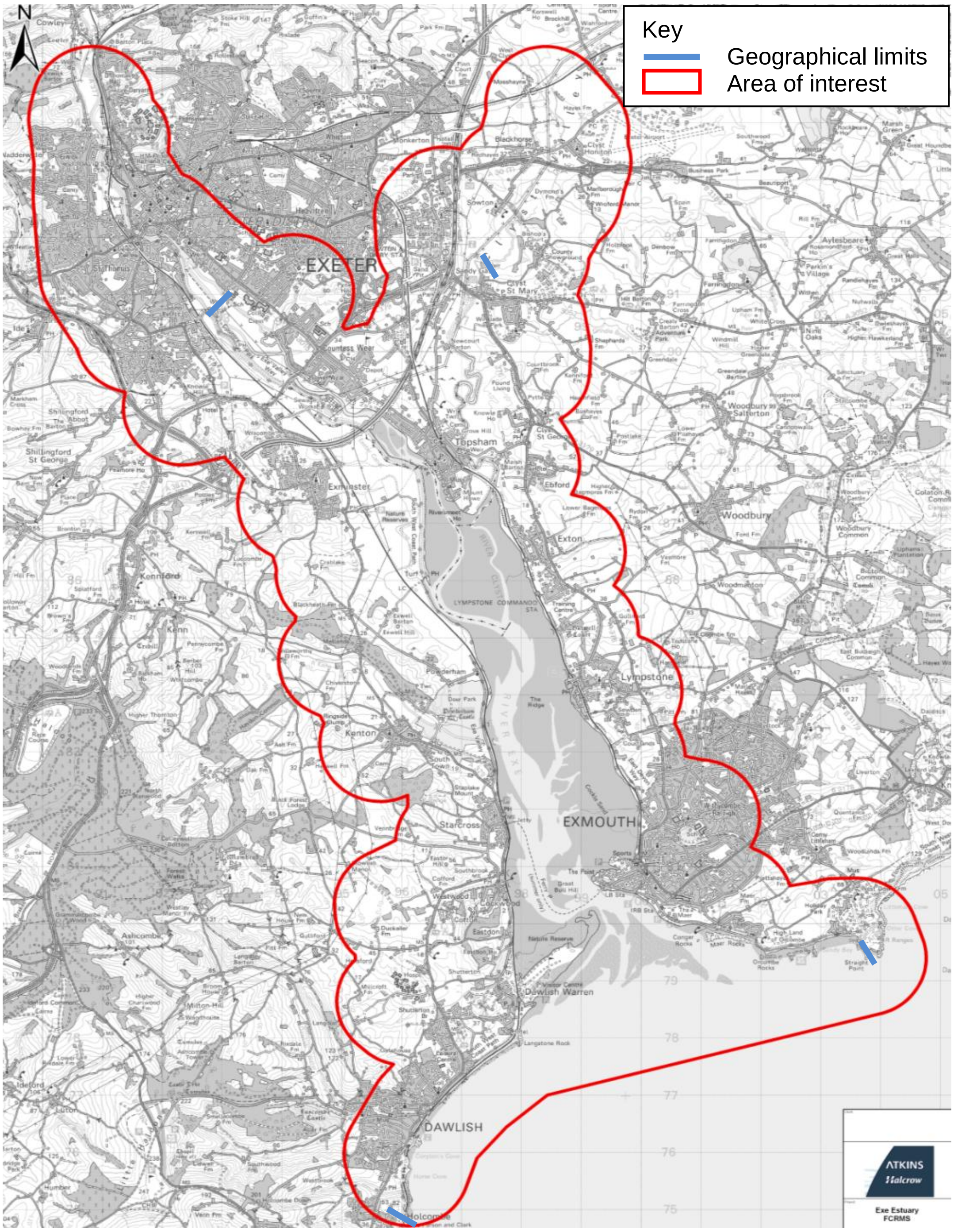


Figure 1.2 – Initial Study Area.

1.4.2 Sandy Bay, The Maer and Exmouth

Sandy Bay to Exmouth comprises a cliffed area to the east with the reclaimed spit of Exmouth having been heavily developed over the last two centuries. Tidal currents and the wave climate generated in the English Channel are significant along this section of coast. Land use is predominantly urban. Strategic infrastructure includes 4 electricity sub-stations, 2 care homes and a school.

Figure 1.3 – Exmouth and Sandy Bay.

1.4.3 Courtlands to Exton

The east bank of the Exe Estuary is an area of historically reclaimed land, formed when the railway was constructed. Tidal levels are significant along this section of shoreline, with the local wind wave climate being less important. Land use is a mixture of agricultural land, villages and dispersed communities. Strategic infrastructure includes the branch line railway.

Figure 1.4 – Lympstone and Exton.

1.4.4 Lower Clyst

The Lower Clyst is an area of historically reclaimed land, formed for agricultural purposes. Tidal levels and fluvial flows are significant along this section of shoreline. Land use is a mixture of agricultural land, villages and dispersed communities. Infrastructure includes the C527 road, and bridges across the Clyst, which are significant local transport links.

Figure 1.5 – Mouth of the River Clyst and Clyst St. Mary.

1.4.5 Topsham and Countess Wear

The head of the Exe estuary and the River Exe are areas where tidal levels and fluvial flows are significant, with the local wind wave climate being less important. Land use is predominantly urban. Strategic infrastructure includes a sewage treatment works, 3 electricity sub-stations, the M5 motorway, and the A379 road.

Figure 1.6 – Topsham, the M5 and Countess Wear.

1.4.6 Exminster to Cockwood

The west bank of the Exe Estuary is an area of historically reclaimed land, formed when the railway and canal were constructed. Tidal levels are significant along this section of shoreline, with the local wind wave climate being less important. Land use is a mixture of agricultural land, villages and dispersed communities. Strategic infrastructure includes a the mainline railway, A379 road, 7 electricity sub-stations and a school.

Figure 1.7 – Turf Lock and Starcross.

1.4.7 Dawlish Warren to Holcombe

Dawlish Warren is a partially inactive sand spit across the mouth of the Exe Estuary. West to Holcombe is a cliffed area. Tidal currents and the wave climate generated in the English Channel are significant along this section of coast. Land use is predominantly urban. Strategic infrastructure includes the mainline railway, the A379 road and 2 electricity sub-stations.

Figure 1.8 – Dawlish Warren and Dawlish beach.

1.5 Switching Point Analysis

1.5.1 Baseline Scenarios

The FCERM-AG (Defra, 2010) notes that switching point analysis should be undertaken where key issues could change preferred options for FCRM. The FCERM-AG (Defra, 2010) notes that a Do Nothing scenario (equivalent to the SMP2 No Active Intervention policy) needs to be defined. The Do Nothing scenario assumes that assets with a FCRM function will not be maintained into the future, and consequently would deteriorate and lose their FCRM function over time. However, where there are legal requirements in place to maintain assets, the FCERM-AG notes that fulfilment of these legal requirements becomes part of the Do Nothing scenario. In addition to the Do Nothing scenario, the Do Minimum scenario (equivalent to the CFMP Maintain FRM scenario, and the least active form of SMP2 Hold The Line policy) is included in this report. The Do Minimum scenario assumes that assets with a FCRM function will have works undertaken to maintain the structural integrity of the FCRM assets over time, consisting of repair of damage and breach after storm events, and refurbishment to extend the design life to 2110. The impact of predicted climate change will reduce the Standard of Protection (SoP) in the future.

The Do Nothing and Do Minimum scenarios represent progressively diverging situations where FCRM assets are allowed to deteriorate or are maintained. This divergence starts occurring by 2030 when weaker assets would have failed, and is fully realised by 2060 when all standard FCRM assets would have failed under the Do Nothing scenario. However, for maintained FCRM assets (the Do Minimum scenario), by 2110 the magnitude of climate change would likely still result in loss of their FCRM function (i.e. they would experience breach or allow flooding on at least an annual basis). This would result in the Do Nothing and Do Minimum scenarios converging to the same situation.

A complicating factor is that there are two key issues within the Exe Estuary that could result in further splitting of the baseline scenarios. The first is the future evolution of Dawlish Warren. If a significant amount of damage is allowed to occur at Dawlish Warren, flood risk within the estuary could be increased due to increased wave and tide climate. This issue is less important in the Do Nothing scenario, as the majority of FCRM assets would have already failed by the time Dawlish Warren was seriously damaged. This means that there would be limited FCRM or socio-economic impact over and above the wider Do Nothing assumptions. However, it is of greater importance to the Do Minimum scenario, as the maintained FCRM assets would experience increased extremes.

The second is the future management of the railway embankments. If the railway embankments were allowed to deteriorate over time, they would likely have failed by 2060. However, if they were maintained for non-FCRM reasons, this would reduce flood risk within the estuary. This issue is less important for the Do Minimum scenario, as this would assume the railway embankments are maintained anyway. However, it is of greater importance to the Do Nothing scenario, as the maintained railway embankments would reduce flood risk to some areas. This issue is critical in the Exe Estuary, as around 30% of the shoreline within the study area consists of railway embankments that currently provide a FCRM function, although they would not have been specifically designed or constructed for that purpose. Recent guidance (CIRIA, 2010) indicates that railway assets should be maintained so that they remain fully operational during periods of normal and abnormal (4-2% AEP events) weather, and they do not fail catastrophically during periods of extreme weather (0.5-0.2% AEP events for coastal assets). The Do Nothing scenario looks at the situation with the railways failing when their structural integrity would be lost, and the situation with the railways maintained over the 100 year timescale.

These switching point events are shown conceptually as an event tree in Figure 1.9, from 2010 to 2110. Whilst the general timing of these decisions is shown in Figure 1.9, this is purely for illustrative purposes; it is the purpose of the analyses described within this report to determine the likelihood, timing and magnitude of these switching points.

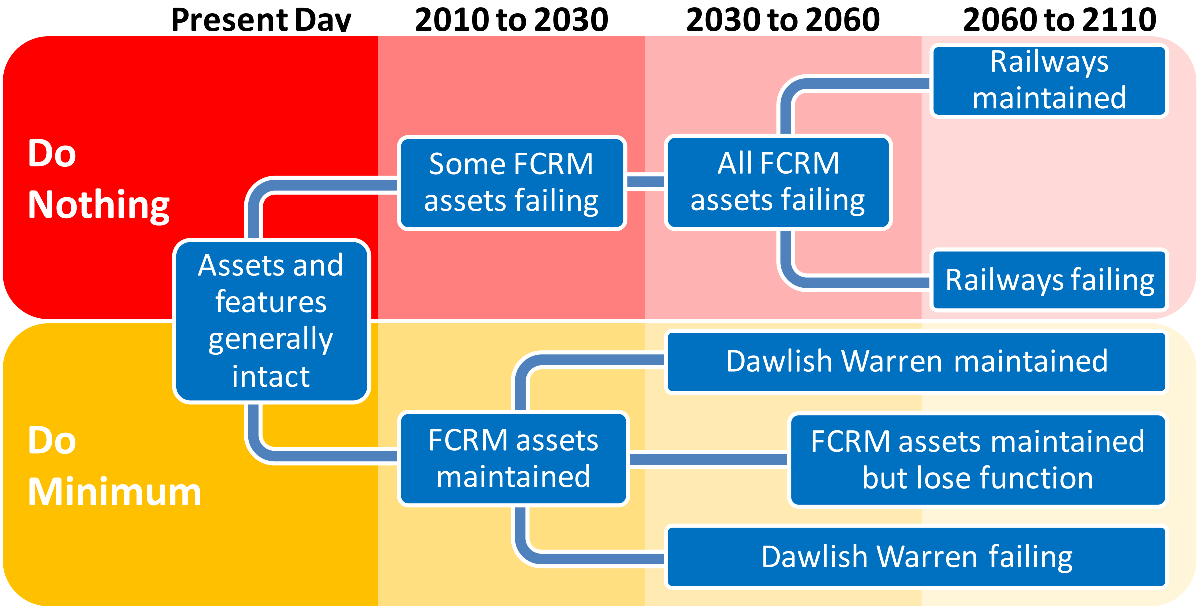


Figure 1.9 – Swiching point event tree with climate change context.

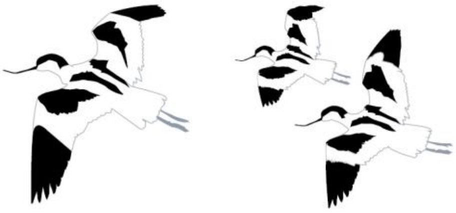
1.5.2 Climate Change

Projections

A large body of evidence now supports the fact that climate change is occurring, and will continue to occur in the future. Global predictions of the effect of climate change on sea levels are published by the IPCC (the latest of which is AR4, 2007), with average sea level rise over the next 100 years varying between 0.18m and 0.59m dependent on emission scenarios. These predictions are further developed specifically for the UK by the Met Office, with results published by the UK Climate Impact Programme (UKCP09). Whilst climate models have improved considerably over the last two decades, there is still a high level of uncertainty on the actual level of sea level rise that will occur over the next 100 years.

In response to the developing view from climate change science, formal guidance for appraisal purposes has been published at regular intervals (Defra, 2000; Defra, 2006; and now Environment Agency, 2011). The Environment Agency (2011) guidance refers to UKCP09 predictions for climate change, which are probabilistic rather than deterministic, geographically more detailed that Defra (2006), and relate to a range of emissions scenarios.

Table 1.2 summarises the relative sea level rise (RSLR) and river flood flow predictions from Environment Agency (2011). The RSLR scenarios include a further ‘upper end plus surge increase’, which accounts for the potential for a significant increase in surge, specifically in relation to EWLs. Potential increases to wave climate are not clearly defined in Environment Agency (2011), due to large uncertainties within the UKCP09 findings. Figure 1.10**Error! Reference source not found.** shows the relative sea level rise for the range of emissions scenarios; it is noted that the Defra (2006) guidance is similar to the Environment Agency (2011) upper end scenario.



Parameter	UKCP09 emissions scenario	2030	2060	2110
Relative sea level rise (mm) since 2010	Low 50%ile	+0.065	+0.178	+0.410
	Medium 95%ile	+0.114	+0.317	+0.750
	Upper end	+0.095	+0.345	+1.015
	Upper end + surge increase	+0.295	+0.695	+1.715
Change to river flood flow (%)	Low 50%ile	-5	0	+5
	Medium 95%ile	+15	+20	+30
	Upper end	+30	+40	+75

Table 1.2 – Climate change guidance (Environment Agency, 2011).

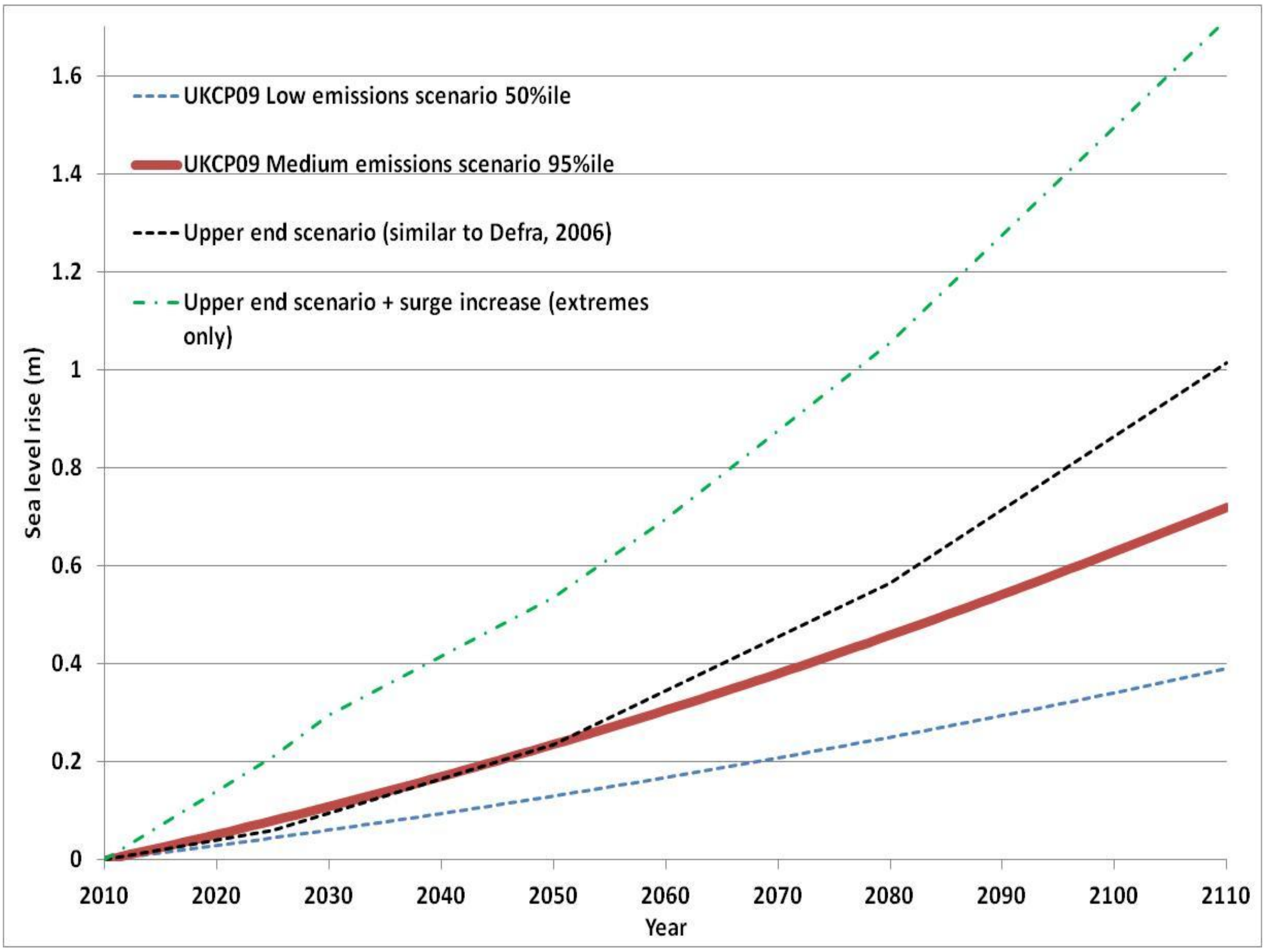
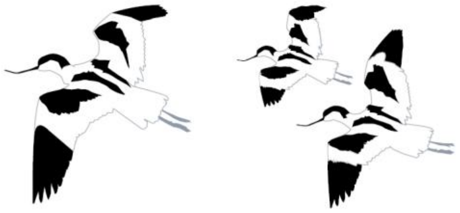


Figure 1.10 – Variation in sea level rise (Environment Agency, 2011).



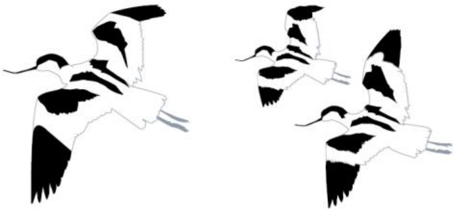
Application

The Environment Agency (2011) guidance defines that the medium 95%ile emissions scenario is the core scenario for FCRM planning. In addition to this it gives a broad methodology on how to apply the other emissions scenarios to understand the sensitivity or robustness of flood and coastal risk to variable emissions scenarios.

For the baseline assessment stage, the guidance identifies that tasks include:

- Evaluating the potential range of change, determined by the lower and upper (or upper plus surge increase) scenarios.
- Developing test scenarios to enable exploration of test scenario sensitivities. The test scenarios are Do Nothing and Do Minimum in the context of this work.
- Undertaking broad risk assessment, to understand the change in risk over time.
- Identifying areas sensitive to change.

These tasks were undertaken as part of the baseline stage, and are documented in this report. Within each main section, findings are given for the medium emissions scenario, with further information on the wide climate change scenario sensitivity given in the switching point analysis sub-sections.



1.6 Flood and Coastal Risk Management Units

1.6.1 Policy and FCRM Units

FCRM units were developed based on consideration of SMP2 and CFMP policy units, flood cells and shoreline processes. The relationship between policy and FCRM units is given in Table 1.3, with the SMP2 policies and FCRM units being shown graphically in Figure 1.11.

Location	SMP2 policy unit	CFMP policy unit	FCRM unit
Sandy Bay	6a42	PU3	FCRMU01
The Maer	6a43-44		FCRMU02
Exmouth	6a45-6b01	PU5	FCRMU03
Courtlands	6b02		FCRMU04
Lympstone	6b03		FCRMU05
Lympstone Commando	6b04-5		FCRMU06
Exton	6b07		FCRMU07
East bank of the Lower Clyst	6b08		FCRMU08
Clyst St. Mary	Not covered	PU3	FCRMU09
Sowton	Not covered		FCRMU10
West bank of the Lower Clyst	6b08	PU5	FCRMU11
Topsham	6b09		FCRMU12
Countess Wear	6b10		FCRMU13
Exminster Marshes and Powderham Banks	6b11-14		FCRM14
Kenn Valley	6b15		FCRM15
Starcross	6b16-17		FCRM16
Dawlish Warren	6b18-21	Not covered	FCRM17
Dawlish to Holcombe	6b22-23	PU5	FCRM18

Table 1.3 – Geographic relationship between policy and FCRM units.

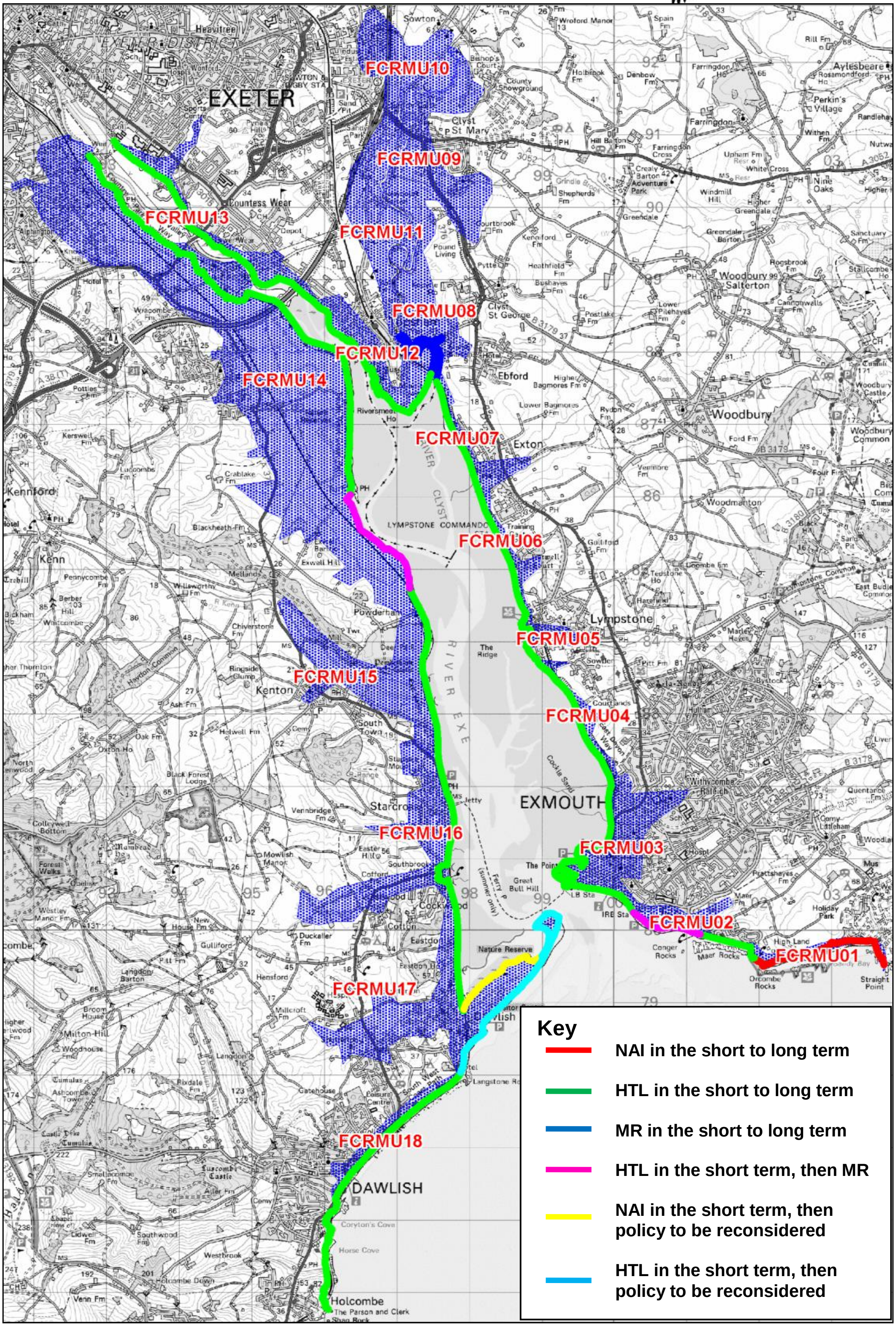
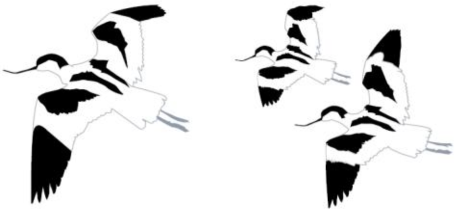


Figure 1.11 – SMP Policy and FCRM Units.



2. Physical Processes

2.1 Introduction and Methodology

The Exe Estuary is a highly dynamic environment. Whilst tidal processes dominate throughout the study area, the coastline is open to wind and swell waves, with the inner estuary experiencing internally generated wind waves and fluvial influences from the Rivers Exe and Clyst.

The following sections describe the work carried out to:

- Define the historic geomorphological evolution of the estuary.
- Extrapolate the future geomorphological evolution of the estuary.
- Assess the correlation between the extreme wave, tidal and fluvial climate.
- Define the extreme wave climate throughout the study area.
- Define the fluvial and tidal Extreme Water Levels (EWLs) throughout the study area.
- Assess the impact of switching points on the above analyses.

2.2 Summary of Expert Geomorphological Assessment

2.2.1 Methodology

Expert Geomorphological Assessment (EGA) brings together a number of techniques to come to a coherent view of historic and future changes. Within the EEFCRMS the following techniques have been applied:

- Initial Conceptual Model.
- Natural Events Review.
- Human Impacts Review.
- Historic spatial analysis (Ordnance Survey mapping and vertical aerial photography).
- Historic volumetric analysis (UKHO bathymetric charts, LiDAR and beach profiling).
- Breach analysis of Dawlish Warren sand spit.

The above tasks provide different sets of information with varying timescales, certainty and coverage. However, conceptually, the recent past and future will have more certainty and detail, whereas the more distant past and future will have more uncertainty attached. This is shown graphically in Figure 2.1. In relation to this, the following commentary on historic and future changes generally follow this trend.

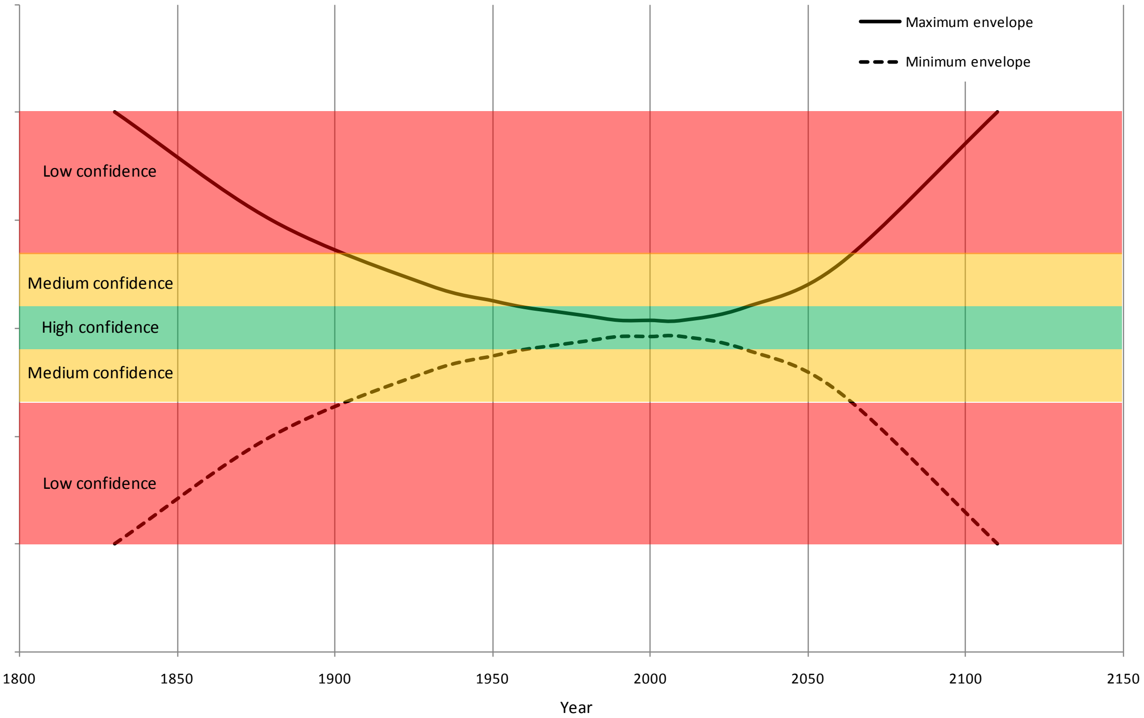


Figure 2.1 – Change in certainty over different timescales.

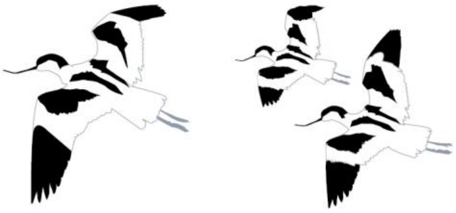
2.2.2 Historic Geomorphological Evolution

The historic evolution of the Exe Estuary is described in detail in Appendix A. Table 2.1 gives a summary of this. Key findings are that:

- Dawlish Warren sand spit appears to have an increasing trend of damage (7% to 10% AEP) and breach (3% to 4% AEP) Standard of Protection (SoP).
- General siltation within the wider inner estuary has slowed down from 0.05m/yr in the early 1900s, to 0.0005m/yr in the present day.

Epoch	Evolution
1810-1930	Storms indicate damage SoP of 7% AEP and breach SoP of 3% AEP at Dawlish Warren. Large scale human intervention in the form of reclamation. General trend of in-estuary movement of central and distal sections of Dawlish Warren by 3-7m/yr. Pole Sands and Bull Hill Banks reduce in size but vertically accrete. Evidence that the inner estuary may have accreted by up to 0.05m/yr.
1930-2010	Storms indicate damage SoP of 10% AEP and breach SoP of 4% AEP at Dawlish Warren, even though significant protection measures are constructed. In-estuary movement of central and distal sections of Dawlish Warren slows to 1-2m/yr. The well documented breach event in around 1946 indicates that Dawlish Warren distal end regenerated within 10 years. Bull Hill Banks increases volumetrically and spatially, whilst Pole Sands increases spatially but has a marginal trend of erosion. Complementary evidence that the inner estuary was accreting more slowly than previously, with a marginal trend of 0.0005m/yr.

Table 2.1 – Summary of historic evolution.



2.2.3 Prediction of Future Geomorphological Evolution

The future evolution of the Exe Estuary is again described in detail in Appendix A. Table 2.2 gives a summary of this for the Do Nothing and Do Minimum scenarios. Key predictions are:

- In the Do Nothing scenario, the distal end of Dawlish Warren would be permanently flattened between 2030 and 2060, allowing offshore waves to penetrate further into the inner estuary.
- In the Do Minimum scenario, the distal end would be permanently flattened between 2060-2110, again allowing offshore waves to penetrate further into the inner estuary.
- By 2110 both the Do Nothing and Do Minimum scenarios would have similar consequences at the estuary mouth.
- General siltation within the wider inner estuary would not be significant until 2110 when it would be of the order of 0.1m in total.

Epoch	Do Nothing scenario	Do Minimum scenario
2010-2030	Dunes, beach, groynes and gabions deteriorating rapidly. Central Dawlish Warren would intermittently be damaged, with the distal end being separated on a temporary basis. Dawlish Warren would continue to provide shelter from offshore waves.	Dunes, beach, groynes and gabions would require regular maintenance. Central Dawlish Warren would intermittently be damaged, with the distal end being separated on a temporary basis. Dawlish Warren would continue to provide shelter from offshore waves.
2030-2060	Central Dawlish Warren permanently damaged and open to in-estuary movement of up to 60m (2m/yr). The distal end would be permanently separated by 2060, allowing some penetration of offshore waves into the inner estuary.	Central Dawlish Warren protection would require extensive regular maintenance to remain fixed in place. The distal end would be regularly separated but still exist as an island feature, providing shelter from offshore waves for the inner estuary.
2060-2110	Dawlish Warren would move in-estuary and become an intermittent intertidal sandbank feature, but would continue to provide some shelter from offshore waves. Some siltation of the wider inner estuary would occur of the order of 0-0.1m.	

Table 2.2 – Summary of future evolution.

2.3 Joint Probability Assessments

2.3.1 Methodology

Simplified Method JPAs were carried out using the Simplified Method (Defra, 2005), which consists of:

- Define a Correlation Factor (CF, for general use), correlation coefficient (ρ, for wave-tidal combinations) or dependence measure (א, for fluvial-tidal combinations) between the two variables of interest.

- For each combined return period of interest, interpolate the resultant return periods for the two variables for the previously calculated or calibrated CF value.
- Generate the combined probability tables for each of the combined probability return periods.

2.3.2 Wave-Tidal Interdependency

The interdependency of wave and tidal events was assessed using the relevant tide gauges of Weymouth and Newlyn, the closest locations to the study area with documented wave-tide interdependency data in Defra (2005). The Simplified Method JPA work was also calibrated from back-analysis of a previous JOIN-SEA JPA from the Exe Estuary Coastal Management Study (Halcrow, 2006). Back analysis of the original JOIN-SEA results indicates that extreme wave and tide events are moderately correlated, with the calibrated CF for all wave directions derived as 78 (with a maximum variation from 10 to 116).The results are summarised in Table 2.3. Full details of the JPA tables are given in Appendix B.

Tide gauge	Average CF value	Sector with maximum CF value	Maximum CF value	Sector with minimum CF value	Minimum CF value
Newlyn	6	60-280	46	180-360	7
Weymouth	29	70-210	76	210-280	13
JOIN-SEA calibrated	78	150-225	116	165-210	10

Table 2.3 – Summary of Wave-Tidal Interdependency.

2.3.3 Fluvial-Tidal Interdependency

The influence of fluvial inputs on local EWLs was assessed for the tributaries discharging into the Exe Estuary. This assessment was carried out using the closest relevant flow and tide gauges, with the results summarised in Table 2.4. The only relevant flow gauge present within the FD2308 guidance was on the river Exe at Thoverton, and similarly the relevant tide gauges were at Newlyn and Weymouth. An average value of 0.1 was applied, indicative of weak correlation between fluvial and tidal events. This finding means that tidal and fluvial extreme events can be modelled separately.

Tide gauge	Flow gauge	א value	Comment
Newlyn	Thoverton	0.08	No correlation
Weymouth	Thoverton	0.13	Weak correlation

Table 2.4 – Summary of Fluvial-Tidal Interdependency.

2.4 Wave Modelling

2.4.1 Methodology

Wave modelling was carried out using the MIKE21SW model recently used for the Dawlish to Teignmouth study (Halcrow, 2009). The model bathymetry was updated with recent LiDAR sourced from the Environment Agency in 2010, with the offshore bathymetry derived from Admiralty Chart data. The model mesh and bathymetry for the existing condition can be seen in Figure 2.2.

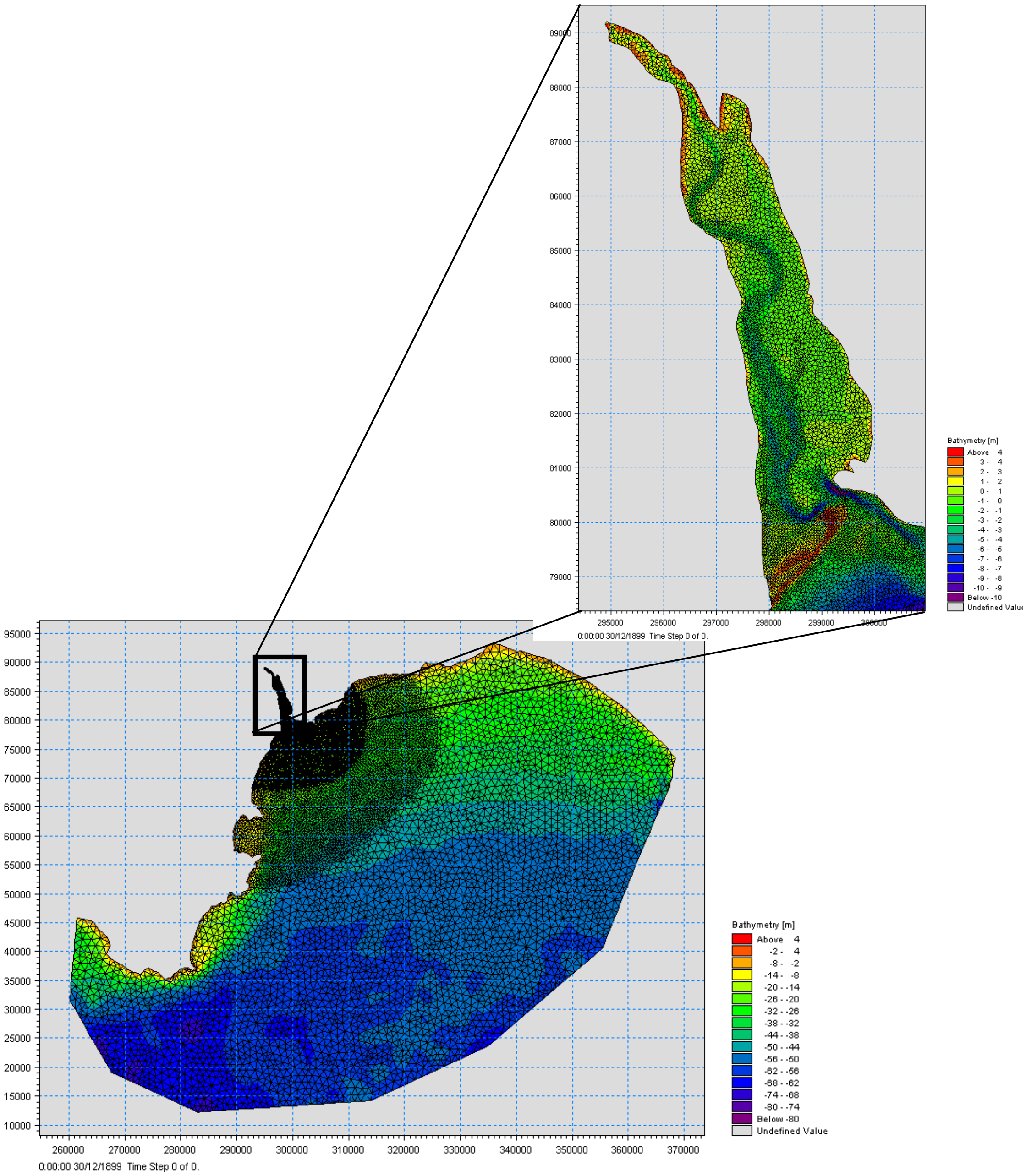


Figure 2.2 – MIKE21SW model layout.

2.4.2 Calibration and Validation

The previous model boundary conditions/meteorological conditions were applied to the existing model mesh in the same manner as in Halcrow (2008) and waves were prescribed along the entire length of the offshore boundary with winds assumed to be spatially constant.

There were two calibration points outside of the entrance to the Exe estuary at which significant wave height data was available, shown in Figure 2.3. The model was run for the same period as the available data, with Station 6 and Station 5 having a RMS error for wave height of 0.29-0.25m. Sensitivity to the phasing between the predicted wave height and the observed wave heights at Station 5 was undertaken, with the wave height RMS error reduced to 0.23m. This level of agreement is considered to be reasonable.

Internal wave heights generated by MIKE21SW were checked against British Standard 6349 (Maritime Structures) and Yarde et al (1996). This examination of the results found that the wave heights produced by the MIKE21SW model inside the estuary were lower than suggested by empirical methods and anecdotal evidence. Reconsideration of the MIKE21SW model found that a limiting wave steepness parameter was applied inappropriately within MIKE21SW. This parameter was amended, with the result of increased wave heights within the estuary. As the inner estuary is less well calibrated due to no available wave records, this represents a useful check on the sensibility of the MIKE21SW model results.

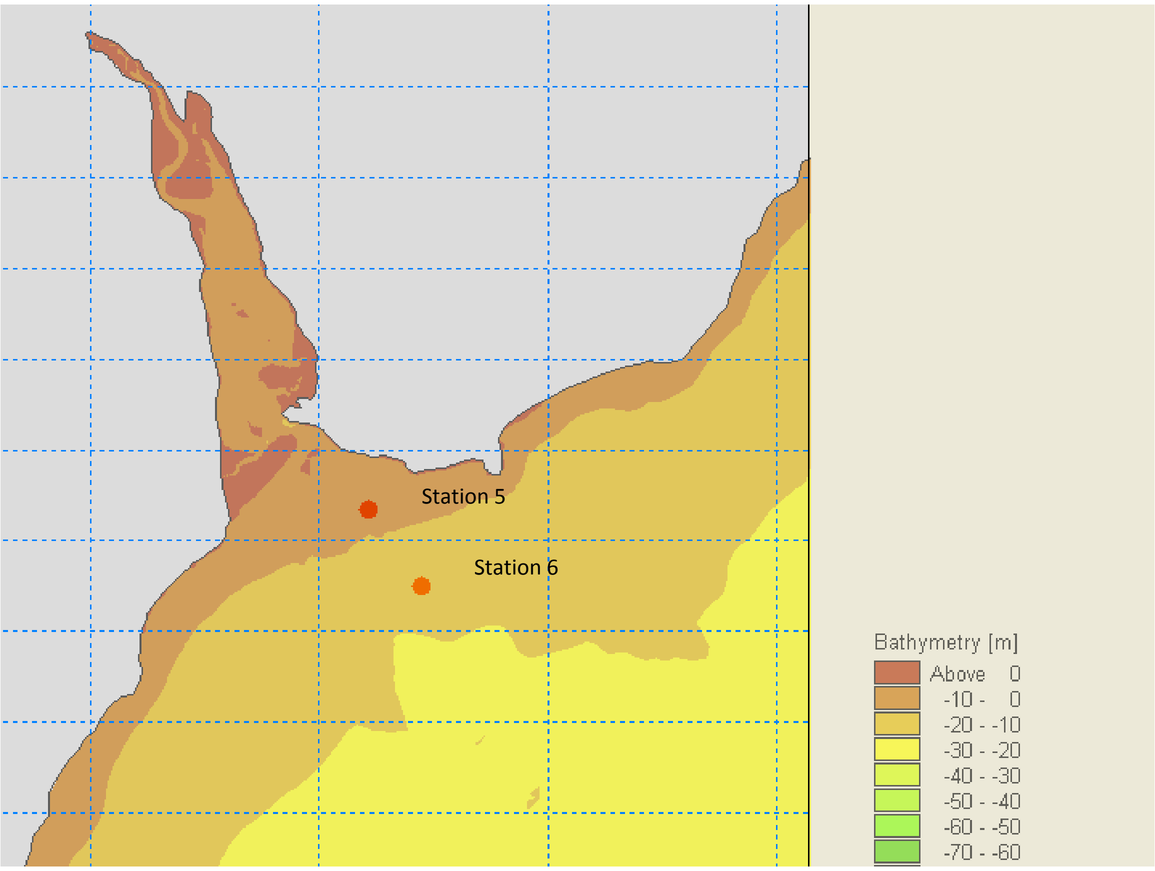
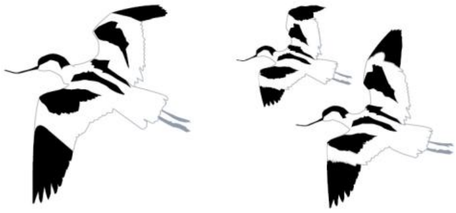


Figure 2.3 – Location of calibration points.



2.4.3 Extreme Wave Climate

To generate the extreme wave climate, the MIKE21SW model was run for extreme wind and wave conditions under the full 360 degree range, analysed by 30 degree sectors. For those sectors where waves arrive from offshore (90-270°) the extreme wave heights were applied to the model (with an associated wind speed) and for all other directions an extreme wind speed was applied with a nominal offshore wave height. Wave heights for FCRMU08-11 and 13 are not given, as these are wave sheltered fluvial areas. The extreme wave climate was defined as summarised in Table 2.5.

Location	FCRM Unit	100% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
Sandy Bay	01	2.76	2.81	2.86	2.88	2.90	2.92	2.93	2.94
The Maer	02	2.39	2.44	2.48	2.50	2.52	2.54	2.55	2.55
Exmouth*	03	0.44	0.57	0.62	0.67	0.73	0.78	0.82	0.92
Courtlands	04	0.66	0.76	0.81	0.87	0.91	0.96	1.00	1.10
Lympstone	05	0.60	0.69	0.73	0.79	0.83	0.87	0.91	1.01
Lympstone Commando	06	0.61	0.70	0.74	0.80	0.84	0.88	0.92	1.02
Exton	07	0.57	0.66	0.69	0.74	0.78	0.82	0.85	0.93
Topsham	12	0.55	0.63	0.66	0.70	0.73	0.76	0.78	0.84
Exminster	14	0.21	0.24	0.26	0.27	0.29	0.30	0.31	0.34
Powderham	15	0.32	0.42	0.46	0.53	0.57	0.62	0.67	0.78
Starcross	16	0.35	0.45	0.49	0.55	0.60	0.64	0.69	0.79
Dawlish Warren*	17	0.31	0.36	0.41	0.44	0.48	0.53	0.57	0.61
Dawlish to Holcombe	18	2.62	2.81	3.00	3.10	3.20	3.25	3.29	3.31

* The quoted wave heights refer to in-estuary facing locations, rather than coastal facing.

Table 2.5 – Extreme Wave Climate (significant wave height, m).

2.5 Tidal and Fluvial Modelling

2.5.1 Methodology

The morphology of the Exe Estuary is known to result in water levels varying as tides propagate within the estuary. Modelling of tidal propagation was carried out using the DAWN model developed in Halcrow (2008). The model bathymetry was updated with recent LiDAR sourced from the Environment Agency in 2010. The tidal boundary applied the relevant EWL sourced from Environment Agency (2011) to stretch a MHWS tide curve as required.

2.5.2 Calibration and Validation

The DAWN model was validated against the up-estuary increase in EWLs quoted for Starcross and Topsham in Environment Agency (2003). The DAWN model results were within 0.02m and 0.08m respectively; these results confirm that the DAWN model is replicating the slight increase in EWLs in the upper estuary. It is noted that the Environment Agency (both 2003 and 2011) EWLs for the upper estuary have less confidence attached than at the mouth of the Exe Estuary.

2.5.3 Extreme Water Levels

The estuary-wide EWLs were defined as summarised in Table 2.6. This shows a clear increase in EWLs as the tide propagates in-estuary. Fluvial processes in the river Exe and Clyst were modelled using the ISIS models developed for the Lower Clyst project (Halcrow, 2009) and Exeter PAR (AHA, 2010). Within the EEFCRMS study area it was found that extreme tidal levels generally exceed extreme fluvial levels, with fluvial influence becoming increasingly important upstream of the Grindle Brook on the River Clyst. An example of the comparative EWLs in 2010 on the River Clyst is given in Figure 2.4.

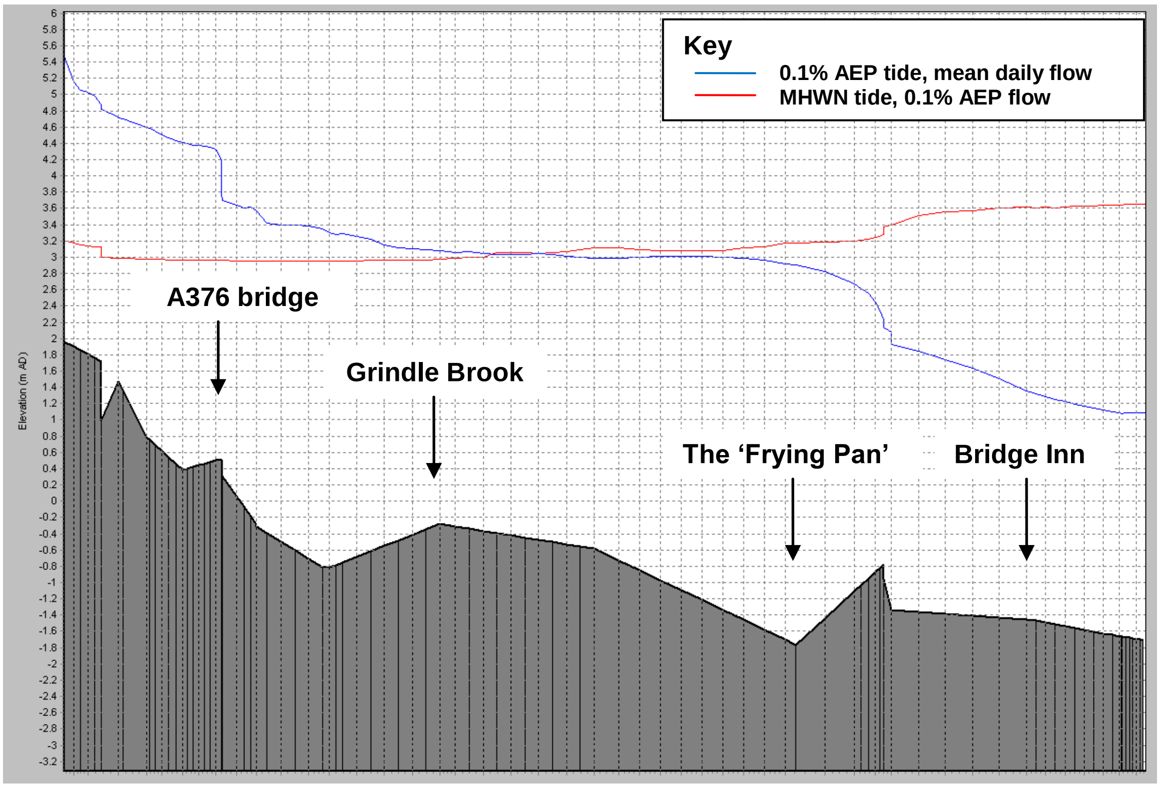


Figure 2.4 – Comparison between extreme fluvial and tidal water levels.

In the estuary, and particularly along the coast, wave set-up during storm events may increase EWLs; this was assessed by applying the method in the Coastal Engineering Manual (USACE, 2010). An indicative summary of the findings of the wave set-up assessment is given in Table 2.7 (bathymetry and hydrodynamic conditions varied the wave set-up amounts at a local scale).

Location	FCRM Unit	100% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
Sandy Bay to Exmouth	01-03	2.74	2.90	2.97	3.06	3.13	3.20	3.27	3.46
Courtlands	04	2.78	2.94	3.01	3.10	3.17	3.24	3.31	3.50
Lympstone	05	2.83	2.99	3.06	3.15	3.22	3.29	3.36	3.55
Lympstone Commando	06	2.85	3.01	3.08	3.17	3.24	3.31	3.38	3.57
Exton	07	2.87	3.03	3.10	3.19	3.26	3.33	3.40	3.59
East bank of the Clyst	08	2.89	3.05	3.12	3.21	3.28	3.35	3.42	3.61
Clyst St. Mary	09	Fluvially influenced							
Sowton	10								
West bank of the Clyst	11	2.89	3.05	3.12	3.21	3.28	3.35	3.42	3.61
Topsham	12	2.88	3.04	3.11	3.20	3.27	3.34	3.41	3.60
Countess Wear	13	2.89	3.05	3.12	3.21	3.28	3.35	3.42	3.61
Exminster Marshes and Powderham Banks	14	2.88	3.04	3.11	3.20	3.27	3.34	3.41	3.60
Kenn Valley	15	2.80	2.96	3.03	3.12	3.19	3.26	3.33	3.52
Starcross	16	2.77	2.93	3.00	3.09	3.16	3.23	3.30	3.49
Dawlish Warren to Holcombe	17-18	2.75	2.91	2.98	3.07	3.14	3.21	3.28	3.47

Table 2.6 – Extreme Water Levels (mAOD).

Location	FCRM Unit	100% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
Sandy Bay to Exmouth	01-03	0.27	0.29	0.30	0.31	0.33	0.34	0.35	0.38
Inner Estuary	04-07, 14-16	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04
Rivers Clyst and Exe	08-13	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dawlish Warren to Holcombe	17-18	0.35	0.37	0.39	0.41	0.43	0.45	0.47	0.49

Table 2.7 – Indicative wave set-up under extreme wave conditions (m).

2.6 Switching Point Analysis

2.6.1 Future Evolution of Dawlish Warren sand spit

The predicted evolution of Dawlish Warren sand spit represents a clear situation under which estuarine processes could be significantly changed. To assess the impact of damage to Dawlish Warren sand spit as defined in the EGA (see Appendix A), the distal end of Dawlish Warren sand spit was lowered to 0mAOD over an area similarly affected in the 1946 event. The bathymetry for this layout can be seen in Figure 2.5 beside the existing layout. The change in wave climate and water levels due to damage to Dawlish Warren sand spit are given in Table 2.8. This shows that the majority of FCRM units are not overly sensitive to this change. The exception to this is FCRMU16 (Starcross) where wave heights could increase by 0.3m. This qualitatively agrees with historical observations at this location. The increase in EWLs is up to 0.1m.

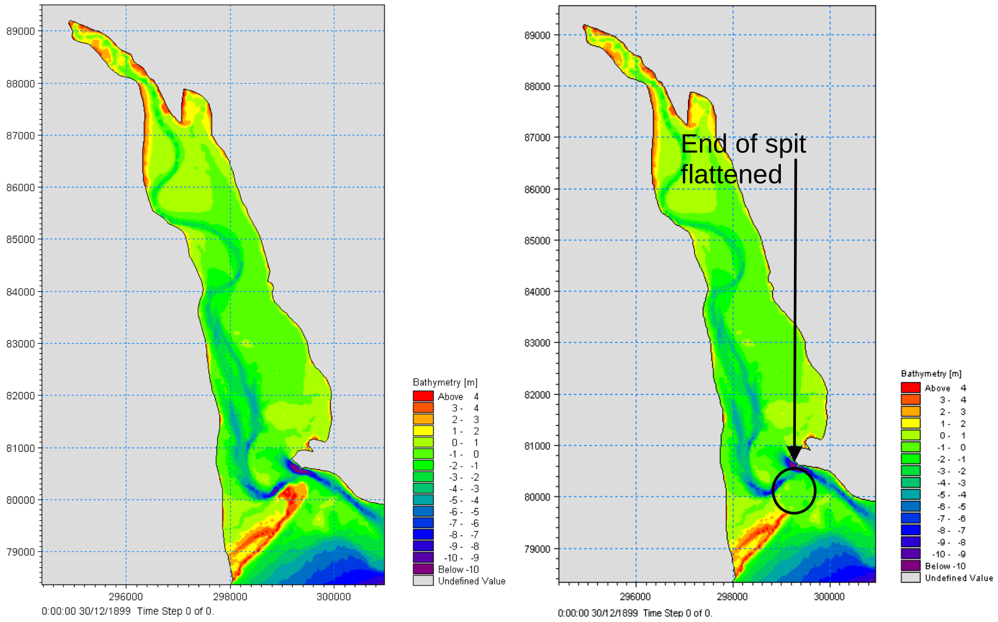


Figure 2.5 – Bathymetry with distal end of Dawlish Warren flattened.

Location	FCRM Unit	Shoreline Hs increase (m)	EWL increase (m)
Exmouth, Courtlands, Lympstone, Lympstone Commando and Kenn Valley	03, 04, 05, 06, 15	0.1	Up to 0.1
Exton, Topsham, Exminster Marshes and Powderham Banks	07, 12, 14	0.0	
Starcross	16	0.3	

Table 2.8 – Extreme wave climate increase with distal end of Dawlish Warren flattened.

2.6.2 Climate Change Scenarios

To assess potential impacts, the range of climate change scenario projections were applied to the hydrodynamic and geomorphological parameters. Table 2.9 summarises the consequential variations due to climate change variation (i.e. the basic variations in SLR and flow defined by guidance are not shown, but further impacts caused by them are). It can be seen that the majority of consequential sensitivity is relatively small compared to the basic variations in SLR and flow, except for the potential erosion to Dawlish Warren sand spit.

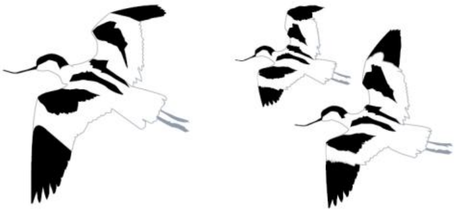
Location	FCRM Unit	Year		
		2030	2060	2110
Sandy Bay to Exmouth	01 to 03	Wave set-up increased by 0-0.1m.		Wave set-up increased by 0.1-0.2m.
Inner Estuary	04-07, 14-16	Negligible estuary-wide accretion.	Estuary-wide accretion of 0-0.1m.	Estuary-wide accretion of 0-0.2m.
Rivers Clyst and Exe	08-13	Tidal EWLs predominate over fluvial peak water levels.		
Dawlish Warren to Holcombe	17 to 18	10-20% erosion of inter/supra-tidal sand spit volume.	20-40% erosion of inter/supra-tidal sand spit volume.	40%+ erosion of inter/supra-tidal sand spit volume.

Table 2.9 – Impact of different emissions scenarios.

2.7 Summary

The geomorphological and hydrodynamic analyses provide a coherent dataset for the study area. The extremes dataset will be used to inform the performance assessment of FCRM assets.

A key finding is that Dawlish Warren sand spit is likely to rotate anti-clockwise in estuary and the distal end eventually be permanently separated and flattened, with a likely timescale of occurrence of 2030-2060 (likely towards 2060 for the Do Minimum scenario) under the medium emissions scenario. This would result in reduced sheltering from extreme events. The analysis indicates that the impact would be an increase in EWLs of up to 0.1mAOD throughout the wider inner estuary, and an increase in wave heights of up to 0.3m.



3. Performance and Inundation Assessment

3.1 Introduction and Methodology

The FCRM structures around the Exe Estuary experience wave, tidal and fluvial impacts depending on their location within the estuary and on the coast. To assess the performance of the FCRM assets, three datasets are required: hydrodynamic inputs, FCRM asset and foreshore geometry, and FCRM asset condition and construction type. The FCRM assets throughout the Exe Estuary are split into sub-reaches, which are representative of regions with consistent hydrodynamic exposure, asset and foreshore geometry, and asset condition and construction. The FCRM asset failure modes are based on European Community (2009), hydraulic response to wave overtopping and/or continuous weiring is based on the European Community (2007), and residual life is based on Environment Agency (2010).

The following sections describe the work carried out to:

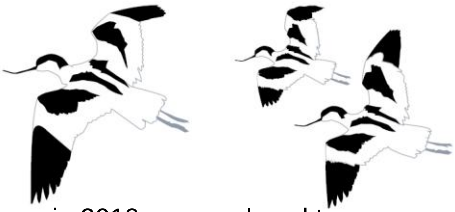
- Characterise the FCRM asset reaches.
- Define the critical design parameters such as damage, breach and residual life criteria.
- Model the hydrodynamic and structural performance of the strategic sub-reaches, defining overtopping rates and the Standard of Protection (SoP) against wave overtopping, tidal weiring, damage and breach. The sensitivity of the performance assessment to the evolution of Dawlish Warren is also included.
- Summarise the findings of the above studies.
- Assess the impact of switching points on the above analyses.

3.2 FCRM asset reaches

Due to the extensive geographic area covered in the EEFCRMS, FCRM asset reaches were defined with lengths of the order of 10-100m, with the actual length predominantly defined by geometrical variation and structure type. Details of FCRM asset characteristics are given in Appendix C. Very short FCRM asset lengths that are particularly weak will not be captured within the strategy level analysis.

The sources and quality of topographic data throughout the Exe Estuary is variable. The specific use of datasets and an estimate of their relative accuracy are given in Table 3.1. The geometry of the FCRM assets and their adjacent foreshore was based on the following hierarchy of information:

- Topographic surveys: These were carried out between the years 2006 and 2009.
- NFCDD: Where available, crest level and geometry data from the NFCDD was used to corroborate or otherwise topographic survey data.
- Scheme or structural data: Where available, scheme data received from the Environment Agency in 2010 was analysed to define crest level, defence type and front face slope. This was used to corroborate NFCDD, or as a primary source of data if NFCDD information was not present.



- LiDAR data: LiDAR data received from the Environment Agency in 2010 was analysed to generate foreshore cross-sections at sub-reach intervals. Where no acceptable topographic or NFCDD information on geometry was present, LiDAR data was used.

Location	FCRM unit	Number of FCRM asset reaches	Crest level data source	Estimated crest level accuracy (order of magnitude, m)
Sandy Bay	01	4	NFCDD	0.01
The Maer	02	4		
Exmouth	03	17	Scheme drawings and NFCDD	0.01
Courtlands	04	7	Network Rail and LiDAR	0.1
Lympstone	05	11	Scheme drawings and NFCDD	0.01
Lympstone Commando	06	3	Network Rail and LiDAR	0.1
Exton	07	3		
East bank of the Lower Clyst	08	7	NFCDD	0.01
Clyst St. Mary	09	5	LiDAR	0.1
Sowton	10	2		
West bank of the Lower Clyst	11	7		
Topsham	12	39	NFCDD	0.01
Countess Wear	13	11		
Exminster Marshes and Powderham Banks	14	14	NFCDD, Network Rail and LiDAR	0.1
Kenn Valley	15	5	Network Rail and LiDAR	0.1
Starcross	16	8	NFCDD	0.01
Dawlish Warren	17	14		
Dawlish to Holcombe	18	2	Network Rail and LiDAR	0.1

Table 3.1 – Summary of data used to define geometry.

3.3 Critical Performance Parameters

3.3.1 Failure Modes

Assessment of the initiation of damage and breach for FCRM assets is the focus of ongoing international research. However, work carried out within the Integrated Project FLOODsite (EC, 2007) has drawn together and extended previous work from the Joint Defra/EA Flood and Coastal Erosion Risk Management R&D Programme (FD2411, FD2412 and FD2318, 2006-2007), as well as the IMPACT (EC, 2006) and EuroTOP (EC, 2007) projects. This has developed reliability equations to support analyses on the initiation of damage and breach for a wide range of FCRM assets.

The approach used to assess damage and breach to FCRM assets within the Exe Estuary follows the general approach described by the Integrated Project FLOODsite (EC, 2007). Three principal sources of hydraulic loading are considered:

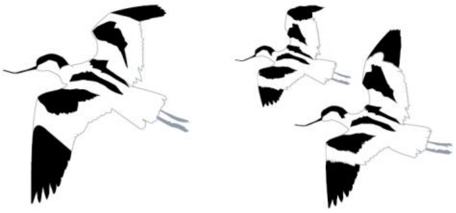
- Fluvial-tidal weiring over the assets.
- Wave loading (overtopping) of the assets.
- Structural degradation of the assets, generally critical from the medium term onwards.

3.3.2 Failure Criteria

The framework within which the assets have been assessed is based on a limiting state equation Z = R – S, where S and R are conceptually the ‘loading’ on and the ‘strength’ of the FCRM asset respectively (with two forms used: R_D for damage and R_B for breach). Values for R_D and R_B were generated by consideration of the Integrated Project FLOODsite (EC, 2007) guidance and are summarised in Table 3.2. Further details of the assessment are given in Appendix C.

FCRM asset type	Damage criteria, R_D	Breach criteria, R_B
FCRM engineered (adhering to design codes)		
Impermeable earth embankment and similar ‘soft’ structures	q > 0.002m^3/s/m	q > 0.03m^3/s/m
Concrete revetments and similar ‘hard’ structures	q > 0.05m^3/s/m	q > 0.2m^3/s/m
Massive hard engineered structures	q > 0.2m^3/s/m	NA
Non-FCRM engineered (not adhering to design codes)		
Shingle ridges and sand dunes	q > 0.002m^3/s/m	q > 0.002m^3/s/m
Fragile structures (such as private walls)	q > 0.002m^3/s/m	q > 0.03m^3/s/m
‘Hard’ structures (such as railway embankments)	q > 0.05m^3/s/m	q > 0.2m^3/s/m

Table 3.2 – Criteria for onset of damage and breach.



3.3.3 Residual Life

The residual life of the FCRM assets was based on condition and structural information held within NFCDD, visual inspections carried out in 2010, and the original design life. Consideration of these sources of data in conjunction with guidance (EA, 2010) was used to define the duration of structural integrity for FCRM assets within the Exe Estuary. The common types of asset and residual life in the Exe Estuary are summarised in Table 3.3.

3.4 Hydrodynamic and Structural Performance

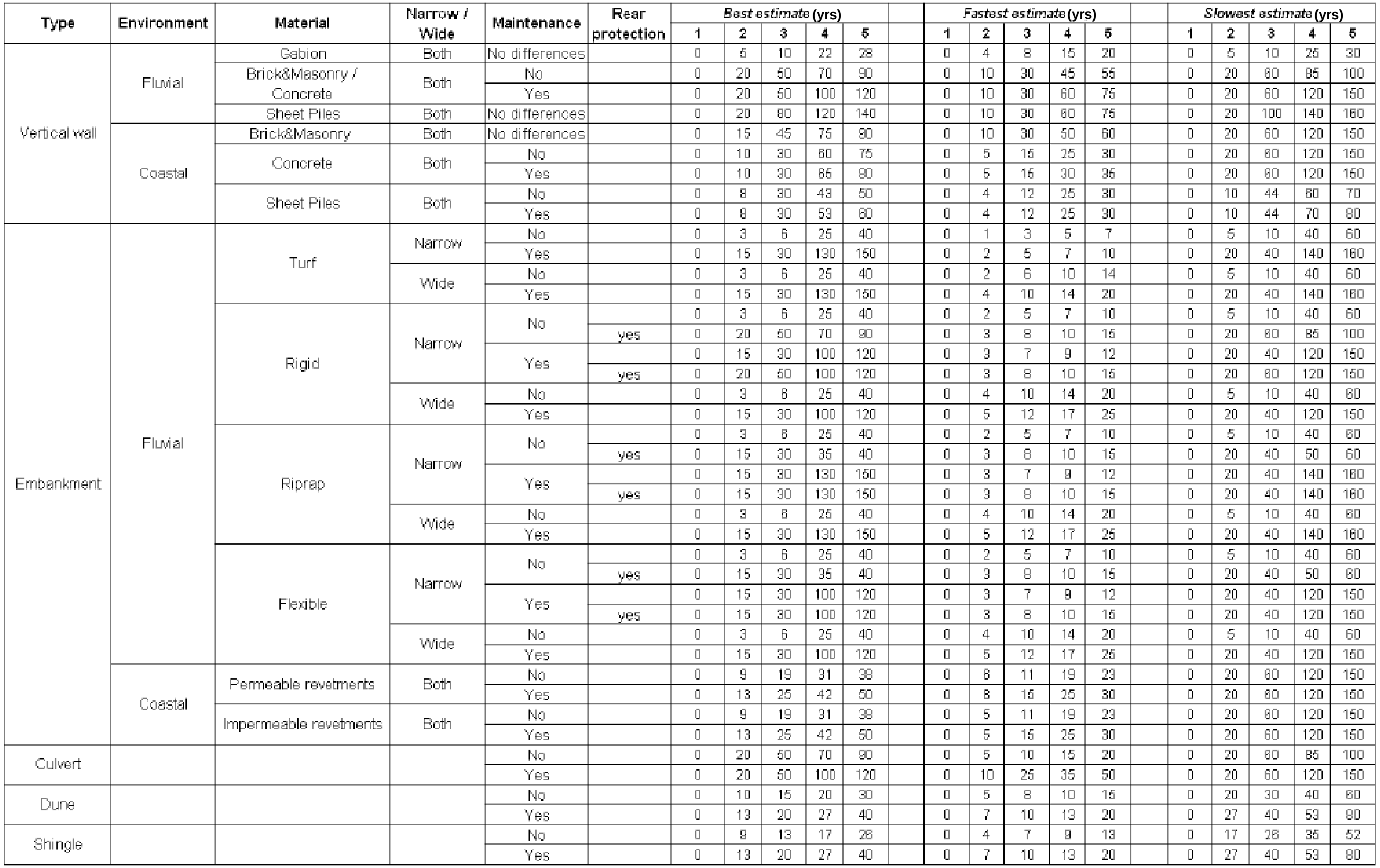
3.4.1 Overtopping Model

The overtopping model was developed as a spreadsheet application of the empirical equations from the EuroTOP manual (EC, 2007) and CIRIA 116 (1987). CIRIA 116 provides guidance on modelling weiring velocities, whilst the EuroTOP manual provides guidance on modelling wave and tidal overtopping rates. Details and examples of the overtopping model are given in Appendix D.

The overtopping model was applied to the strategic sub-reaches for four over-arching modes, with damage and breach noted where specific criteria were exceeded:

- Wave overtopping of impermeable embankments (EuroTOP manual Chapter 5).
- Wave overtopping of semi-permeable embankments (EuroTOP manual Chapter 6).
- Wave overtopping of vertical or near-vertical structures (EuroTOP manual Chapter 7).
- Tidal weiring of all structures (applying the broad-crested weir equation).

The performance of each of the FCRM asset reaches was modelled for each of the joint probability events. A summary of the model parameters is given in Table 3.4.



Type	Environment	Material	Narrow / Wide	Maintenance	Rear protection	*Best estimate* (yrs)						*Fastest estimate* (yrs)						*Slowest estimate* (yrs)				
						1	2	3	4	5		1	2	3	4	5		1	2	3	4	5
Vertical wall	Fluvial	Gabion	Both	No differences		0	5	10	22	28		0	4	8	15	20		0	5	10	25	30
		Brick&Masonry / Concrete	Both	No		0	20	50	70	90		0	10	30	45	55		0	20	60	85	100
				Yes		0	20	50	100	120		0	10	30	60	75		0	20	60	120	150
		Sheet Piles	Both	No differences		0	20	80	120	140		0	10	30	60	75		0	20	100	140	160
	Coastal	Brick&Masonry	Both	No differences		0	15	45	75	90		0	10	30	50	60		0	20	60	120	150
		Concrete	Both	No		0	10	30	60	75		0	5	15	25	30		0	20	60	120	150
				Yes		0	10	30	65	80		0	5	15	30	35		0	20	60	120	160
		Sheet Piles	Both	No		0	8	30	43	50		0	4	12	25	30		0	10	44	60	70
				Yes		0	8	30	53	60		0	4	12	25	30		0	10	44	70	80
Embankment	Fluvial	Turf	Narrow	No		0	3	6	25	40		0	1	3	5	7		0	5	10	40	60
				Yes		0	15	30	130	150		0	2	5	7	10		0	20	40	140	160
			Wide	No		0	3	6	25	40		0	2	6	10	14		0	5	10	40	60
				Yes		0	15	30	130	150		0	4	10	14	20		0	20	40	140	160
		Rigid	Narrow	No		0	3	6	25	40		0	2	5	7	10		0	5	10	40	60
					yes	0	20	50	70	90		0	3	8	10	15		0	20	60	85	100
				Yes		0	15	30	100	120		0	3	7	9	12		0	20	40	120	150
					yes	0	20	50	100	120		0	3	8	10	15		0	20	60	120	150
			Wide	No		0	3	6	25	40		0	4	10	14	20		0	5	10	40	60
				Yes		0	15	30	100	120		0	5	12	17	25		0	20	40	120	150
		Riprap	Narrow	No		0	3	6	25	40		0	2	5	7	10		0	5	10	40	60
					yes	0	15	30	35	40		0	3	8	10	15		0	20	40	50	60
				Yes		0	15	30	130	150		0	3	7	9	12		0	20	40	140	160
					yes	0	15	30	130	150		0	3	8	10	15		0	20	40	140	160
			Wide	No		0	3	6	25	40		0	4	10	14	20		0	5	10	40	60
				Yes		0	15	30	130	150		0	5	12	17	25		0	20	40	140	160
		Flexible	Narrow	No		0	3	6	25	40		0	2	5	7	10		0	5	10	40	60
					yes	0	15	30	35	40		0	3	8	10	15		0	20	40	50	60
				Yes		0	15	30	100	120		0	3	7	9	12		0	20	40	120	150
					yes	0	15	30	100	120		0	3	8	10	15		0	20	40	120	150
			Wide	No		0	3	6	25	40		0	4	10	14	20		0	5	10	40	60
				Yes		0	15	30	100	120		0	5	12	17	25		0	20	40	120	150
	Coastal	Permeable revetments	Both	No		0	9	19	31	38		0	6	11	19	23		0	20	60	120	150
				Yes		0	13	25	42	50		0	8	15	25	30		0	20	60	120	150
		Impermeable revetments	Both	No		0	9	19	31	38		0	5	11	19	23		0	20	60	120	150
				Yes		0	13	25	42	50		0	5	15	25	30		0	20	60	120	150
Culvert				No		0	20	50	70	90		0	5	10	15	20		0	20	60	85	100
				Yes		0	20	50	100	120		0	10	25	35	50		0	20	60	120	150
Dune				No		0	10	15	20	30		0	5	8	10	15		0	20	30	40	60
				Yes		0	13	20	27	40		0	7	10	13	20		0	27	40	53	80
Shingle				No		0	9	13	17	28		0	4	7	9	13		0	17	28	35	52
				Yes		0	13	20	27	40		0	7	10	13	20		0	27	40	53	80

Table 3.3 – Duration of structural integrity.

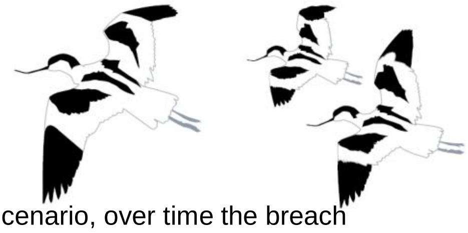
FCRM units	Number of FCRM asset reaches	JPA pairs	Epochs	JPRPs	Climate change scenarios	Number of performance assessments
01	4	12	4	8	4	4,992
02	4					4,992
03	17					21,216
04	7					8,736
05	11					13,728
06	3					3,744
07	3					3,744
08	7	1				728
09	5					520
10	2					208
11	7					728
12	39	12				48,672
13	11					13,728
14	14					17,472
15	5					6,240
16	8					9,984
17	14					17,472
18	2					2,496
Total						**179,400**

Table 3.4 – Summary of model parameters.

3.4.2 Inundation Model

The approach for assessing inundation was based on the onset of breach predicted by the performance assessment, considered as the primary cause of significant inundation within the strategic FCRM units. To provide a robust strategic approach to define under what conditions significant inundation would occur, a number of assumptions were made as described below.

For non-breach conditions at each strategic flood sub-cell, it was assumed that no significant inundation volume was generated from wave overtopping. This assumption was supported from previous studies (Atkins, 2004, 2006) that used detailed modelling of wave overtopping hydrographs to model inundation, and found that wave overtopping volumes were 3 or more orders of magnitude less than breach volumes. For reaches of the estuary that are susceptible to tidal-fluvial weiring, damage and breach soon resulted once incident EWLs were above the FCRM asset crest level.



For breach conditions it was assumed that, for the Do Nothing scenario, over time the breach initiation would progressively extend laterally due to no repair and maintenance, resulting in large scale failure of the FCRM asset. For the Do Minimum scenario, it was assumed that where breach was predicted to occur, this would be repaired within 3 tide cycles (supported by Environment Agency, 2009).

Physical appropriateness calculations and 1D (ISIS) modelling were carried out for each FCRM unit to confirm that the volume required to inundate the flood cell to the incident EWL could be achieved, under both Do Nothing and Do Minimum scenarios. Complete filling of the flood cells was found to occur, with inundation depths based on processed LiDAR data provided for the whole floodplain system and the EWL relevant to each FCRM unit.

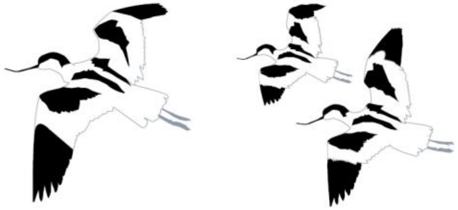
It is noted that guidance regarding the precise definition of breach geometry is limited presently, and the focus of ongoing research (EC, 2006). However, outline guidance is available as defined for Strategic Flood Risk Assessments (SFRA). This guidance (Environment Agency, 2004 and 2009), although developed for a different purpose to align with Planning Policy Statement 25, indicates breach geometries that should be used for generic hydrodynamic climates and defence types (summarised in Table 3.5). For assessment of the Do Minimum scenario the SFRA guidance was used.

Location	FCRM asset type	Breach width (m)	Breach toe
Open coast (FCRM units 1-3, 17-18)	Soft	200	The highest of adjacent seaward or landward ground level
	Hard	50	
Estuary (FCRM units 4-16)	Soft	50	
	Hard	20	

Table 3.5 – Breach geometry.

3.5 Present Day Flood and Coastal Risk

Whilst the coherent hydrodynamic dataset derived in section 2 was predominantly calibrated and validated, performance of FCRM assets is more difficult to verify in a conventional sense due to extremely limited field data. However, to build confidence in the performance assessment, structure specific verification was carried out where SoP were considered already well observed, modelled or defined. Comparison between the performance assessment and previous observations, design and modelling are summarised in Table 3.6. The comparison shows that the model adequately represents the expected SoP.



FCRM unit	EEFCRMS SoP, using EA (2011) EWLs	Evidence from Royal Haskoning (2008), using EA (2003) EWLs	Evidence from natural events analysis
01	Damage occurs on a regular basis, but no breach.	Not covered.	No storms recorded.
02	Sand dunes and wall would experience wave overtopping and damage, but no breach.	Not covered.	Storm events in 1811, 1960 and 2004 caused damage or flooding. These three events coarsely indicate a SoP of 1% AEP.
03	Tidal weiring into back gardens can occur at 100% AEP near Shelly Road and Camperdown Terrace. Tidal weiring and damage affecting property occurs in the 4% AEP and 20% AEP events respectively. Actual breach of assets is unlikely to occur.	Wave overtopping assessment indicates 722m^3 in the 10% AEP event, then increasing rapidly to 2-3000m^3 for the 4% and 2% AEP events. Then a further increase to 8-15000m^3 for the 1% and 0.5% AEP events. The 10% to 2% AEP events are probably not overly significant, but the 1% and 0.5% AEP events potentially are.	Storm events in 1811, 1889, 1960 and 2008 caused damage or flooding. These four events coarsely indicate a SoP of 2% AEP.
04	Constrained tidal flooding can occur in 20% AEP events locally near Sowden Farm. More widely the railway line provides protection against tidal weiring, damage and breach up to the 0.1% AEP event.	Not covered.	No storms recorded.
05	Lympstone tide gates provide protection against weiring, damage and breach for 1-0.1% AEP events generally.	Compartment 1 (Lympstone) gives a 2095m^3 flood volume in the 0.5% AEP event. This indicates some flooding could occur more frequently than the 0.5% AEP event.	Storm events in 1960 and 1989 caused damage or flooding. These two events coarsely indicate a SoP of 4% AEP, prior to the tidal gates being constructed.
06	The railway line provides protection against tidal weiring, damage and breach up to the 0.1% AEP event.	Not covered.	No storms recorded.
07	The railway line provides protection against tidal weiring, damage and breach up to the 0.1% AEP event. Local tidal inundation, controlled by high ground, can occur where bridges/culverts under the railway allow.	Not covered.	

FCRM unit	EEFCRMS SoP, using EA (2011) EWLs	Evidence from Royal Haskoning (2008), using EA (2003) EWLs	Evidence from natural events analysis
08	Embankments have a variable SoP, with tidal weiring, damage and breach occurring between 20-0.1% AEP events. This would flood agricultural land and the C527 road.	Output points indicate flooding in the 10% AEP event.	Road flooding in the December 2012 fluvial storm event, with near overtopping of the Frog Lane embankment.
09	Embankments between Grindle Brook and the A376 bridge allow weiring, damage and breach in the 0.5-0.1% AEP event. This would flood agricultural land, but not the A376 road. Upstream of the A376 bridge weiring, damage and breach is affected by fluvial events.	Output points indicate flooding more regular than 10% AEP event downstream of the Grindle Brook.	
10	Upstream of the A376 bridge fluvial-tidal weiring, damage and breach is unlikely to occur.	Output points indicate no flooding.	No storms recorded.
11	Embankments have a variable SoP, with tidal weiring, damage and breach occurring between 20-0.1% AEP events. This would flood agricultural land, but not the A376 or Clyst Road.	Output points generally indicate flooding more regular than the 10% AEP event.	
12	Various assets give a wide range of SoPs, varying between 10% to 0.1% AEP for tidal weiring and damage, with constrained flooding. Breach is unlikely.	Only partly covered by output points. Indicates flooding in the 4% event, but also up to 0.1% AEP event.	A storm event in 1957 occurred. This coarsely indicates a SoP of 2% AEP.
13	Variable risk of weiring, with non-residential areas flooding in the 100% AEP event, and residential areas in the 0.1% AEP event. The sewage treatment works embankments would experience tidal weiring in the 4-2% AEP event.	Compartment 20 (Sewage Works on an island near Countess Weir) floods in the 1% AEP event.	Storm events in 1869, 1926, 1929 and 1960 caused damage or flooding, although not clearly at Countess Wear or Exminster.
14	From St James Weir to Powderham, tidal weiring generally in the 0.1% event. A weaker spot near Powderham would experience breach in the 2% AEP event.	Compartments 1 (north of Powderham Manor), 3 (north of 1), 4 (north of 3), 9 to 13 (opposite Exminster and north to Bridge Road), 19 (contained by 13), and 28 (muddy area north of Bridge road) all flood more regularly than the 10% AEP event. Compartment 2 (south of Turf Lock and seaward of railway) floods in the 0.5% AEP event. Compartment 5 (south of Turf Lock) floods in the 2% AEP event. Compartment 6	

FCRM unit	EEFCRMS SoP, using EA (2011) EWLs	Evidence from Royal Haskoning (2008), using EA (2003) EWLs	Evidence from natural events analysis
		(north of Turf Lock) floods in the 1% AEP event. Compartments 7 and 8 (west of 6), and 18 (the canal itself north of Turf Lock) do not flood. Compartments 14-18, 21-22 and 29 all flood more regularly than the 10% AEP event.	
15	The River Kenn valley would experience tidal weiring in the 0.1% AEP event, damage in the 1% AEP event, and breach in the 0.5% AEP event.	Compartments 23 (Sewage works), 24 (nr Powderham Castle), 26 (by landing stage near Powderham Manor) and 27 (within 24) flood more regularly than the 10% AEP event. Compartment 25 (into Kenton) does not flood.	No storms recorded.
16	At Starcross, tidal weiring, damage and breach would be experienced in the 1-0.1% AEP event, with localised flooding in the 2% AEP event at low spots adjacent to the northern extent of the Strand, fishing club jetty and Generals Lane. At Cockwood, tidal weiring and damage would occur in the 4-10% AEP event, with breach unlikely.	Compartment 1 (Staplake Golf Course) flood in more regularly than the 10% AEP event. Compartment 2 (Starcross) floods in the 4% AEP event. Compartment 3 (harbour) and 4 (Middlewood and Westwood) do not flood.	Storm events in 1945 and 1957 caused damage and flooding. This coarsely indicates a SoP of 3% AEP.
17	The estuary side of Dawlish Warrensand spit and the village would experience tidal weiring in the 4-0.5% AEP event, with flood routes from Eales Dock and the sand spit. The coast facing distal and central sections of the sand spit would be damaged in the 10-100% AEP events, with potential breach in 10-1% AEP events. The proximal section of the sand spit would be damaged in the 0.1% AEP event.	Compartment 5 (Eastdon and south Cockwood), 6 (Welcome and Dawlish Warren Holiday Parks) and 8 (Dawlish Warren itself) all flood more regularly than the 10% AEP event. Compartment 7 (Lee Cliff Park) floods in the 4% AEP event. Compartment 9 does not flood.	Storm events in 1817, 1823, 1824, 1838, 1844, 1859, 1862, 1869, 1911, 1930, 1937, 1939, 1944-46, 1962, 1963, 1969, 1973, 1989, 1990, 2000 and 2004 caused erosion and flooding. The postwar storms coarsely indicate a SoP of 15% AEP.
18	Damage to the railway line and defences would occur in the 100% AEP event, with breach occurring in the 4% AEP event due to wave set-up influence.	Not covered.	Storm events in 1864, 1867, 1869, 1872-73, 1875, 1945, 1974 and 1989 caused damage and flooding. The 20th century storms coarsely indicate a SoP of 5% AEP.

Table 3.6 – Comparison of Standards of Protection for the year 2010.

3.6 Switching Point Analysis

3.6.1 Baseline Scenarios

The Do Nothing scenario is described by the application of all critical design parameters, namely damage, breach and design life criteria, assuming that the structural integrity of the FCRM assets is not maintained. SoP reduces in the short to medium term due to climate change impact, but in the longer term structural failure dominates. The Do Minimum scenario is described by the application of only the damage and breach criteria, assuming that the structural integrity of the FCRM assets is maintained: SoP reduces over the short to long term due to climate change impacts. The combined performance assessment results are given graphically in Appendix D, and a description is given below. An example diagram of how SoP reduces over time for the Do Nothing and Do Minimum scenarios is given in Figure 3.1.

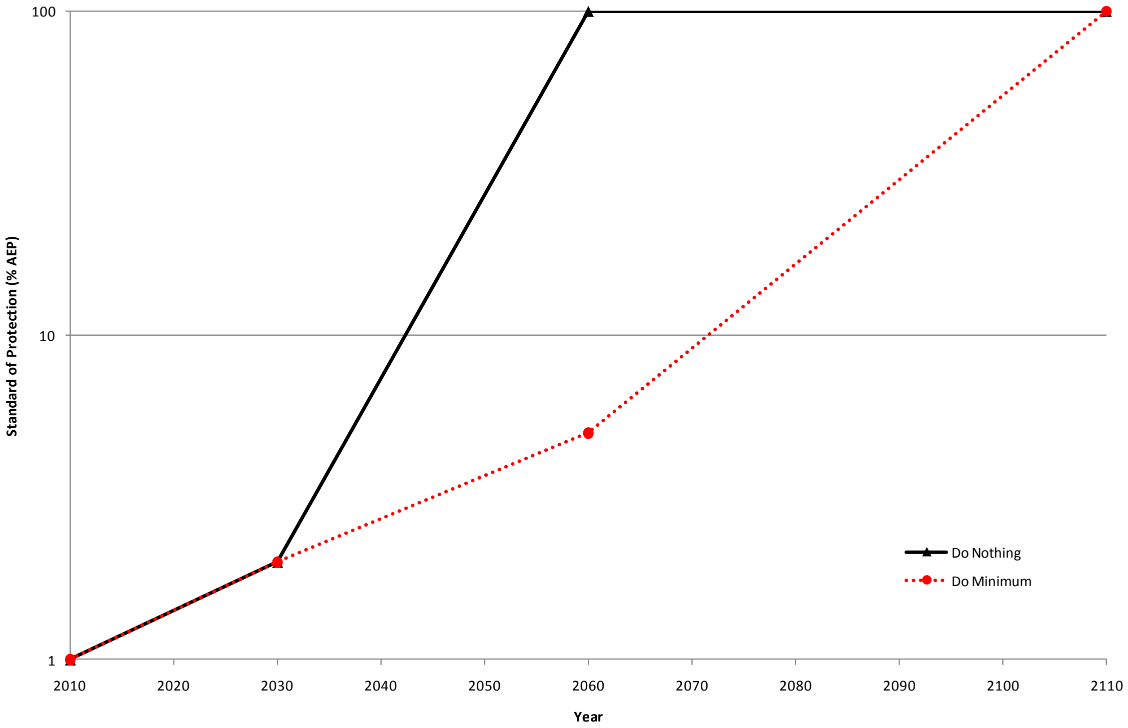
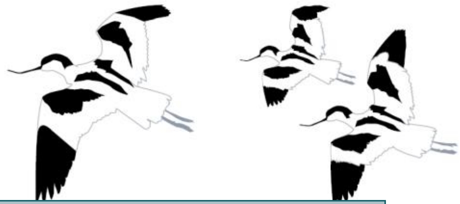


Figure 3.1 – Example change in SoP for the Do Nothing and Do Minimum scenarios.

3.6.2 Future Evolution of Dawlish Warren Sand Spit

The predicted evolution of Dawlish Warren sand spit represents a clear situation under which flood risk could be significantly changed. Accordingly, the impact of this loss was assessed against the Do Minimum scenario, regardless of when specifically the distal end of Dawlish Warren would be permanently flattened. The findings are summarised in Table 3.7. In summary, FCRMU08-13 would not experience any significant change in SoP, and FCRMU16 would experience a large reduction of SoP to 20-100% AEP. Elsewhere the impact is a minor reduction in SoP.



Location	FCRM units	Wider impacts
Sandy Bay to the Maer	01 to 02	No change in SoP.
Exmouth	03	Tidal weiring SoP reduced from 4% to 10% AEP for 2010. No change in SoP for 2030-2110.
Lympstone	05	Breach SoP reduced from 1% to 4% AEP for 2010, from 2% to 20% AEP for 2030, and from 20% to 100% AEP for 2060. Breach SoP in 2110 remains as 100% AEP.
Courtlands, Lympstone Commando, Exton	04, 06, 07	No change in SoP in 2010-2060. Breach SoP in 2110 reduced from 0.1% to 2% AEP.
Clyst St. Mary to Countess Wear	08 to 13	No change in SoP.
Exminster Marshes and Powderham Banks	14	Breach SoP reduced from 0.1% to 0.5% AEP for 2010, and from 1% to 2% AEP in 2030. Breach SoPs in 2060 and 2110 remain as 10% and 100% AEP respectively.
Kenn Valley	15	Breach SoP reduced from 0.1% to 2% AEP for 2010-2030, from 2% to 10% AEP in 2060, and from 10% to 100% AEP in 2110.
Starcross	16	Breach SoP reduced from 0.1% to 20% AEP for 2010, and from 1-4% to 100% AEP for 2030-2060. Breach SoP in 2110 remains as 100% AEP.
Dawlish Warren to Holcombe	17 to 18	No change in SoP.

Table 3.7 – Impact of Dawlish Warren sand spit evolution on breach risk.

3.6.3 Future Management of Railways

The future management of the railways also represents a clear situation under which flood risk could be significantly changed. The impact of this has been assessed against the Do Nothing scenario, with the performance assessment indicating that during 2030 to 2060 the railways would no longer fulfil their FCRM function. The findings are summarised in Table 3.8.

3.6.4 Climate Change Scenarios

The predicted future probability of flooding (measured by SoP) within the study area is also dependent on the choice of climate change scenario. The variation in probability is summarised in Table 3.9. Locations that show relatively high sensitivity to climate change variations consist of Exmouth, Lympstone, Exminster, Powderham and Starcross. At these locations the SoP in 2030 would vary by at least an order of magnitude.

Location	FCRM units	Wider impacts
Sandy Bay to Lympstone, Clyst St. Mary to Countess Wear, Dawlish Warren	01 to 05, 08 to 13, 17	No change in SoP.
Lympstone Commando and Exton	06 and 07	No change in SoP for 2010 and 2030. Breach SoP reduced from 0.5-0.1% to 100% AEP for 2060-2110.
Exminster Marshes and Powderham Banks, Kenn Valley	14 to 15	No change in SoP for 2010 and 2030. Breach SoP reduced from 4% to 100% AEP for 2060, and from 10-100% to 100% AEP in 2110.
Starcross	16	No change in SoP for 2010 and 2110. Breach SoP reduced from 1-4% to 100% AEP for 2030-2060.
Dawlish Warren to Holcombe	18	No change in SoP for 2010, 2030 and 2110. Breach SoP reduced from 4% to 100% AEP for 2060.

Table 3.8 – Impact of future management of railways on breach risk.

Location	FCRM units	Climate change scenario influence
Sandy Bay	01	In all climate change scenarios, the beach and cliff control the level of erosion risk until 2110, by which time if the cliffs are allowed to erode, the local caravan park would be partly undermined. If the cliff position is maintained, no assets would be at risk.
The Maer	02	In the low to upper end emissions scenarios, the seaward dunes and wall would be damaged in the short term, but flood risk limited due to ground levels through to 2110. In the upper end plus surge scenario, flooding could occur in 2110 for the 1-0.1% AEP events.
Exmouth	03	In the low to upper end emissions scenarios, tidal weiring occurs in the 10% AEP event in 2030, and 20-100% AEP event in 2060-2110. In the upper end plus surge scenario, tidal weiring would occur in the 100% AEP event from 2030 onwards.
Courtlands	04	In all emissions scenarios, the railway provides protection against tidal weiring, damage and breach up to the 0.1% AEP event in 2010-2030. In the low to medium emissions scenarios, this reduces to between 0.5-0.1% AEP in 2060-110. In the upper end and plus surge scenarios, this reduces to 4%-100% AEP in 2060-2110.
Lympstone	05	In the low to upper end emissions scenarios, the tide gates provide protection against breach for 2% AEP events in 2030, and 10-20% AEP events in 2060. In the upper end plus surge scenario, the tide gates provide protection against breach for 20-100% AEP events in 2030-2110.
Lympstone	06	In all emissions scenarios, the railway line provides protection

Location	FCRM units	Climate change scenario influence
Commando		against breach up to the 0.5-0.1% AEP events in 2030-2060, and between the 0.5-100% AEP events in 2110.
Exton	07	
East bank of the Lower Clyst	08	In all emissions scenarios, the embankments would experience tidal weiring and breach in the 100% AEP event in 2030-2110. The C road would be flooded in all the scenarios. In the low to upper end emissions scenarios, the A376 and Clyst Road would be flooded to varying degrees between 2060-2110. In the upper end plus surge scenario this would occur by 2030.
Clyst St. George	09	
West bank of the Lower Clyst	11	
Sowton	10	In all emissions scenarios, the embankments would experience tidal weiring and breach in the 2-0.1% AEP events between 2030-2060, and between 100-0.1% AEP events in 2110.
Topsham	12	In all emissions scenarios the various assets would give a wide range of SoPs, varying between 20% to 0.1% AEP for tidal weiring and damage, with constrained flooding. The sewage works embankments would experience tidal weiring in the 20-4% AEP events in 2030, and 100-20% AEP events in 2060-2110.
Countess Wear	13	
Exminster Marshes and Powderham Banks	14	In the low to upper end scenarios, the embankments would experience breach in the 0.5-0.1% AEP events in 2030, 20-10% AEP events in 2060, and 100%-20% AEP events in 2110. In the upper end plus surge scenario, breach would occur in the 4% AEP event in 2030, and 100% AEP event in 2060-2110.
Kenn Valley	15	In the low to upper end scenarios, the embankments would experience breach in the 2-0.5% AEP events in 2030, 4-2% AEP events in 2060, and 100%-4% AEP events in 2110. In the upper end plus surge scenario, breach would occur in the 20-2% AEP events in 2030, and 100-20% AEP events in 2060-2110.
Starcross	16	
Dawlish Warren	17	For all emissions scenarios, the estuary side of Dawlish Warren would experience tidal weiring in the 10-100% AEP events in 2030-2110. The coast facing distal and central sections would experience potential breach in 20-4% AEP events in 2030, and 100-20% AEP events in 2060-2110.
Dawlish to Holcombe	18	In the low to upper end scenarios, the railway defences would experience breach in the 2-1% AEP events in 2030, 4-2% AEP events in 2060, and 100%-10% AEP events in 2110. In the upper end plus surge scenario, breach would occur in the 4% AEP event in 2030, and 100% AEP event in 2060-2110.

Table 3.9 – Impact of climate change scenarios on flood and coastal risk.

3.7 Summary

At a strategic level, regardless of whether structural integrity is maintained, by 2110 the predicted climate change impact would reduce SoP against breach to low levels around the majority of the Exe Estuary. This implies that in the longer term active decisions would need to be made to either allow FCRM assets to become non-functional or to carry out some form of improvement.

Analysis of the role of Dawlish Warren sand spit in controlling flood risk throughout the Exe Estuary indicates that the future management of Dawlish Warren sand spit is a truly strategic issue that significantly impacts on flood risk in the wider estuary. In relation to this, the analysis of climate change scenarios indicates that the predicted evolution of Dawlish Warren sand spit (likely separation and permanent flattening of the distal end towards 2060) is relatively insensitive for the low to upper end scenarios. In the upper end plus surge scenario the timing of significant change to the distal end could potentially move towards 2030. Future management of the mainline and branch railways is also significant, but its influence is more spatially intermittent.

4. Socio-Economic Damage Assessment

4.1 Introduction and Methodology

4.1.1 Problem Definition

This section summarises the socio-economic appraisal undertaken to estimate the Do Nothing and Do Minimum damages within the study area. The economic benefit assessment has been produced in accordance with HM Treasury Guidance, the FCERM-AG, the Flood Hazard Research Centre's Multi-Coloured Manual and Handbook (2010) and the latest Defra guidance.

4.1.2 Study Area

There are approximately 3,918 properties at flood or erosion risk in the study area in 2010, with a total population of approximately 7,000. Of the 3,918 properties, 3,148 are residential and 770 are commercial properties. This increases to 5,421 properties by 2110 due to predicted sea level rise. Land use in the study area is extremely varied, containing both large industrial / commercial and residential areas, and small, rural areas with few, scattered properties. The study area includes a number of key infrastructure assets, including electricity sub-stations, sewage treatment works, and regionally important rail links. FCRM assets across the study area vary from heavily engineered revetments through to non-engineered embankments.

4.1.3 Study Time Horizon

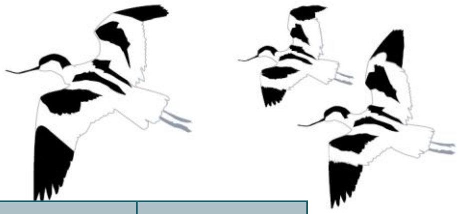
It is recommended by FCERM-AG that the economic appraisal covers the life of the longest lasting scheme. As this stage of the strategy does not consider any flood risk management Do Something options, it is proposed that a 100-year time horizon is adopted for this appraisal.

Extreme water levels at eight return period events (100%, 20%, 10%, 5%, 2%, 1%, 0.5% and 0.1% AEP events) and at four points in time (years 2010, 2030, 2060 and 2110) across our study time horizon have been used to determine damages over time.

4.2 Assets at Flood and Coastal Risk

4.2.1 Property

Table 4.1 outlines the numbers of residential and non-residential properties (NRPs) within each FCRM unit in the strategy area, and this is shown graphically in Figure 4.1. It is evident that the majority of the properties at risk are located in FCRM unit 3, 12, 14, 16 and 17.



Location	FCRM Unit	Number of residential properties	Number of NRPs	Total
Sandy Bay	01	0	0	0
The Maer	02	0	0	0
Exmouth	03	1563	476	2039
Courtlands	04	0	0	0
Lympstone	05	115	26	141
Lympstone Commando	06	0	0	0
Exton	07	1	1	2
East bank of the Lower Clyst	08	11	29	40
Clyst St. Mary	09	27	7	34
Sowton	10	0	0	0
West bank of the Lower Clyst	11	1	1	2
Topsham	12	110	17	127
Countess Wear	13	5	4	9
Exminster Marshes and Powderham Banks	14	86	64	150
Kenn Valley	15	13	14	27
Starcross	16	568	78	646
Dawlish Warren	17	635	53	688
Dawlish to Holcombe	18	13	0	13
Total		**3148**	**770**	**3918**

Table 4.1 – Total numbers of properties at flood risk (0.1%AEP) in 2010 in each FCRM unit.

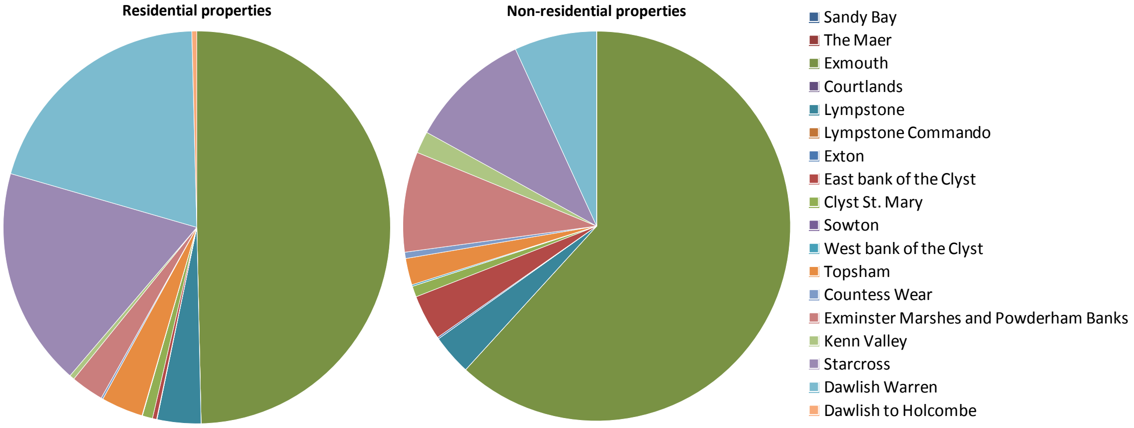


Figure 4.1 – Proportion of residential and non-residential properties across the study area.

There are a number of Local Authority Plans of relevance that outline targets for the future development of residential and commercial assets. For example, the Exeter City Local Development Framework (October 2006) aims to provide 7,875 dwellings and up to 60 ha of employment land between 2006 and 2021. The East Devon Local Plan (July 2006) makes provision for the allocation of 1.39 Ha employment land in Exmouth. However, the location of these proposed developments is not specified, and hence whether these sites would be at risk of flooding is not known. In line with the Environment Agency's 'Economic evaluation of damages for Flood Risk Management projects' (May 2008), these planned developments cannot be included as part of the economic appraisal of benefits.

4.2.2 Agricultural Land and Environmental Sites

The impact of flooding on environmental sites will be analysed in the Strategic Environmental Assessment (SEA) later in the development of the strategy. Table 4.2 shows the areas of agricultural land by Agricultural Land Classification (ALC); this demonstrates that whilst 50% of the agricultural land in the Strategy area is Grade 4, 25% is Grade 1.

Agricultural Land Grade	Area in the FCRM Units (km²)
1	4.9
2	0.5
3	3.9
4	9.7
5	0
Total	**19**

Table 4.2 – Total areas of agricultural land by grade in the Strategy study area.

4.2.3 Transport Infrastructure

Locally and regionally transport infrastructure at risk includes:

- C527 road (significant local link) connecting Topsham and Ebford;
- A376, A379;
- Branch railway line connecting Exeter and Exmouth; and,
- Mainline railway between Exeter and Dawlish.

4.2.4 Caravan Sites

There are two locations within the strategy area where caravan sites and mobile home parks are at risk; with the majority in and around Dawlish Warren (FCRMU17), where a total of approximately 611 caravans are at risk from the 0.1% AEP event in 2110. In FCRMU 1 (Sandy Bay) there are approximately 58 caravans at risk from erosion of the cliff face.

4.2.5 Recreation

Tourism is a vitally important industry and employer within Devon, and within the study area at locations such as Exmouth and Dawlish Warren. In 2008 the total related visitor spend within Devon was estimated to be £2.1 billion, with tourism related employment estimated to be 11%. Whilst figures for visitor numbers and spend within the study area are not known in detail, it has been suggested that Dawlish Warren alone receives 500,000 visitors per year. Based on this estimate, and using average loss values per adult visit provided in Chapter 8 of the MCH would suggest Do Nothing damages for the loss of the Dawlish Warren site in excess of £3 million. It should be noted however that this value assumes write off in year 0, and is not therefore subject to discounting.

Although other sites in the study area are not thought to attract as many visitors as Dawlish Warren, they remain popular tourist destinations which are locally important for income and employment in the Strategy area.

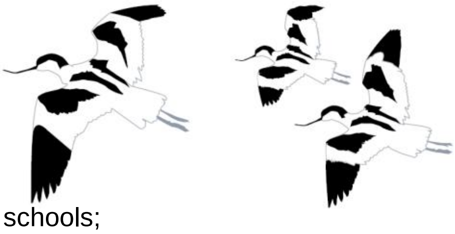
Recreational assets at risk within the study area include:

- Exeter Canal;
- Dawlish Warren sea front, golf course and associated attractions; and,
- Recreational assets in Exmouth including the sea front, Imperial Recreation Ground and Exmouth Town Football Club.

Recreational benefits or losses have not been calculated in detail at this stage. This will be reviewed however for marginal flood cells where the inclusion of recreational benefits may influence the preferred option.

4.2.6 Receptors Vulnerable to Flooding

The Environment Agency’s Receptors Vulnerable to Flooding Database was interrogated to assess the potential impact on key infrastructure assets such as water treatment plants, electricity sub stations and schools. This analysis indicated that at the 0.1% AEP event in 2110 the following assets would be at risk:



- 5 waste management sites;
- 1 telephone exchange;
- 1 site containing radioactive substances;
- 2 sewage treatment works;
- 2 schools;
- 3 railway stations;
- 25 electricity sub-stations;
- 1 emergency response centre and,
- 4 care homes.

4.3 Valuation of Assets at Risk

4.3.1 Identification of Property Type

The 2009 edition of the National Property Database (NPD), provided by the Environment Agency, has been used to identify all of the residential and non-residential (NRP) properties within the flood risk area. Using the FOCUS property type code provided in the NPD, the property use was looked up in the FOCUS-MCM Indicative depth-damage spreadsheet by John Chatterton, to determine its equivalent MCM code. Where no FOCUS property type code was provided for NRP a weighted average for NRP was applied.

A substantial number of properties (approximately 2,254 of 12,350) within the NPD were coded with ‘XTRA’, and could not therefore be accurately or readily defined. To manually define this number of properties (using OS mapping, aerial photographs and site visits) would take a considerable amount of time and effort, and would be beyond the scope of this study. A simplified approach to identifying these properties was therefore applied. Correspondence with the developers of the NPD revealed that these ‘XTRA’ coded properties were generally NRP’s, and more specifically outbuildings, storage units or warehouses. All ‘XTRA’ coded properties were therefore defined as Warehouses and assigned the appropriate MCM code; this approach was considered appropriate for a strategy level study.

4.3.2 Flood Depth-Damage Calculations

The depth-damage statistics provided in the MCM (2010) are quoted at 2010 prices and do not therefore need to be adjusted for inflation using the Retail Price Index (RPI).

Residential Properties

Flood damages for residential properties have been taken from the Flood Hazard Research Centre’s (FHRC) Multi-Coloured Manual (MCM). The MCM contains depth-damage data for a range of residential and non-residential property types. This enables specific depth-damage calculations to be made according to the type and age of a property.

Residential property types were defined based on that provided in the NPD, and have been classified as either flat, terrace, bungalow, semi-detached and detached. As a strategy level study it was not felt appropriate to define residential properties by age. Socio-economic equity issues have been taken into account by applying Distributional Impact factors to residential capital values. This was based on social class information provided on the ONS website (http://www.neighbourhood.statistics.gov.uk).

In line with guidance from the MCM damages to residential building fabric have been increased by 10% to take into account the impact of saline flooding.

Non-Residential Properties

The depth-damage data for the NRP’s is based on the figures published in the MCM. MCM data for NRP’s is provided in damages per m². It should be noted that basement flood damages have

been removed from the damage assessment; this will under-estimate flood damages since it assumes that no properties have basements when in reality this is unlikely to be the case.

4.3.3 Capital Value of Residential and Non-Residential Properties

Residential property capital values have been derived from those provided in the NPD (2009/10), and adjusted for the distributional impact factor. The NPD also provided capital values for the majority of the NRP's in the study area. However, where no capital value was provided by the NPD, the NRP's capital values are based on rateable value figures for the south-west published by Communities and Local Government, floor area as specified in the NPD, and equivalent yields published by the Environment Agency. Total capital values are summarised in Table 4.3.

Location	FCRM Unit	Residential Capital Value (£)	NRP Capital Value (£)
Sandy Bay	1	£190,187	N/A
The Maer	2	£5,076,355	£2,931,953
Exmouth	3	£766,701,385	£85,803,702
Courtlands	4	£3,154,756	£174,408
Lympstone	5	£44,859,236	£1,961,459
Lympstone Commando	6	£180,749	£698,421
Exton	7	£23,294,554	£1,986,549
East bank of the Lower Clyst	8	£3,028,828	£14,919,025
Clyst St. Mary	9	£30,965,383	£14,015,758
Sowton	10	£818,704	£54,475,832
West bank of the Lower Clyst	11	£14,693,664	£3,760,302
Topsham	12	£267,813,435	£15,898,568
Countess Wear	13	£127,220,166	£5,378,260
Exminster Marshes and Powderham Banks	14	£121,704,004	£180,544,788
Kenn Valley	15	£35,407,712	£3,907,197
Starcross	16	£190,947,074	£11,008,450
Dawlish Warren	17	£95,136,575	£23,974,826
Dawlish to Holcombe	18	£174,459,181	£9,346,748
	Total	£1,905,461,761	£430,786,246

Table 4.3 – Total property capital values.

4.3.4 Transport Infrastructure

Estimation of losses to transport infrastructure have been limited to that related to the railway network since the roads affected by flooding are either relatively minor, or have short diversion routes, and as a result would incur minimal economic damages. There are two components of potential damages associated with the disruption of the railway service following breach:

1. Loss of revenue to the train operator.
2. Replacement of damaged track / equipment.

Guidance and data from Chapter 6 of the MCM has been applied, based on a case study of damages associated with the Paddington to South Wales Inter-City rail link and Midlands regional railway which cross the Gwent Levels. Network Rail is responsible for paying train operators compensation if a line is closed as a result of flooding. The case study in the MCM estimates a compensation payment of £74,000 per day, and assumes that the line is closed for one week following a breach. This gives a total compensation value of £518,000 per breach. To estimate the additional cost of replacing and repairing the line, the MCM states that the cost to raise the track and armour the embankments against future slippage was £3.6 million per kilometre (at 2000 prices). This study has pro-rated this value according to the length of breach, although it is accepted this value may underestimate the true cost at today's prices. The total damages following a 20 metre breach of the line are therefore estimated to be £590,000. These values were discussed with Network Rail and found to be reasonable within the context of the railways of interest for this study, although Network Rail have noted that traffic on rail is expected to increase.

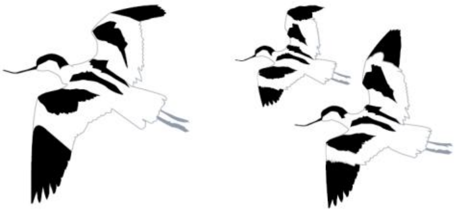
Under the Do Nothing scenario it is reasonable to consider as part of the write-off damages the cost of re-laying the track following a different route inland away from tidal flooding. However, due to the extremely high costs involved, and the variety of potential routes available such a scenario has not been included since it was not thought to provide an accurate representation of the damages, and would significantly distort the baseline case. Furthermore, based on guidance in the MCM the process of re-laying a new line would take at least 20 years and include a convoluted process of negotiating wayleaves and Acts of Parliament.

4.3.5 Agricultural Land

Agricultural damages have been calculated following Defra guidance, and applying average market values by agricultural grade provided in the MCM. Under the Do Nothing scenario we have assumed that agricultural land is written off since the progressive ingress of saline water would make the land unsuitable for agriculture. The area written off is equal to the 0.1% AEP flood event outline in 2110. Table 4.4 contains the market and write-off values applied in this assessment.

Agricultural Land Grade	Approximate market value (£/ha)	Write-off value (£/ha)
1	6,890	6,290
2	6,890	6,290
3	7,650	7,050
4	5,100	4,500
5	5,100	4,500

Table 4.4 – Market value of agricultural land.



4.3.6 Caravan Parks

The assessment of caravan park damages has only been undertaken for FCRM units 1 and 17; elsewhere in the study area the number and size of caravan parks does not justify such a detailed approach. Damages to caravan parks have been calculated following guidance provided by the Environment Agency (2008); this recommends applying a relocation cost of £4500 to £6000 per caravan in the Do Nothing scenario. In this assessment we have taken a mid-value of £5000 per unit as the write-off value for each caravan. Aerial images were used to calculate the number of caravans within each park.

4.3.7 Other

The MCH 2010 recommends using a variable factor to account for the costs of emergency services, with 5.6% being used for dense, urban areas, and 10.7% for dispersed, rural areas. The 5.6% adjustment has been applied for areas upstream of Topsham (but also including Exmouth); elsewhere the 10.7% factor has been applied.

Temporary accommodation costs are based on figures provided by the Flood Hazard Research Centre (FHRC), based on analysis of the flooding events occurring in summer 2007. These give temporary accommodation costs of £6,695 for residential properties and £5,461 for non-residential properties.

4.3.8 Calculation of Average Annual Damages, Write-off and Capping

Average annual damage (AAD) figures were calculated across the 100-year appraisal period, based on the four time horizons (2010, 2030, 2060 and 2110) with AAD's interpolated between these years.

The AAD's were used to determine present value damages (PVds) over the 100-year appraisal period for each flood cell. Where properties are shown to have flood damages above their capital value, based on the discounted value of the property specific AAD over the 100-year time horizon, it has been assumed that the property should be abandoned and has been written off.

4.3.9 Discounting

Damages were discounted using the HM Treasury recommended rates, as published in the Green Book and given in Table 4.5. Discounting will have the effect of reducing the value of damages that are incurred in the future.

Year	Discount Rate (%)
0-30	3.5
31-75	3
76-100	2.5

Table 4.5 – Variable discount rate.

4.4 Economic Damages

Table 4.6 summarises the economic damages for each FCRM unit for the Do Nothing scenario. This demonstrates that the highest economic damages are incurred in FCRM unit 3 (Exmouth) and FCRM unit 16 (Starcross). For FCRM unit 4, 6, 7 and 18 over 80%, and for FCRM unit 15-17 20-70% of the total PVd is incurred from railway damages. Table 4.7 summarises the Do Minimum scenario economic damages and benefits compared to Do Nothing.

Location	FCRM Unit	RP PVd (£k)	NRP PVd (£k)	Railway PVd (£k)	Indirect PVd* (£k)	Total PVd (£k)	Write-off (£k)
Sandy Bay	1	0	0	0	0	15	290
The Maer	2	0	4	0	0	4	0
Exmouth	3	39,062	5,026	0	27,233	354,911	285,695
Courtlands	4	2	2	41	3	7,266	7,218
Lympstone	5	4,471	79	0	1,871	22,051	15,837
Lympstone Commando	6	0	7	62	5	7,288	7,214
Exton	7	137	7	45	19	7,468	7,260
East bank of the Lower Clyst	8	0	339	0	476	4,852	4,064
Clyst St. Mary	9	2,485	41	0	508	4,219	1,184
Sowton	10	0	0	0	0	166	166
West bank of the Lower Clyst	11	1	33	0	51	706	621
Topsham	12	5,109	756	0	1,394	16,585	9,379
Countess Wear	13	590	2	0	147	903	162
Exminster Marshes and Powderham Banks	14	9,051	139	108	2,089	37,027	34,333
Kenn Valley	15	452	37	247	290	10,703	9,673
Starcross	16	11,734	55	16,167	6,218	145,441	117,379
Dawlish Warren	17	1,752	134	188	1,088	13,135	12,318
Dawlish to Holcombe	18	3,329	1	16,167	404	21,755	9,000
Total		**78,175**	**6,663**	**33,024**	**40,719**	**654,495**	**521,795**

** Indirect PVd includes for temporary accommodation and emergency services.*

Table 4.6 – Summary of Do Nothing economic damages.

Location	FCRM Unit	Total PVd (£k)	Total PVb (£k)
Sandy Bay	1	0	15
The Maer	2	4	0
Exmouth	3	216,365	138,546
Courtlands	4	141	7,125
Lympstone	5	14,985	7,066
Lympstone Commando	6	78	7,211
Exton	7	62	7,406
East bank of the Lower Clyst	8	4,880	-28
Clyst St. Mary	9	3,217	1,002
Sowton	10	9	157
West bank of the Lower Clyst	11	706	0
Topsham	12	17,965	-1,379
Countess Wear	13	802	101
Exminster Marshes and Powderham Banks	14	30,518	6,509
Kenn Valley	15	1,574	9,129
Starcross	16	50,894	94,547
Dawlish Warren	17	12,948	188
Dawlish to Holcombe	18	12,181	9,574
Total		**367,329**	**287,169**

Table 4.7 – Summary of Do Minimum economic damages and benefits.

4.5 Risks to People and Social Vulnerability

The potential impact of flooding on communities in this study area is significant. In the 0.1% AEP event in 2110 there are an estimated 4400 residential properties at risk of flooding, putting approximately 10,500 people at risk (based on the average of 2.36 people per household derived from the 2001 census). The number of residential properties written off is 2400, impacting on approximately 5500 people.

As well as the distress experienced during and following flooding, people have to cope with the time, effort and cost of cleaning up and making repairs. Some people may also have the disruption of living in temporary accommodation. This can cause people to suffer from extreme stress and can result in illness. Specific groups of people will be more vulnerable than others to

these effects of flooding. We have assessed how vulnerable the population is to flooding incidents by using the Flood Hazard Research Centre's Social Flood Vulnerability Index (SFVI).

The SFVI is a national dataset that covers the whole of England and Wales, and categorises vulnerability by output areas based on the latest survey information and aims to identify communities that are most vulnerable to the adverse health and social effects associated with floods. A SFVI of 1 is very low social vulnerability to flooding, whilst a SFVI of 5 is very high social vulnerability to flooding. The factors used to define vulnerability to flooding are:

- people aged 75 and over;
- people suffering from long term limiting illnesses;
- lone parent households; and,
- financially deprived households (unemployment, overcrowding, non-car ownership, non-home owning).

The first three variables are directly available from census data. The financial deprivation is represented by the Townsend Index, which uses unemployment, overcrowding, non-car ownership and non home ownership as indicators. This index was created in the context of a "broad-scale" approach to the assessment of vulnerability and cannot be used for more detailed applications. Five resulting categories of risk are defined ranging from very low to very high vulnerability. From Table 4.8 it is clear that there are significant numbers of people within SFVI categories 3 and 4 at risk from flooding in the Strategy area.

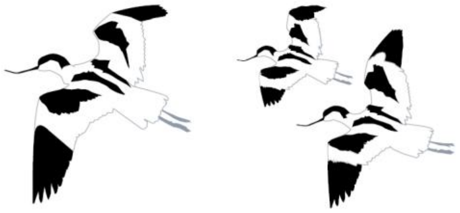
Social Flood Vulnerability Index (SFVI)	Number of Wards	Approximate total population	Approximate % at risk of flooding
1	0	0	0%
2	3	740	20%
3	90	24,442	28%
4	36	8,621	39%
5	0	0	0%

Table 4.8 – Social Flood Vulnerability Index.

4.6 Switching Point Analysis

4.6.1 Economic Benefit of Dawlish Warren Sand Spit

The variation in SoP related to how Dawlish Warren sand spit evolves into the future was applied within the Do Minimum economic appraisal. This is summarised in Table 4.9, related to when the distal end of Dawlish Warren sand spit is damaged permanently. This analysis includes the effect of variation in Standard of Protection, but not the much lesser effect of a less than 0.1m increase in EWLs. The findings indicate that whilst the variation in SoP affects the estuary generally, the economic consequence of this variation is focussed predominantly at Exmouth (FCRMU03), Lympstone (FCRMU05) and Kenn Valley to Starcross (FCRMU15-16). Elsewhere the consequences are much more limited. The most likely economic benefit is around £92 Million, based on the distal end of Dawlish Warren sand spit being permanently separated and flattened by 2060.

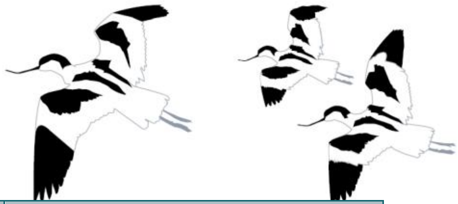


FCRM Unit	Present Value Benefit (£k) with Dawlish Warren sand spit maintained compared to Dawlish Warren sand spit damaged in…			
	2010	2030	2060	2110
1	0	0	0	0
2	0	0	0	0
3	15,933	16,185	16,944	13,552
4	31	31	31	30
5	-899	-902	-1,076	-1,041
6	101	101	101	101
7	15	15	15	15
8	0	0	0	0
9	0	0	0	0
10	0	0	0	0
11	0	0	0	0
12	0	0	0	0
13	0	0	0	0
14	2,344	2,611	2,574	2,425
15	9,333	8,825	8,522	7,909
16	193,779	163,170	64,555	2,924
17	0	0	0	0
18	0	0	0	0
Total	**220,636**	**190,036**	**91,665**	**25,915**

Table 4.9 – Economic benefit of permanently maintaining the structure of Dawlish Warren sand spit.

4.6.2 Economic Benefit of Railways

The variation in SoP related to how railway embankments are managed into the future was applied within the Do Nothing economic appraisal. This is summarised in Table 4.10. Whilst this analysis shows a total PVb of £53 Million, these findings are sensitive to assumptions surrounding when and if railway annual damages and write-off should occur.



FCRM Unit	Do Nothing PVd (£k)	Railways maintained PVd (£k)	Benefit of railways maintained PVb (£k)
1	15	15	0
2	4	4	0
3	354,911	354,911	0
4	7,266	155	7,110
5	22,051	22,051	0
6	7,288	98	7,190
7	7,468	59	7,410
8	4,852	4,852	0
9	4,219	4,219	0
10	166	166	0
11	706	706	0
12	16,585	16,585	0
13	903	903	0
14	37,027	37,027	0
15	10,703	2,412	8,291
16	145,441	132,352	13,089
17	13,135	12,948	188
18	21,755	11,712	10,043
Total	**654,495**	**601,175**	**53,321**

Table 4.10 – Economic benefit of permanently maintaining the railway embankments.

4.6.3 Economic Influence of Climate Change

The variation in SoP relating to the range of climate change scenarios was applied within the Do Nothing and Do Minimum economic appraisal. This is summarised in Table 4.11 and Table 4.12. Locations that show relatively high sensitivity of Do Nothing PVd to climate change variation include FCRMU05 (Lympstone), FCRMU09 (Clyst St. Mary), FCRMU11-14 (West Bank of the Lower Clyst, Topsham, Countess Wear, Exminster Marshes and Powderham Banks) and FCRMU18 (Dawlish to Holcombe). Locations that show relatively high sensitivity of Do Minimum PVb to climate change variation include FCRMU03 (Exmouth), FCRMU05 (Lympstone), FCRMU09 (Clyst St. Mary), FCRMU12 (Topsham), FCRMU14 (Exminster Marshes and Powderham Banks) and FCRMU16-18 (Starcross to Holcombe).

FCRM Unit	Present Value Damages (£k) in climate change scenario		
	Minimum scenario (low 50% emissions)	Core scenario (medium 95% emissions)	Maximum scenario (upper end plus surge)
1	15	15	15
2	0	4	38
3	282,244	354,911	559,179
4	7,259	7,266	7,515
5	13,100	22,051	28,460
6	7,277	7,288	7,568
7	7,314	7,468	8,646
8	3,830	4,852	7,222
9	991	4,219	13,546
10	166	166	210
11	653	706	3,274
12	7,307	16,585	45,180
13	302	903	9,058
14	27,679	37,027	98,375
15	9,971	10,703	15,403
16	111,821	145,441	204,996
17	10,449	13,135	24,771
18	2,822	21,755	33,910
Total	**493,199**	**654,495**	**1,067,366**

Table 4.11 – Economic influence of climate change scenarios on Do Nothing Present Value damages.

FCRM Unit	Present Value Benefits (£k) in climate change scenario		
	Minimum scenario (low 50% emissions)	Core scenario (medium 95% emissions)	Maximum scenario (upper end plus surge)
1	15	15	15
2	0	0	7
3	113,361	138,546	0
4	7,124	7,125	7,322
5	3,536	7,066	96
6	7,200	7,211	7,259
7	7,252	7,406	7,568
8	0	-28	0
9	0	1,002	4,175
10	157	157	162
11	0	0	0
12	-3,767	-1,379	7,926
13	27	101	162
14	17,494	6,509	9,471
15	8,657	9,129	8,862
16	74,367	94,547	31,554
17	4,364	188	188
18	1,581	9,574	15,428
Total	**241,368**	**287,169**	**100,196**

Table 4.12 – Economic influence of climate change scenarios on Do Minimum Present Value benefits.

4.7 Summary

The analysis of Do Nothing and Do Minimum scenario economic damages has highlighted that Do Minimum PVb is largest for Exmouth (FCRMU03) and Starcross (FCRMU16), and notable for Courtlands to Exton (FCRMU04 to 7) and Exminster to Holcombe (FCRMU14-18). This indicates that for the FCRM units outside these areas, FCRM options with greater improvements than Do Minimum would be required to possibly generate significant PVb. Analysis of the economic benefit of maintaining Dawlish Warren sand spit has indicated that this would have a PVb value of around £92 Million. The majority of these benefits come from Starcross (FCRMU16). Analysis of the economic benefit of maintaining the railway embankments indicates a PVb value of around £53 Million. Analysis of the relative sensitivity to climate change variation has indicated that the locations of Exmouth (FCRMU03), Lympstone (FCRMU05), Clyst St. Mary (FCRMU09), West Bank of the Lower Clyst, Topsham, Countess Wear, Exminster Marshes and Powderham Banks (FCRMU11-14) and Starcross to Holcombe (FCRMU16-18), have greatest sensitivity.

5. Conclusions and Recommendations

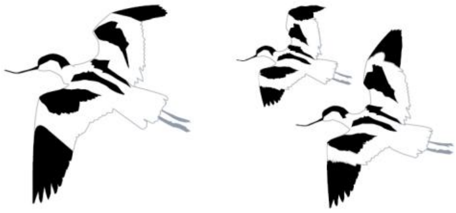
5.1 Strategic Conclusions

This stage of the EEFCRMS has identified the following:

- The Do Nothing analysis indicates that wide-scale inundation would occur by 2060 due to structural degradation of the majority of FCRM assets. This would seriously affect both man-made development and natural environments.
- Present Value damages for the Do Nothing scenario are estimated at £655 Million for the whole estuary. These damages are heavily weighted towards the areas of Exmouth and Starcross. £33 Million of the whole estuary damages are related to railway impacts.
- Present Value damages for the Do Minimum scenario are estimated at £367 Million for the whole estuary. Again these damages are heavily weighted towards the areas of Exmouth and Starcross.
- The future evolution of Dawlish Warren sand spit has been defined strategically as permanent separation and flattening of the distal end of Dawlish Warren sand spit by 2060, dependent on the Do Nothing or Do Minimum scenario. The main body of Dawlish Warren sand spit is expected to remain in existence in some form throughout the 100 year timescale, carrying out its remaining wave sheltering role.
- Switching point analysis has defined the economic Present Value benefit of Dawlish Warren sand spit and the railway embankments to the estuary. For Dawlish Warren sand spit this is estimated to be around £92 Million. The Present Value Benefit of maintaining the railway embankments is highly variable between FCRM units, amounting to a whole estuary value of £53 Million.
- Switching point analysis has also defined the influence of future climate change scenarios. The locations of Exmouth, Lympstone, Clyst St. Mary, West Bank of the Lower Clyst, Topsham, Countess Wear, Exminster Marshes and Powderham Banks and Starcross to Holcombe, have greatest sensitivity**.**

5.2 Strategic Recommendations

The key recommendation is that the predicted consequences of the current and future flood and coastal risk provides a sound case for further progression to developing and assessing options to manage flood risk and habitats over the next 100 years.



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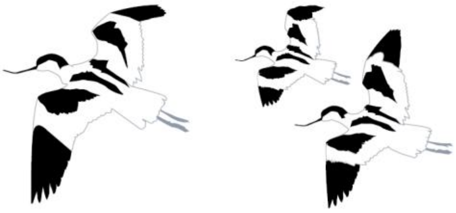
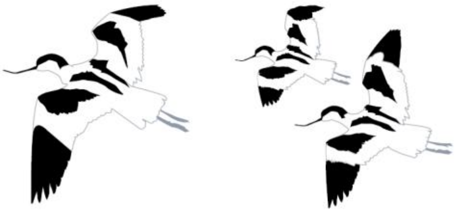
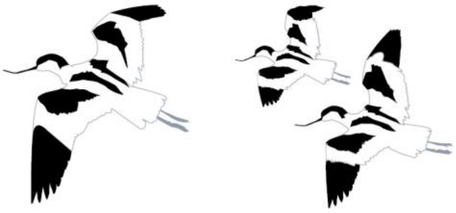




Appendix A : Expert Geomorphological Assessment



1 Introduction

1 Introduction

A number of studies have already been completed to understand the coastal and estuarine processes, particularly including:

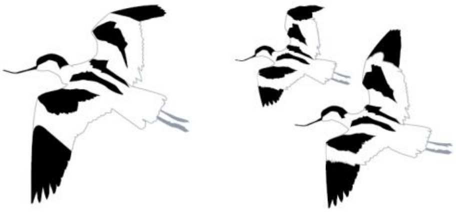
- FutureCoast (Defra, 2002)
- the Lyme Bay and South East Devon Sediment Transport Study (SCOPAC, 2003),
- the Exe Estuary Coastal Management Study (EECMS) (Halcrow, 2008), and
- the South Devon and Dorset Shoreline Management Plan 2 (Halcrow, 2010).

This report aims to summarise and integrate this previous work, and in light of historic evolution and the conceptual model, predict how key elements of the estuary and open coast will evolve into the future. This will particularly be defined for the key time horizons of 2030, 2060 and 2110.

This report includes a number of analyses, with the intention to build a robust evidence base for future predictions of geomorphological change. These analyses consist of:

- Baseline Understanding, which sets out the current understanding of the estuary system (Section 2)
- Human Impacts Review, which provides a timeline of human impacts and how they have affected the evolution of the estuary (Section 3).
- Natural Events Review, which provides a timeline of storm events in and around the estuary to give information and qualitative confirmation of key areas of risk (Section 4).
- Beach Profile and Storms Analysis, which provides information on the short term (decades) volumetric and spatial changes along Dawlish Warren and Exmouth beach (Section 5).
- Historic Spatial Analysis, which provides a long term (centuries) assessment of the spatial changes to the intertidal and supratidal features in the Exe Estuary(Section 6).
- Historic Volumetric Analysis, which defines giving a long term (centuries) assessment of the volumetric changes throughout the Exe estuary and more specifically around the estuary mouth (Section 7).
- Breach Analysis at Dawlish Warren, which defines the likelihood of breach of this key feature using a variety of methods (Section 8).
- Conceptual Model, which brings the above analyses together to develop an improved understanding of how the estuary system works, how it has evolved historically, and how it could evolve into the future (Section 9).

These analyses are described in the subsequent sections.



2 Baseline Understanding

1 Purpose

This section documents the existing understanding of the Exe Estuary system. The rationale for undertaking this work is that this basic understanding of the system provides the context for other analyses, highlights the areas where further understanding is required, and provides the basis for development of the conceptual model.

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2 Geomorphological Overview

The study area is comprised of three general systems:

- the open coast system, comprising embayments separated by headlands or large man-made structures. This is composed of two of sub systems:
    - Holcombe Rock to Langstone Rock
    - Straight Point to Orcombe Rock
- the estuary system, composed of two sub-systems:
    - the outer estuary, comprising the approach channel, related sandbanks and the spits of Dawlish Warren and Exmouth, limited by Langstone Rock and Orcombe Rock.
    - the inner estuary, including the main estuary body as well as the tidal reaches of the rivers Exe and Clyst up to St. James Weir and the weir near Clyst St. Mary respectively.

Further important sub systems that define the overall morphology are defined in the subsequent sections, using the terminology specified by defra/EA (2009).

3 Open Coast Processes: Holcombe to Langstone Rock

3.1 Geomorphological Context and Description

The open coast extends between the headlands of Holcombe to Straight Point. The coastline is defined by breccia and sandstone cliffs between Holcombe (the Parson and Clerk headland) and the smaller headland of Langstone Rock (and its associate groyne). A shore platform extends seawards, overlain by a sandy beach.

The key features are (moving from west to east):

- Parson and Clerk Headland
- Holcombe beach and Shell Cove
- Horse Rocks
- Coryton’s Cove
- Old Maid Rock
- Dawlish beach
- Langstone Rock

3.2 Anthropogenic Influences

The open coast between Holcombe and Langstone Rock has been heavily influenced by anthropogenic activities. The mainline railway was constructed in 1849, which has removed the impact of wave erosion for the majority of the coastline. Subsequent to this further groynes and seawalls were constructed. Further details are given in the Human Impacts Review.

3.3 Forcing Factors

The extreme wave climate was defined as part of the EEFCRMS study. Astronomic and extreme tide levels have previously been defined by Environment Agency (2011), summarised in Table 1. It is noted that the extreme tide levels are under review.

	MLWS	MHWS	100% AEP	10% AEP	1% AEP	0.1% AEP
Wave height (m)	NA	NA	2.33	2.81	3.03	3.14
Tide level (mAOD)	-1.63	2.17	2.75	2.98	3.21	3.47

Table 1. Wave and Tide Climate.

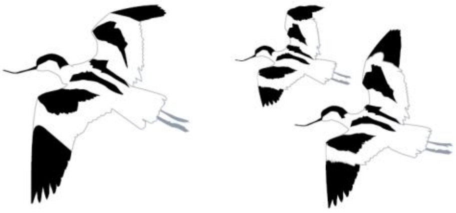
Tidal currents have not been quantified by previous work, but it is noted (SCOPAC, 2003) that they are relatively weak in comparison to those experienced at the Exe estuary inlet (1 to 3m/s on spring-neap cycles). Further details are given in the Natural Events Review.

3.4 Sediment Budget

The main source of sediment between Holcombe and Langstone Rock is supplied by erosion of the adjacent cliffs. However this mechanism is now predominantly inactive due to the railway construction (SCOPAC, 2003), as the construction of the Exeter to Plymouth main line railway in 1849 runs along the cliff toe between Dawlish Warren and Teignmouth. The railway artificially holds the shoreline in its present position and prevents the potential input of sediment from wave action at the cliffs. For the limited lengths of cliff which are still active, Posford Duvivier (1998) indicate a recession rate of 0.5m/yr, corroborated by Halcrow (2010). As the active cliff length is now much less than 1km, the amount of sediment supplied by this mechanism will be minimal (of the order of 1000m^3/yr) and centred around Shell Cove and Coryton’s Cove.

There is no known semi-permanent store of sediment, although it is noted (Posford Duvivier, 1998a) that there is significant cross-shore exchange under summer and winter wave conditions. Whilst Langstone Rock is noted as a barrier to longshore sediment transport, under more extreme wave conditions it is thought that sediment can bypass (SCOPAC, 2003).

Current understanding is that the net direction of littoral drift is south-west to north-east, with hindcast wave modelling (Posford Duviver, 1998) indicating that drift potential is between 68,000m^3/yr (Holcombe) and 13,000m^3/yr (Langstone Rock), assuming there is no limit on available sediment. SCOPAC (2004) noted that actual transport would be much lower than this, as suggested by the above estimate of 1000m^3/yr.



3.5 Potential Geomorphological Change

The potential change into the future is very dependent on future management of the mainline railway and Langstone Groyne. Beach erosion will continue into the future, and the difference in drift potential and available sediment would suggest that if Langstone Groyne was damaged or removed, significantly accelerated beach erosion could occur. Sea level rise and increased storminess will likely result in either unnaturally steepened beach slopes, or beach lowering, particularly in the medium to long term.

4 Open Coast Processes: Straight Point to Orcombe Rocks

4.1 Geomorphological Context and Description

The open coast extends between the headlands of Holcombe to Straight Point. The coastline is defined by sandstone cliffs between Straight Point and Orcombe Rocks. An intertidal shore platform extends seawards, overlain by a sandy beach.

The key features are (moving from east to west):

- Straight Point headland
- Sandy Bay beach
- Orcombe Cliff
- Orcombe Rocks headland

4.2 Anthropogenic Influences

The open coast between Straight Point and Orcombe Rocks has had very limited anthropogenic intervention. Further details are given in the Human Impacts Review.

4.3 Forcing Factors

The extreme wave climate was defined as part of the EEFCRMS study. Astronomic and extreme tide levels have previously been defined by Environment Agency (2011), summarised in Table 2. It is noted that the extreme tide levels are under review.

	MLWS	MHWS	100% AEP	10% AEP	1% AEP	0.1% AEP
Wave height (m)	NA	NA	1.97	2.37	2.65	2.80
Tide level (mAOD)	-1.63	2.17	2.75	2.98	3.21	3.47

Table 2. Wave and Tide Climate.

Tidal currents have not been quantified by previous work, but it is noted (SCOPAC, 2003) that they are relatively weak in comparison to those experienced at the Exe estuary inlet (1 to 3m/s on spring-neap cycles). Further details are given in the Natural Events Review.

4.4 Sediment Budget

Previous work (SCOPAC, 2003) has suggested that continued slow erosion of 0.5m/yr along the Orcombe cliffs could provide 30,000m^3/yr, assuming the whole cliff face is activated. Closer inspection of LiDAR data indicates that it is more likely that the bottom 10-15m would be active regularly, which would provide a proportionate 10,000m^3/yr, whilst the upper cliff face would be less regularly active.

There is no known semi-permanent store of sediment, although it is noted (Posford Duvivier, 1998a) that there is significant cross-shore exchange under summer and winter wave conditions. There is some disagreement on the net direction of littoral drift, although Posford Duvivier (1998) estimated a westward drift potential of 10-15,000m^3/yr from Straight Point to Orcombe Rocks. This tends to agree with the observation that Sandy Bay is not eroding, with the orders of magnitude of eroded cliff material and net drift potential being similar.

4.5 Potential Geomorphological Change

Sea level rise and increased storminess will likely result in accelerated cliff erosion, particularly in the medium to long term. This would increase the supply of sediment to the beach, although this may be counteracted by increased net drift potential.

5 Outer Estuary Processes

5.1 Geomorphological Context and Description

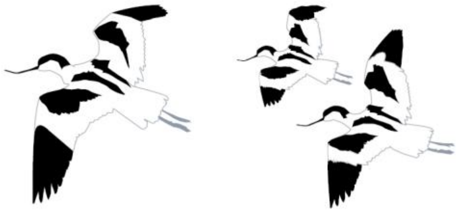
The outer estuary includes the spits of Dawlish Warren and Exmouth (between Langstone Rock and Orcombe Rocks), as well as sandbanks, the ebb (Pole Sands) and flood (Bull Hill Banks) deltas and the estuary mouth. The historic evolution of the outer estuary (comprising Dawlish Warren and Exmouth spits, the approach channel and related sandbanks and deltas) has been a topic of significant previous study, most recently in Halcrow (2008 and 2010). The potential key issue is the future evolution and management of Dawlish Warren, which potentially performs a flood risk management function for the wider inner estuary.

The key features are (moving from west to east):

- Dawlish Warren spit
- Dawlish Warren beach
- Intertidal sandbanks (such as Monster Bank)
- Estuary mouth
- Bull Hill Banks (flood delta)
- Pole Sands (ebb delta)
- Exmouth spit
- Exmouth beach

5.2 Anthropogenic Influences

Dawlish Warren and Exmouth spits have had a long history of anthropogenic influence. Dawlish Warren was increasingly managed from the early 1900s onwards. Exmouth spit was ‘reclaimed’ in the early 1800s, with the spit now rendered effectively inactive, with the town of Exmouth located on it, protected by hard defences. Further details are given in the Human Impacts Review.



5.3 Forcing Factors

The extreme wave climate was defined as part of the EEFCRMS study. Astronomic and extreme tide levels have previously been defined by Environment Agency (2011), summarised in Table 3. It is noted that the extreme tide levels are under review. Tidal currents have been quantified by SCOPAC (2004), noted as 1m/s and 3m/s on neap and spring tides respectively.

	MLWS	MHWS	100% AEP	10% AEP	1% AEP	0.1% AEP
Wave height (m)	NA	NA	2.6	3.0	3.2	3.3
Tide level (mAOD)	-1.59	2.21	2.75	2.98	3.21	3.47

Table 3. Wave and Tide Climate.

5.4 Sediment Budget

The consensus of opinion is that the coastlines either side of the spits both act as an input of sediment to the outer estuary (SCOPAC, 2003; Halcrow, 2008 and 2010). Posford Duviver (1998) reported that the net potential drift from Orcombe Point westwards is 15,000m^3/yr, reducing to 4,500m^3/yr near the Maer.

Similarly, the eastward gross potential drift from Langstone Rock is estimated as 8,400m^3/yr reducing to 1,100m^3/yr at the distal end of Dawlish Warren (Posford Duvivier, 1998). Beach profile analysis within the EEFCRMS study has noted that the distal end accreted between 1998-2010 whilst the proximal and central section generally eroded: this tends to support the reducing drift rates. It is suggested (SCOPAC, 2003) and supported by Halcrow (2008 and 2010), that there is no direct supply of sediment from Dawlish Warren to Exmouth, although the complex sediment pathways via the sandbanks and deltas provide an indirect route. Input of sediment from the inner estuary is not considered to be significant in the present day.

Dredging around the estuary mouth has previously been quantified as removing 500m^3/yr between 1961-1986, with further intermittent removal of 40,000m^3 in both 1986 and 1996, although the disposal site for these dredging operations is not known. This represents a total removal of nearly 100,000m^3 to the present day. In contrast to this, Laming and Weir (1992) estimated that around 156,000m^3 was deposited in the estuary mouth between 1986 and 1992.

Pole Sands, whilst remaining constant in size historically is estimated to have increased in volume by around 1,800,000m^3 since 1840, which gives a broad average of 10,000m^3/yr. There is disagreement whether Pole Sands receives sediment from further offshore, or whether it is a finite resource, although the consensus appears to be moving towards the latter (as noted in SCOPAC, 2004).

Previous studies, notably SCOPAC (2004) and Halcrow (2008), have described the conceptual understanding of sediment transport around Dawlish Warren, Pole Sands, the estuary mouth, Bull Hill Banks, and Exmouth. It is considered (SCOPAC, 2003; Posford Duviver, 1998; Halcrow, 2008) that there are two main systems of sediment transport. The first is wave net onshore (and longshore) movement from Pole Sands to Dawlish Warren, and the second is dominant ebb tidal transport south-east along the estuary mouth to sandbanks flanking the Maer channel. It is also suggested (SCOPAC, 2003) that sediment can be transported from the distal end of Dawlish Warren to Bull Hill Banks under flood tides, and then passed back to Pole Sands on ebb tides.

5.5 Potential Geomorphological Change

The future evolution of Dawlish Warren is a key issue for the wider estuary, as there is evidence it controls flood risk (i.e. extreme waves and water levels) in the inner estuary (HR Wallingford, 1965, and anecdotal records from storms in December 1945). Exmouth spit is now inactive and built-up, whilst Dawlish Warren is held in place by defences, except along its distal end, where defences are now buried by sand. The future evolution of Dawlish Warren is dependent on future changes in hydrodynamic climate, sediment supply and management of the existing defences between Langstone Rock and the distal end. Previous work by Halcrow (2008) state that in the short term (to 2030), extreme events could cause a temporary breach in Dawlish Warren (most likely at the neck or where other breach events occurred such as in 1962), and that continuation of historical trends would result in the coastal frontage of Dawlish Warren rotating anti-clockwise (in-estuary at the distal end). Between 2030 and 2060, if the complete deterioration of existing defences is allowed, it is highlighted that the anti-clockwise rotation would continue, hinged at the proximal end. By 2110, Dawlish Warren would continue this rotation, and may also partially breakdown to sand shoals or banks. These banks could still coalesce into a more coherent form into the future. However, it should be noted that predictions in the medium to long term have greater uncertainty attached to them.

6 Inner Estuary Processes

6.1 Geomorphological Context and Description

The inner estuary extends from Cockwood and the northern section of Exmouth, up to the tidal limits of the rivers Exe and Clyst. The inner estuary includes saltmarsh and mudflats, as well as sub-tidal estuarine channels.

The key features are:

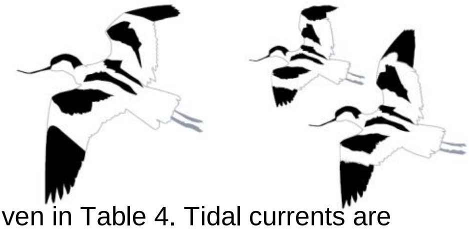
- Sub-tidal channels
- Mudflats
- Saltmarsh
- Floodplains (generally now inactive)
- High ground
- River Exe
- River Clyst

6.2 Anthropogenic Influences

The inner estuary has had a long history of anthropogenic influence, particularly related to construction of the railway lines, which rendered the floodplains generally inactive. Further details are given in the Human Impacts Review.

6.3 Forcing Factors

The extreme wave climate was defined as part of the EEFCRMS study, and varies significantly throughout the estuary dependent on shoreline orientation and available fetch. Astronomic and extreme tide levels have previously been defined by Environment Agency (2003). It is noted that



the extreme tide levels are under review. The parameters are given in Table 4. Tidal currents are weak, and noted to be less than 1m/s. SCOPAC (2004) suggests that the Exe Estuary is ebb dominant, however studies by Halcrow (2008) and review by Dun (2010) indicate that the majority of the estuary is neutral in terms of tidal domination, with both flood and ebb domination present in the estuary mouth. Freshwater flows into the inner estuary can be important, and are highly seasonal. In the River Exe, annual mean flow is 23m^3/s, whilst maximum flows can be up to 370m^3/s.

Tidal State	Tide Level (mOD)				
	Exmouth (Approaches)	Exmouth Docks	Starcross	Turf Lock	Topsham
MHWS	2.16	2.17	2.27	2.12	3.25
MHWN	0.96	0.97	1.07	1.02	1.05
MSL	0.07	0.27	0.36	0.25	No Data
MLWN	-0.74	-0.53	-0.43	-0.78	No Data
MLWS	-1.94	-1.63	-1.13	-1.38	No Data
Tide cycle		Spring		Neap	
Mean tidal range (Exmouth)		3.80m		1.48m	
Maximum tidal current velocities		Up to 3m/s		Up to 1m/s	

Table 4. Tide Climate.

6.4 Sediment Budget

For sands and gravel the inner estuary is considered a temporary store (SCOPAC, 2003), whereas for muddy sediment it is considered a sink, supported by qualitative observations that the Exe estuary mudflats have accreted slowly over time. SCOPAC (2004) states that the River Exe is the main source of fluvial sediment into the inner estuary. This is estimated as 1,900m^3/yr of fine sediment, which is stored in the inner estuary intertidal area. The Rivers Kenn and Clyst are also noted as potential smaller sources of sediment, but not quantified. Erosion of the estuary banks, although not quantified, is presumably negligible as an input due to the presence of the railway line and flood defences. In contrast to this, it is suggested (SCOPAC, 2003) that 1,000m^3/yr (predominantly sand) is moved from the outer estuary (specifically Bull Hill Banks) to the inner estuary. Whilst this represents a net continuous gain to the inner estuary, it is also noted that non-storm tidal input to the inner estuary is in balance i.e. any net gain comes from storm events. If the net gain is considered to spread across the inner estuary planform, this would on average represent 0.2mm/yr of vertical accretion; if continued over the next 100 years this would amount to 20mm. However, it is recognised that particular locations, such as Bull Hill Banks, are a focus for accretionary processes, rather than the general estuary.

6.5 Potential Geomorphological Change

Over the last 40 years, sea levels on the UK south coast have risen on average around 2mm/yr (UK Permanent Service for Mean Sea Level). Future projections (defra, 2006) give guidance that up to 2030, 2060 and 2110, sea level rise will be around 3.5mm/yr, 8mm/yr, and then 13mm/yr. Current understanding of the estuarine system suggests that marginal accretion of the inner is occurring and would potentially continue into the future.

3 Human Impacts Review

1 Purpose

This section documents the main human impacts that have occurred in / around the Exe Estuary. The period of time that is covered is from circa 12th Century to present day (2010), although some reference is made to earlier Roman times.

The rationale for undertaking this work derives from previous experience of public consultation on similar studies / strategies, which has shown that being able to demonstrate a detailed local knowledge of past interventions can improve stakeholder confidence in the purpose of the study / strategy and its deliverables.

Additionally, understanding such human impacts is potentially useful in understanding how the present form of the estuary has arisen. Other relevant factors include the ongoing physical processes and the significant storm events that have occurred. Ultimately, understanding how the estuary has developed in the past provides an insight into how it might develop in the future.

Information is recorded under the following sub-headings:

- Date;
- Details of event;
- Location;
- FCRM Unit; and
- Impact of event.

Annex A and **Figure 1**, attached to this section of the report, tabulate and depict, respectively, the various human impacts in chronological detail.

2 Approach

This review consisted of a desktop study of evidence from readily available sources of historic information. These sources comprised existing studies and reports, books and local literature as well as a brief internet search.

This review of available information focused on the following human activities within the estuary:

- Coastal defence construction;
- Reclamation;
- Managed Realignment; and
- Dredging.

The location of human impacts within the estuary and the surrounding area has been classified in accordance with the FCRM units defined in the main strategy report.

3 Summary of Data

The graphical representation of human impacts in Figure 1 also includes indicative reference timelines for key events occurring during the period under review (for example, World Wars, changes in management authority including the Regional Water Authorities, National Rivers Authority and the Environment Agency). These timelines are intended to assist in the understanding of where gaps or other trends are apparent in the available information.

4 Findings

The following summary statements can be drawn from the review of available data on human impacts in / around the Exe Estuary.

4.1 Construction of Coastal Defences

The earliest record of significant construction was at Topsham Quay in 1613, with other construction activities continuing with increasing frequency around the estuary to the present day. The data shows a tendency for most construction activities to be located along the higher energy coastal frontages, as might be expected. This is apparent at Exmouth where a large number of references refer to large scale capital construction works for the seawall/promenade. The highest number of records (describing human impacts) appears at the location of Dawlish/Dawlish Warren. More recently, these mostly refer to lesser ad-hoc maintenance works where ‘softer’ engineering solutions have been employed.

4.2 Reclamation

One of the most significant early reclamations occurred around the 12th to 13th Centuries at Powderham. This is not shown on the graph in Figure 1 because it is the only data point pre-1600s, which, for best scaling/presentational purposes is when the graph starts. The last and most recent reclamation appears to have occurred circa 1912 to 1932, when The Maer (Exmouth) was reclaimed. Whereas some references relate to reclamation along the exposed coastal frontage at Exmouth, most instances relate to reclamation within the sheltered parts of the inner estuary. This is evident on both the east and west banks of the estuary around Exmouth / Lympstone / Exton and Exminster / Powderham.

Furthermore, there is some speculation over possible roman reclamation around the Exe Estuary (Kate Tobin, *pers. comm.*). For instance, it is well-known that the City of Exeter was a key roman stronghold for circa 25 years; however, there appears to be a lack of strong evidence for roman reclamation around the Exe Estuary. To resolve this, a series of further potential contacts and documents were followed up. However, although this is interesting, the outcome is not critical because ‘Historic Landscapes’ are not within the scope of the strategy and will not affect the chosen policy. Furthermore, it is understood that the Environment Agency Archaeology team declined the option to extend the scope to take Landscape Character into account. In any event, a preliminary investigation into the Historic Landscape Classifications for the Exe Estuary (under Devon County Council website) found there was no mention of ‘Reclamation Sites’. It is a matter that would likely be considered at a project level with an Environmental Impact Assessment.

4.3 Managed Realignment

There appears to be only one reference to managed realignment, which occurred in 2004 at Topsham. This recent managed realignment was undertaken on an area of land that was previously reclaimed from the sea in the early 1800s.

4.4 Dredging

The earliest record of capital dredging appears to date from 1870 at Starcross. More recently dredging was undertaken in 2007 at Topsham which aimed to remove contaminated sediment. The majority of more detailed recent evidence relating to dredging activities is the maintenance dredging of the Exe Approach Channels at Exmouth circa 1980s. Dredging activity is confirmed to have now ceased (Jack Knott, Harbour Master, pers. comm.). The principal exception to this is the capital dredging undertaken at Starcross for the supply of construction materials.

5 Discussion

Generally speaking, Figure 1 indicates two periods of intense human activity. The first, circa 1750 to 1850, comprises mostly defence construction and reclamation. The second, from circa the early 1960s to the present day, comprises defence construction, managed realignment and dredging. This latter period appears to show a trend of increasing activity, which be might be a result of an increase in management, monitoring and reporting systems rather than a real increase in activity. To support this point, Figure 1 shows indicative reference timelines for the changes in management authority from Regional Water Authorities, to the National Rivers Authority, and more recently the Environment Agency.

Furthermore, Figure 1 shows that very little data is available between circa the dates of the First and Second World Wars. It may be that any human intervention during this period was simply not recorded as effectively as during other periods. However, it is more likely that very little interaction was actually undertaken during this period, where the focus of construction activities were more likely on the rebuilding Britain’s infrastructure.

6 Conclusions

A fuller picture of human interventions will be gained from other work, reported as part of this strategy, which is looking at historical maps and aerial photographs. However, the following conclusions can be drawn from the review of available data on human impacts in the Exe Estuary.

- Coastal defences have been constructed around the inner estuary and open coast. The earliest recorded defence was in 1613 at Topsham, although it is likely that other defences were in place before this time associated with land reclamation.
- Land reclamation occurred as early as the 12th and 13th Centuries (and possibly during roman times) and continued up until the 1930s. This has occurred on the open coast and within the estuary.
- There is only one recorded managed realignment scheme within the Exe. The scheme at Topsham was undertaken in 2004.
- Commercial aggregate dredging has been undertaken (since 1870, although it is understood this has ceased) at Starcross. Maintenance dredging of the Exe Approach Channels has also occurred circa 1980s (again, it is understood that this has now ceased).

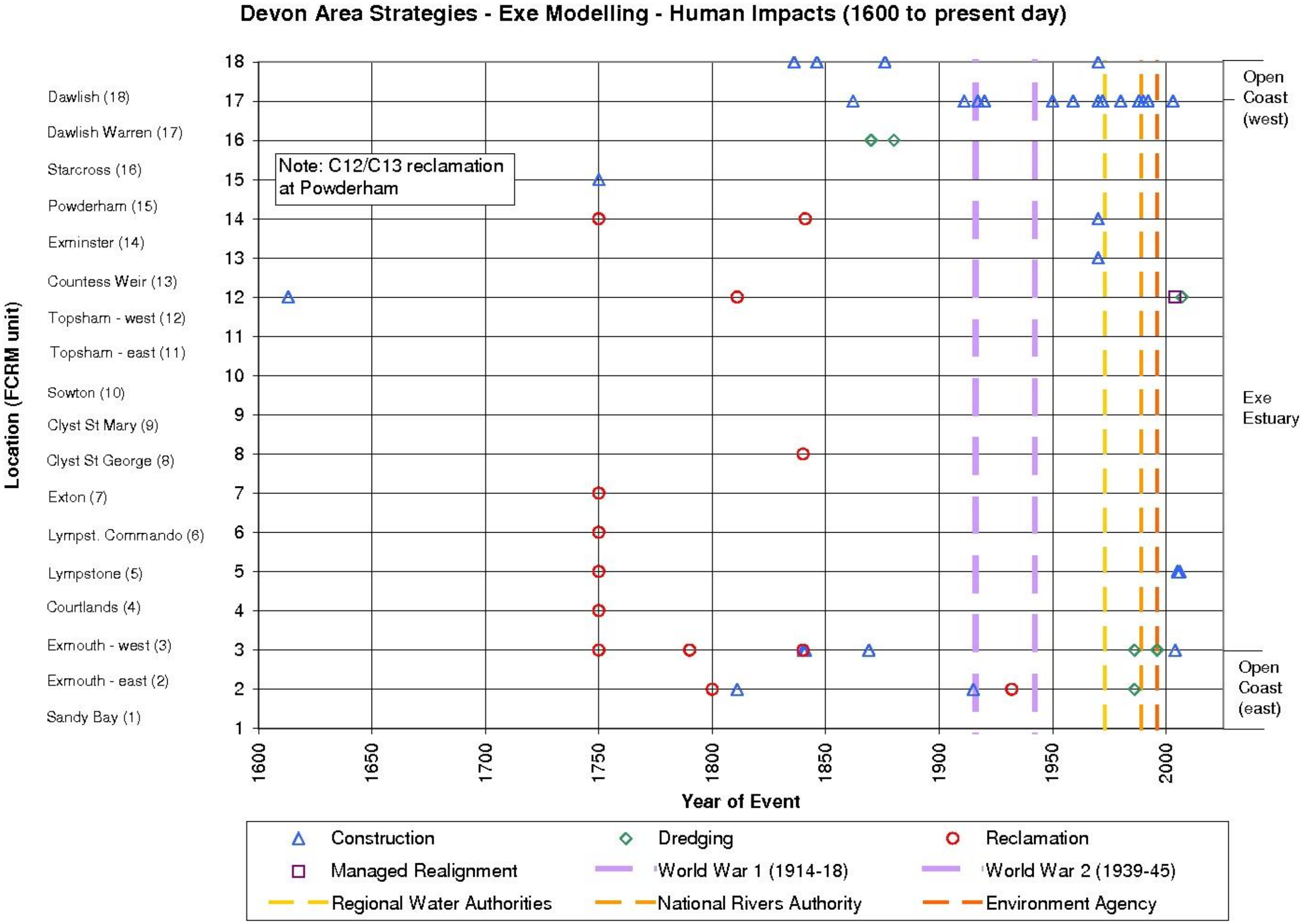
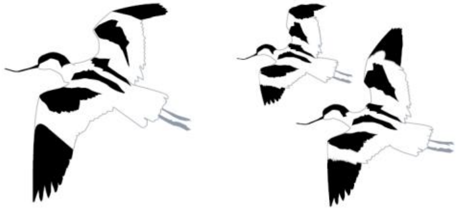


Figure 1. Graphical Representation of Human Impacts data.



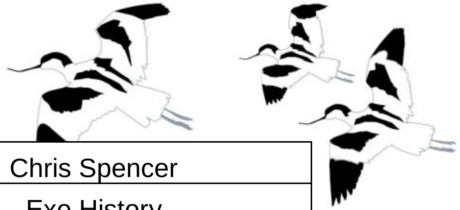
Annex A

Date	Details of Event	Location	FCRM Unit	Impact of Event	Reference
C12-13	Reclamation	Powderham	15	"Much of the land in the Exe Estuary was reclaimed from the sea in the 12th and 13th centuries so that, in earlier times, tides would have run inland to the rising ground on which Powderham Castle now stands. The red sandstone cliffs through which the main road is now cut were part of the coastline…To this day iron rings can be seen in the outer walls of Powderham Castle where, as late as the C18th, fishermen used to tie up their boats"	Book: The book of Dawlish, Grace Griffith, 1984. pg101
1613	Construction	Topsham (west)	12	Courtenay constructed Topsham Quay	Exe History (as cited within e-mail received from Mr Williams-Hawkes 25/11/08)
Mid C17-18	Reclamation	Lympstone to Courtlands	4,5,6,7	"It [saltmarsh] was previously continuous along the margins of the lower Clyst Estuary and the east bank from Exton to south of Lympstone. Land claim was a semi-continuous process between the early eighteenth and mid-nineteenth centuries…."	Report. Sediment Transport Study, University of Portsmouth, 2004 http://www.scopac.org.uk/scopac%20sediment%20db/exe/exe.htm
Mid C17-18	Reclamation	Exminster	14	"Land claim was a semi-continuous process between the early eighteenth and mid-nineteenth centuries, especially along the west bank between the River Denn and Exminster where up to 500 ha could have been involved."	Report. Sediment Transport Study, University of Portsmouth, 2004 http://www.scopac.org.uk/scopac%20sediment%20db/exe/exe.htm
Mid C17-18	Reclamation	Exminster	14	"The majority of land reclamation took place between the early 18th and mid 19th Centuries, impounding intertidal sediments and saltmarsh. Most significantly, around 500ha of land (SCOPAC, 2003) was reclaimed	Exe Estuary Coastal Management Study, Coastal and Estuarine Processes, Halcrow Nov 2008.

				along the west bank of the Exe Estuary (Exminster Marshes), between the River Denn and Exminster.”	
1703 - 1750	Construction	Powderham	15	Courtenay built embankment from Powderham Point to Coff	Exe History (as cited within e-mail received from Mr Williams-Hawkes 25/11/08)
1790	Reclamation	Exmouth (west)	03	This area of land [the Point] was first built upon in 1790 after reclamation from the river by the construction of an embankment.(includes photo)	The Express Issue 52, April 2010 (Page10)
1800	Reclamation	Exmouth (west)	03	“Land reclamation in the early 1800 allowed the town of Exmouth to expand.”	Exe Estuary Coastal Management Study, Coastal and Estuarine Processes, Halcrow Nov 2008.
1811	Reclamation	Exmouth (west)	03	Just around the corner from Exeter Road stood an area known as Mona Island, where boats once sailed from. Work commenced in 1811 to reclaim this area of marshland through construction on an embankment.	The Express Issue 52, April 2010 (Page10)
18th October 1811	Construction	Budleigh Salterton	N/A	The new sea wall which was lately made at Budleigh Salterton was carried into the Ocean.	Extreme storm & weather on the Exe “as bad as ever” (as cited within e-mail received from Mr Williams-Hawkes 28/11/08)
1811	Construction	Exmouth (east)	02	40 acres of foreshore embanked on the Eastern shore at Exmouth	Exe History(as cited within e-mail received from Mr Williams-Hawkes 25/11/08)
1836	Construction	Dawlish	18	“In 1836 a sea wall was built for the protection of the Parade, the foundation stone being laid with due ceremony. The sea wall was quite a small affair , and was supersede by the Railway wall ten years later”	Booklet: Notes on Old Dawlish (1588-1890), Compiled b the late F.J. Carter, 1938, pg16
1840s	Construction	Exmouth (west)	03	“In less tan 10 years from when this picture was created, many changes took place, the most notable of which, the building of the sea wall through the 1840s.”	Article: Olde Exmouth, The express Issue45, Sept 2009
1840s	Construction	Exmouth	03	East Devon District Council is currently carrying out	Website: Exe-Press Autumn

		(west)		works to strengthen the Exmouth Esplanade and Beach Gardens seawalls. The Esplanade wall was constructed in the 1840's and although the wall itself is in good condition, the foundations now require strengthening.	2006, http://www.exe-estuary.org/exe_press_autumn_06.pdf
1840s	Reclamation	Clyst St George, Topsham (west)	08, 12	"The RSPB is aiming to turn the tide of this destruction by returning Goosemoor, six hectares of pasture land at the head of the Exe Estuary, to its original state as an intertidal habitat… The site was reclaimed as pasture land in the 19th Century.	Web Article: New Technology Creates Old Habitat, Insideout southwest 14th Feb 2005, http://www.bbc.co.uk/insideout/southwest/series7/exe-estuary.shtml
1841	Construction	Exmouth (west)	03	The very familiar sea wall had its foundation stone laid in 1841 and a parapet was added in 1869.	The Express Issue 47, November 2009 (Page10)
1841	Construction	Exmouth (west)	03	"It's [Exmouth's] Success as a port is more recent, in 1841 a sea wall was erected that allowed the reclamation of a large strip of coastal land. This development allowed the construction of a deep-water harbour; small shallow bottomed lighters who transferred cargoes from ships anchored offshore had landed all previous imports."	Wed site: http://www.stuartlinecruises.co.uk/rivereducation.doc
1841	Reclamation	Exmouth (west)	03	"It's [Exmouth's] Success as a port is more recent, in 1841 a sea wall was erected that allowed the reclamation of a large strip of coastal land.	Wed site: http://www.stuartlinecruises.co.uk/rivereducation.doc
1841/42	Construction	Exmouth (west)	03	"This wall is believed to have been constructed by John Smeaton in 1841/42, (not the 18th Century lighthouse builder of the same name) and is a masonry wall supported on timber piles sunk into the sand. The	Web brochure, The Background, The Exmouth Sea Wall, East Devon District Council

				Beach Gardens section of the wall is also constructed of masonry, and lies forward of the original 1840's structure.”	
1846	Construction	Dawlish	18	As many as 2000 navies were involved in 1845-1846 in excavating tunnels, blasting cliffs, building the sea wall [between Dawlish Warren and Dawlish], and constructing the line (Kay, 1991). It was opened in 1846	Website referencing: *Rails along the Sea Wall*. Kay , P. 1991). http://www.soton.ac.uk/~imw/Dawlish-Warren.htm#Kay
1846	Construction	Dawlish	18	“In 1836 a sea wall was built for the protection of the Parade, the foundation stone being laid with due ceremony. The sea wall was quite a small affair , and was supersede by the Railway wall ten years later”	Booklet: Notes on Old Dawlish (1588-1890), Compiled b the late F.J. Carter, 1938, pg16
1862	Construction	Dawlish Warren	17	“In 1862 the Earl of Devon gained permission to build an embankment from the south-west corner of the Exe Estuary to Warren Point. He intended to use the land so reclaimed from the sea to breed oysters.”	Book: The book of Dawlish, Grace Griffith, 1984. pg88
1865-9	Construction	Exmouth (west)	03	The harbour is spacious, deep, and good; a recently erected battery commands its entrance; and docks were formed in 1865-9	Wed site: A vision of Britain through Time. http://www.visionofbritain.org.uk/descriptions/entry_page.jsp?text_id=796830&word=NULL
1870	Dredging	Starcross	16	ECC dredge lower river for the first time as it is claimed the main channel had decreased 2ft 6 inches in a year through the extension of Bull Hill bank in a Northwesterly direction towards Starcross. The channel had narrowed to 60 yards.	Exe History (as cited within e-mail received from Mr Williams-Hawkes 25/11/08)
1872-1876	Construction	Dawlish	18	“Seawall build to protect railway”	Coastal defence problems at Dawlish Warren, presentation by University of West of England, Dr



					Chris Spencer
1875	Dredging	tbc		The main channel through the anchorage at Nob Perch began to silt and a wider less circuitous channel developed to the Westward. The new channel was dredged and the silt deposited in the old channel.	Exe History (as cited within e-mail received from Mr Williams-Hawkes 25/11/08)
1880	Dredging	Starcross	16	Thousands of tons of gravel were removed from the bank off the village of Starcross for the building of the Princess Theatre, Torquay. It was said that this changed currents in the mouth of the river and therefore added to the slow destruction of Dawlish Warren through erosion	Griffiths 1984 *(As cited in The History of Dawlish Warren Research document)*
1880	Dredging	Starcross	16	"…But although it was not yet obvious, the sea was beginning to erode the dunes [of the warren]. From 1880 thousand of tons of gravel has been removed from a bank off the village of Starcross for the building of Princess Pier	Book: The book of Dawlish, Grace Griffith, 1984. pg87
1899	Construction - other	Dawlish Warren	17	The first bungalow is built on Dawlish Warren	National Rivers Authority (1993) and Barber (2001) *(As cited within the extract of State of the Exe 2006)*
1905	Construction - other	Dawlish Warren	17	The "Warren Halt" railway platforms were built by the Great Western Railway	National Rivers Authority (1993) and Barber (2001) *(As cited within the extract of State of the Exe 2006)*
1911	Construction	Dawlish Warren	17	"Defences on split were attached to mainland"	Coastal defence problems at Dawlish Warren, presentation by University of West of England, Dr Chris Spencer
1912-32	Reclamation	Exmouth (east)	02	"The Maer at Exmouth appears to have been reclaimed sometime between 1912 and 1932. This is corroborated by SCOPAC (2004), which describes	Exe Estuary Coastal Management Study, Coastal and Estuarine Processes, Halcrow Nov 2008.

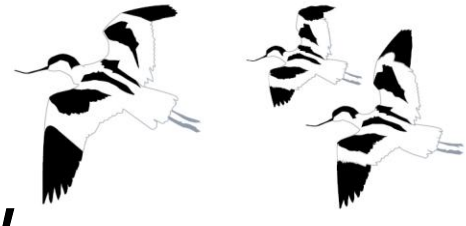
				how the cliffline at Exmouth Beach south through to Orcombe Point, has been protected from direct marine erosion by both land claim (in front of The Beacon and Louisa Terrace) and seawall construction;	
1914 - 1915	Construction	Exmouth (east)	02	Construction of the promenade and seawall behind Maer Rocks and the upper cliff profile regarded in the 1920's. Set of groynes added in 1970's	http://www.scopac.org.uk/scopac%20sediment%20db/exe/exe.htm
1914-15	Construction	Exmouth (east)	02	"…the promenade and seawall behind Maer Rocks was constructed in 1914-15;"	Exe Estuary Coastal Management Study, Coastal and Estuarine Processes, Halcrow Nov 2008.
1917	Construction	Dawlish Warren	17	400 metre rock armoured revetment was constructed to protect the railway line	National Rivers Authority (1993) and Barber (2001) *(As cited within the extract of State of the Exe 2006))*
1920	Construction	Dawlish Warren	17	"Use of rock armour at Dawlish Warren. Granite from southwest England was used here as early as 920 to protect the railway line. In 1992 larvikite from Larvik, near Oslo Norway was brought in by sea to extend sea defence protection towards the northeast.	Web site: http://www.soton.ac.uk/~imw/Dawlish-Warren.htm#BBC
1949 – 1959	Construction	Dawlish Warren	17	Protection of the Warren by British Rail: brushwood fences were erected, trees planted and barriers made of railway sleepers	National Rivers Authority (1993) and Barber (2001) *(As cited within the extract of State of the Exe 2006)*
1950	Construction	Dawlish Warren	17	"Defences on spit attached to mainland"	Coastal defence problems at Dawlish Warren, presentation by University of West of England, Dr Chris Spencer
1959	Construction	Dawlish	17	Dawlish Urban District Council installed five timber	National Rivers Authority (1993)

		Warren		groynes	and Barber (2001) *(As cited within the extract of State of the Exe 2006)*
1959	Construction	Dawlish Warren	17	"In 1959 the Warren was placed into the ownership of the Dawlish Urban District Council and the Devon River Board assumed responsibility for the defences. Following studies, they constructed five large permeable wooden groynes between the end of the Dawlish seawall and the Bridge of Sighs."	Exe Estuary Coastal Management Study, Coastal and Estuarine Processes, Halcrow Nov 2008.
1960	Historical Observation	Dawlish Warren	17	The last home is removed from the Warren in a south-easterly gale	National Rivers Authority (1993) and Barber (2001) *(As cited within the extract of State of the Exe 2006)*
1966-72	Construction	Dawlish Warren	17	"Groynes added [to the spit]"	Coastal defence problems at Dawlish Warren, presentation by University of West of England, Dr Chris Spencer
1970s	Construction	Dawlish	18	"300m long concrete sea wall was built to the east of the railway rock revetment, a promenade was provided on the top of the wall; at the end of the sea wall 300m of gabions, wire cages filled with rocks, were installed to absorb wave energy"	National Rivers Authority (1993) and Barber (2001) *(As cited within the extract of State of the Exe 2006)*
1970s	Construction	Countess Weir, Exminster	13, 14	Flooding remains a problem along some stretches of the river, but a flood defence scheme built in Exeter itself in the 1970s has prevented major incidents in the city.	Article. Devon's Rivers: The Exe last updated: 06/02/2008 at 13:44 created: 05/02/2008
1970	Construction	Dawlish Warren	17	"Since 1946 there have been many schemes aimed at halting erosion [of the spit] and it now seems that the latest one carried out in 1970 by Devon River Board and costing £340k seems to have worked"	Book: The book of Dawlish, Grace Griffith, 1984. pg88

1970s	Construction	Dawlish Warren	17	“Major sea defences were installed at the warren in the mid-1970s.	Newspaper article, WMN 8th Jan 1991
1972-80	Construction	Dawlish Warren	17	“building of revetment and gabions”	Coastal defence problems at Dawlish Warren, presentation by University of West of England, Dr Chris Spencer
1980-2003	Construction	Dawlish Warren	17	“Building of a wave return wall”	Coastal defence problems at Dawlish Warren, presentation by University of West of England, Dr Chris Spencer
1986	Dredging	Exmouth Docks	03	“Posford Duvivier (1998b) state that, for the past several decades, the average annual volume of dredge spoil [from Exmouth dock entrance] has been about 500m^3. However, in 1986, 40,000m^3 was removed, in response to sandbank formation and general accretion over the previous 25 years.”	Report. Sediment Transport Study, University of Portsmouth, 2004 http://www.scopac.org.uk/scopac%20sediment%20db/exe/exe.htm
1986	Dredging	Exmouth (east)	02	“Since the early 1980s the Exmouth approach channel has been steadily accreting. By the mid 1980s accretion was such that it caused navigational difficulties, which led to the grounding of a vessel in 1986. Following the grounding 40,000m^3 of material was dredged from the channel, with further dredging work taking place in 1996.”	Natural and Historic Environment, State of the Exe, 2006
1988	Construction	Dawlish Warren	17	“For the first time that anyone can remember, there is now a sheet cliff edge at Dawlish Warren… Fortunately a protection scheme by South West Water saved the day. Rocks encased in wire mesh were dumped along the threatened area and sand gradually built up on top to hide the works.”	Newspaper article, ETE 15th Nov 1988.
1990	Construction	Dawlish	17	“To reduce the risk of flooding and erosion to the	Website:

		Warren		amenity site at the western end of the Warren, a seawall was also built in the 1990s.	http://www.soton.ac.uk/~imw/Dawlish-Warren.htm
1992	Construction	Dawlish Warren	17	The National Rivers Authority began work to reconstruct the rock armoured revetment; landward of the timber piles, a 300m line of steel sheet piles were sunk to offer further stability; 35,000 tonnes of Norwegian granite boulder were imported.	National Rivers Authority (1993) and Barber (2001) *(As cited within the extract of State of the Exe 2006)*
1996	Dredging	Exmouth (west)	03	By the mid 1980's accretion was such that it caused navigational difficulties, which led to the grounding of a vessel in 1986. Following the grounding 40,000m3 of material was dredged.	Extract from: State of the Exe 2006 Report (Exe Estuary Management Partnership – Cycleau project Team, 2006
1996	Dredging	Exmouth (west)	03	"…A similar quantity [40,000m3 in 1986] was dredged in 1996, because of the formation of several small banks, and their eventual merger into a shallow zone, during the previous 10 years.	Report. Sediment Transport Study, University of Portsmouth, 2004 http://www.scopac.org.uk/scopac%20sediment%20db/exe/exe.htm
Nov 2004	Construction	Exmouth (west)	03	Following the October 2004 storm the failed length of seawall was fronted by rock armour as part of emergency works to provide protection to the seawall.	
17th Dec 2004	Retreat	Topsham (west)	12	"Goosemoor is a six hectare grass field site on the edge of the Exe Estuary in Devon and is owned and managed by the RSPB. … Following the relevant permissions work commenced on the site to make it more suitable for tidal inundation…. Following completion of the engineering works the site was officially opened on 17th December 2004."	Web article: Saltmarsh Management Manual, Case Study - Regulated Tidal Exchange, http://www.saltmarshmanagementmanual.co.uk/Management/ManCaseStudiesRegTidExch.htm
2005	Construction	Lympstone	05	Lympstone's flood defence used to comprise of a series of ad-hoc wooden stop boards (see Image 7m), but thecommunity now benefits from a new tidal defence scheme which was introduced in 2005. As	Extract from: State of the Exe 2006 Report (Exe Estuary Management Partnership – Cycleau project Team, 2006

				well as bespoke metal floodgates in the network of passageways to the foreshore there are new slipways near the sailing club and on the Green (Image 7n).	
2006	Construction	Lympstone	05	In 2006 the Environment Agency spent £900,000 raising Lympstone's sea defences. This scheme involved raising and strengthening walls along the estuary, raising two slipways and installing 7 manually operated electronically monitored gates. Research conducted by the Environment Agency shows 160 houses in Lympstone are at risk of flooding.	http://thedevonweek.newsandmediarepublic.org/2010/06/02/exhibition-to-be-held-to-mark-50th-anniversary-of-lympstone-floods/
Oct 2007	Dredging	Topsham (west)	12	"According to a report from the *Express & Echo* newspaper, the £30,000 project at Topsham's North Quay aims to remove sediment contaminated with TBT and improve boat access."	Web Article: Dredging on River Exe slower process than expected Environmental Issues - October 29, 2007, http://www.sandandgravel.com/news/article.asp?v1=10458



4 Natural Events Review

1 Purpose

This section is a review of available information on historical natural events and their impacts within the area surrounding the Exe Estuary. The period of time that is covered is from circa 1810 to present day (2010).

Similar to the Human Impacts Review, the rationale for undertaking this work derives from previous experience of public consultation on similar studies / strategies, which has shown that being able to demonstrate a detailed local knowledge of past natural events can improve stakeholder confidence in the purpose of the study / strategy and its deliverables.

Additionally, understanding the occurrence and impacts of storms is useful in understanding the seasonality of the events and the key geographical areas that are vulnerable to their impacts.

Information is recorded under the following sub-headings:

- Date;
- Details of event;
- Location;
- FCRM Unit; and
- Impact of event.

Annex A and **Figures 1** & **2**, attached to this section of the report, tabulate and depict, respectively, the various natural events in chronological detail.

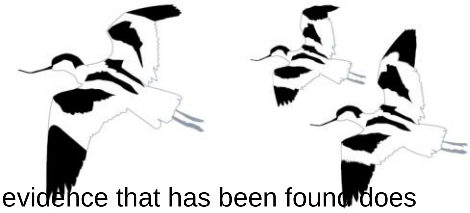
2 Approach

The review consisted of a desktop study of evidence from readily available sources of historic information. These sources comprised existing studies and reports (those undertaken by Halcrow and other consultants), books and local literature as well as a brief internet search.

The review of available information focused on the following:

- References to storms (from anecdotal data);
- References to the breaching around the estuary (from anecdotal data); and
- References to flooding of various low lying areas (from anecdotal data and fully auditable Flood Reconnaissance Information Services data).

In the evidence that has been examined the term ‘storm’ covers a range of conditions including: high wind speed, high waves, high water tide levels, high rainfall. Individual storms differ in terms of the occurrence of these various elements and their magnitudes. The evidence that has been examined also refers to the impacts of storms in terms of breaches and flooding. Sometimes the evidence provides more detail on the impacts of the storms rather than the driving forces of winds, waves, rain and tides.



It should be noted that with the exception of the FRIS data the evidence that has been found does not document the specific details of the individual storms such as wind speeds, wind directions, surge heights, wind speeds, wave heights. Thus, on the basis of the evidence gathered here it is not possible to comment on the relative severity of the individual storms or the meteorological conditions that gave rise to the storms.

The term ‘breach’ can mean different things to different people. In the present report it is taken broadly to mean the significant reduction in elevation of a relatively short length of barrier (such as a spit of flood embankment). A breach is therefore different to the wholesale removal or lowering of feature. Nevertheless, breaching events would be expected to coincide with flood events since they provide a route for water to enter the floodplain.

A key dataset was sourced from the aforementioned Flood Reconnaissance Information Service (FRIS), as referenced in the Devon Tidal Flood Warning Report (Halcrow, 2009); a screenshot from Halcrow (2009) is shown in Figure 2. The FRIS data comprises a tidal flood event dataset from 1945 to 2008 (with partial records from 1804). It is considered that Halcrow (2009) will be a useful validating dataset for subsequent components of the strategy because it describes known historical tidal flooding impacts for four different tidal levels (<2.6mOD; 2.6-2.9mOD; 2.9-3.0mOD; and 3.0-3.2mOD) with known wind speeds/directions.

3 Summary of Data

Details of the historic natural events identified by this study are listed chronologically (1810 to 2010) in the table in Annex A. The data is also presented graphically by date and location as shown in Figure 1. This figure includes indicative reference timelines for key events occurring during the period under review (for example, World Wars, changes in management authority including the Regional Water Authorities, National Rivers Authority and the Environment Agency). These timelines are intended to assist in the understanding of where gaps or other trends are apparent in the available information.

For instance, since circa the 1960s, there appears to be a trend of increasing natural events activity, which be might be a result of an increase in management, monitoring and reporting systems rather than a real increase in activity. To support this point, Figure 1 shows indicative reference timelines for the changes in management authority from Regional Water Authorities, to the National Rivers Authority, and more recently the Environment Agency.

Furthermore, Figure 1 shows that very little data is available between circa the dates of the First and Second World Wars. It may be that some natural events during this period were simply not recorded as effectively as during other periods.

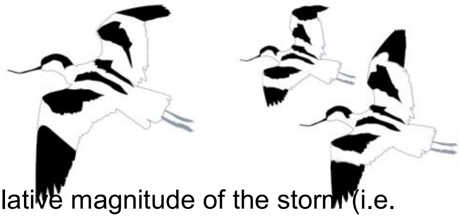
4 Findings and discussion

The following summary statements and discussion have been developed from the review of available data for natural events / impacts surrounding the Exe Estuary.

4.1 Storms

An underlying point that needs to be borne in mind when interpreting the following storm data is that the frequency, level and nature of reporting on storms will probably depend upon some combination of the following factors:

- The relative newsworthiness in the context of other regional events around the time of the storm could lead to ‘selective’ reporting;



- The original observer’s and/or author’s perception of the relative magnitude of the storm (i.e. what defines and describes a storm?); and
- Storm impacts (e.g. flooding) are more likely to be reported and described than the actual storm itself.

Approximately 58 storm events have been discovered covering a period from 1811 to the present day (2010). Roughly speaking this equates to an average of one recorded storm event every three to four years or so since 1811 to the present day. This average figure appears lower than that which might be expected, and is most likely attributable to the three points mentioned above. Accordingly, it is not really possible to draw any key conclusions from this number of storms other than 58 storms over 200 years is perhaps a low number, although it is considered high enough to allow possible further conclusions to be drawn over areas of geographical vulnerability.

Using the 34 known full dates for recorded storms over the period 1811 to 2010, the Table below indicates the monthly spread of storms in terms of a percentage occurrence, which all occurred between the months of October and March in any particular year.

Month	October	November	December	January	February	March
% Occurrence	28	16	18	16	16	6

Generally speaking, as might be expected, this shows that over the last 200 years recorded storms have occurred over the autumn / winter months between October and March (inclusive). It should be noted that the absence of any reported storms in September is possibly an unusual observation. However, it can be deduced from the data under review, that the stormiest month is October. The early autumnal timing is a slightly unusual observation when perhaps more storms would be expected to have occurred throughout the months of December / January. The knowledge (according to this dataset) that October is the stormiest month may prove useful in terms of strategic planning for possible remedial emergency / short-term works in response to storm damage (i.e. anticipate /plan for more of this type of work in October).

More specifically, the earliest record of a ‘tidal storm’ is dated 18th October 1811 at Exmouth (FCRMU03). The earliest record of a ‘fluvial storm’ is dated 1st February 1869 at Exe/Creedy Valley (FCRMU13/14). While the latest storm event is dated 3rd March 2010 at Dawlish Warren (FCRMU17). The data show a trend that the majority of storm events have been reported as occurring along the higher energy open coastal frontages (Dawlish and Exmouth). This likely reflects the fact that the impacts of high wave and water levels events are likely to be greater in these locations. The largest number of storm events is recorded along the Dawlish and Dawlish Warren frontages. Although there are fewer recorded incidents at Exmouth, these are substantiated by a number of sources.

The impacts of relatively recent storms on beaches in the study area are investigated further in the section of this appendix entitled Beach Profile Analysis. This section also considers the effects of storms from different directions. This analysis investigates storms from 2008 to present and considers Exmouth Beach and Dawlish Warren. The storms were previously identified the Plymouth Coastal Observatory (PCO) and included:

- Exmouth - 17/01/2009 and 9/10/2009; and
- Dawlish Warren - 10/03/2008, 17/01/2009, 19/10/2009, 12/11/2009, 03/03/2010.

These dates all appear in Annex A and Figure 1.

It is understood that PCO trigger post-storm surveys for the following reasons:

- When the wave buoy located at Teignmouth pier (Lyme Bay) records a wave height in excess of 2m (although this figure is then interpreted in terms of its significance and likely impact on beaches – see below for survey trigger);
- An operative on the ground (e.g. Environment Agency and / or Local Authority representative) makes a judgement whether the storm has caused significant impact to warrant a survey of beach profiles.

The location of relevant and key Environment Agency and / or Local Authority representatives being centred / resident mostly around Teignbridge may explain why more post-storm surveys have been undertaken at Dawlish Warren (Dawlish Warren lies in the Local Authority of Teignbridge District Council). It is not known if there are any relevant Environment Agency and / or Local Authority representatives centred / resident around Exmouth (where East Devon is the District Council).

4.2 Breaching

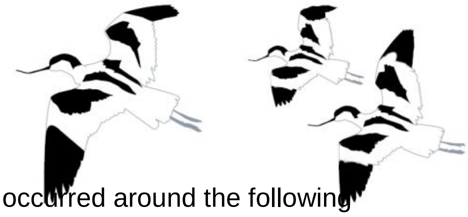
Approximately 5 breaching events across at Dawlish Warren and Exmouth have been discovered covering a period from 1872/3 to the present day. No specific reference to breaching within the inner estuary has been discovered. Caution should be exerted here because it is not known if the definition of breach as described earlier is the same as the original author's intended meaning. In any event, the earliest record of 'breaching' is dated around 1872/3 at Dawlish (FCRMU18). One of the more recent storm events dated 10th March 2008 at Exmouth (FCRMU02/03) is thought to have led to a minor breach. Relatively speaking there are less known breach events when compared to the number of anecdotal records for storms and flooding. This could imply that breaching events do not occur on every storm or that breaching events are under-reported. However, the latter explanation is unlikely given that the impact of breaching is more likely to attract media interest.

It is considered that the number of breaching events is probably 'too low', and is related, in part, to the use of the terms storms and flooding rather than breaching (when breaching may have actually occurred). For instance, it is not known whether flooding resulted from a failure or overtopping of defences.

4.3 Flooding

Approximately 18 flooding events have been discovered covering a period from 1823 to the present day. The earliest discovered record of a 'tidal flooding' event is dated 30th November 1823 at Dawlish Warren (FCRMU17). The most recent major tidal flooding event is dated September 1960 at Lympstone (FCRMU05). The earliest record of 'fluvial flooding' is dated around 1810 at Dawlish (FCRMU18). The most recent major fluvial flooding event is dated 8th December 2000 at Dawlish Warren (FCRMU17).

Regrettably, not all the data distinguishes whether the flooding was marine, fluvial or pluvial; where known a distinction has been made between tidal and fluvial in Annex A. A number of separate flood events have been recorded at the coastal frontages of Dawlish and Dawlish Warren. Furthermore, anecdotal evidence shows a similar number of detailed flood events recorded within the confines of the estuary. This is particularly noticeable from the FRIS data (tidal flood events dataset from 1945 to 2008; partial records from 1804).



The FRIS data shows that a large number of tidal flood events occurred around the following towns/villages (from west to east clockwise around the estuary): Dawlish, Cockwood, Starcross, Powderham, Topsham, Ebford, Lympstone, and Exmouth.

5 Conclusions

This section of the report has reviewed a number of sources of information concerning natural impacts surrounding the Exe Estuary.

Fundamentally, it is considered that Halcrow (2009) will be a useful validating dataset for subsequent components of the strategy because it describes known historical tidal flooding impacts for four different tidal levels (<2.6mOD; 2.6-2.9mOD; 2.9-3.0mOD; and 3.0-3.2mOD) with known wind speeds/directions; Figure 2. The main findings are summarised as follows:

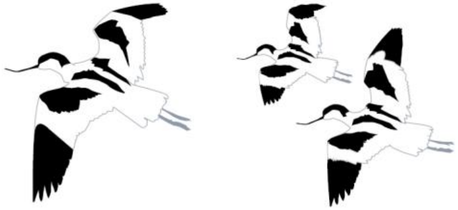
- Approximately 58 storm events have been discovered covering a period from 1811 to the present day. This number is unlikely to reflect the actual number of storms.
- Over the last 200 years recorded storms have occurred over the autumn / winter months between October and March (inclusive).
- The stormiest period is October.
- The data show a trend for the majority of recorded storm events affect the higher energy open coastal frontages (Dawlish and Exmouth), as may be expected.
- Approximately 5 breaching events (mostly circa Dawlish / Dawlish Warren with one reference to Exmouth) have been discovered covering a period from 1872/3 to the present day.

There are less known breach events when compared to the number of anecdotal records for storms and flooding. This could imply that breaching events do not occur on every storm or breaching events are under-reported.

- Approximately 18 flooding events have been discovered covering a period from 1823 to the present day.
- A number of separate flood events have been recorded at the coastal frontages of Dawlish and Dawlish Warren. However, anecdotal evidence shows a similar number of flood events recorded within the confines of the estuary, impacting on several towns and villages.

The main impacts can be summarised as follows:

- In temporal terms, given the stormiest period is October, this knowledge may be useful in terms of strategic planning for possible remedial works in response to storm damage, i.e. anticipate more of this type of work mid- to late- October.
- Spatially speaking the towns/villages most vulnerable to storms (historical tidal flooding), from west to east clockwise around the estuary, appear to be: Dawlish, Cockwood, Starcross, Powderham, Topsham, Ebford, Lympstone, and Exmouth.
- Breaching appears to have occurred in the past at Dawlish and Exmouth, however, there is uncertainty as to the meaning / interpretation of the word breach.
- Finally, it should be noted that defences might have been improved since some of the historical flooding events, which might reduce the likely impact of future natural events.



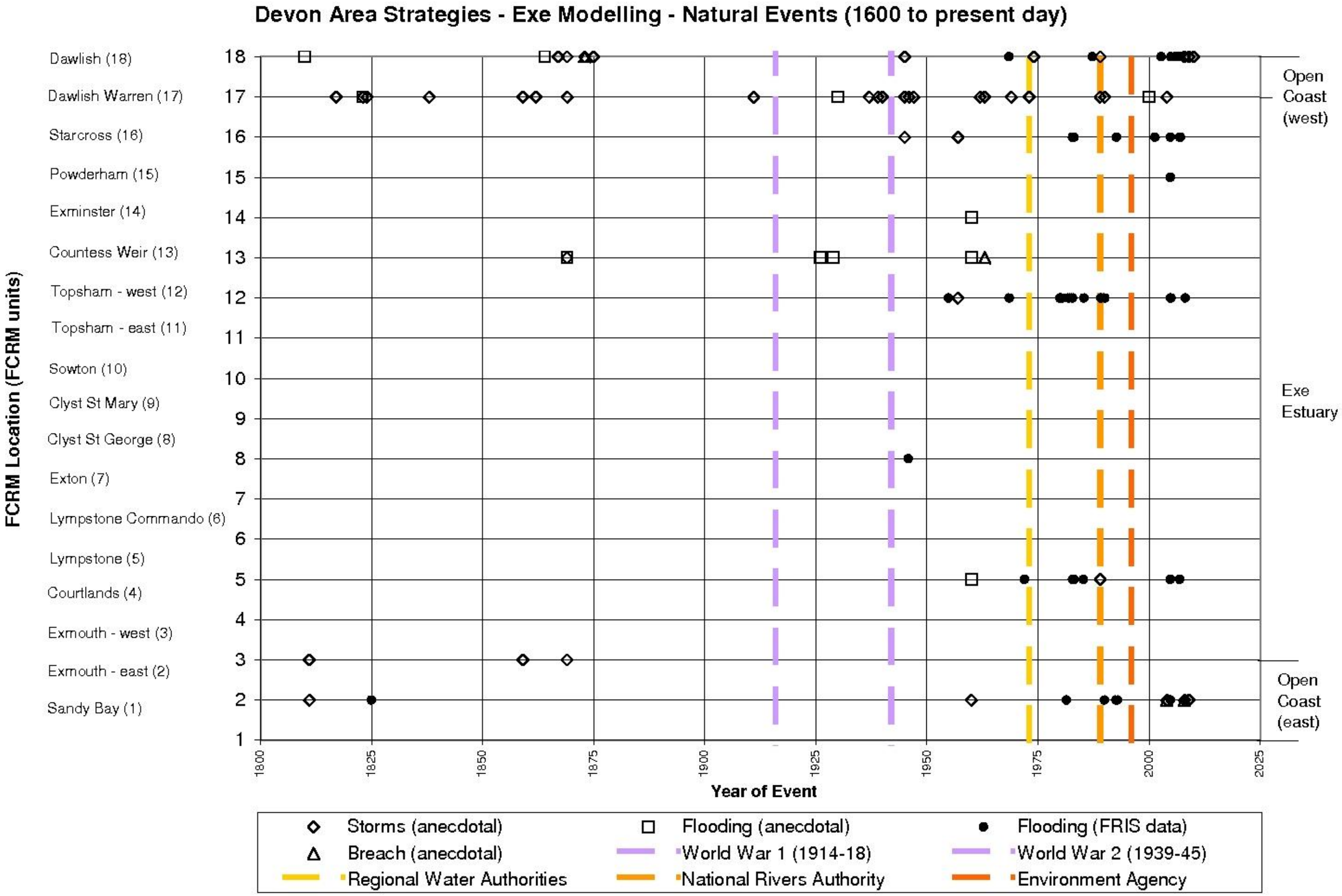


Figure 1. Graphical Representation of Natural Events data.

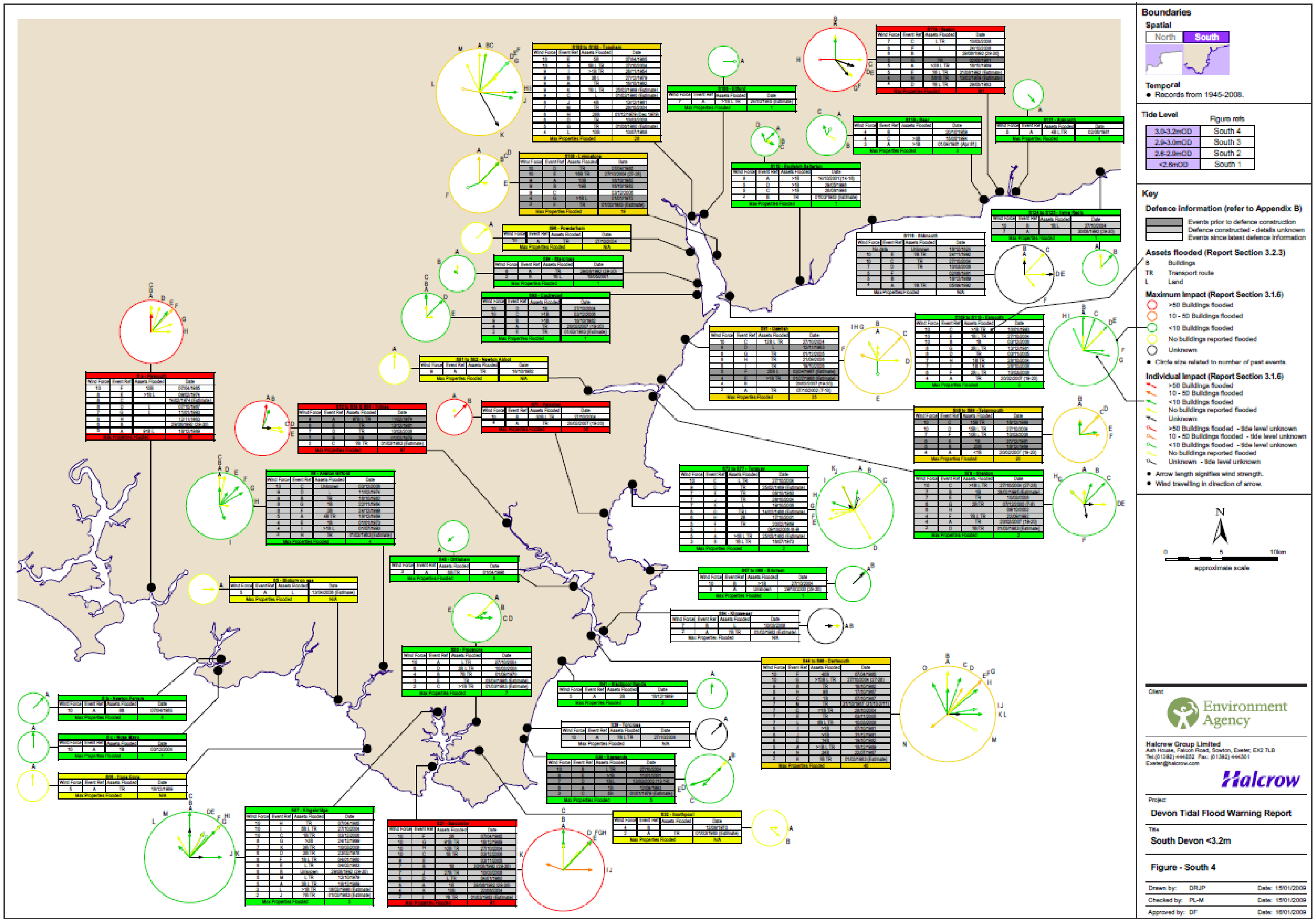
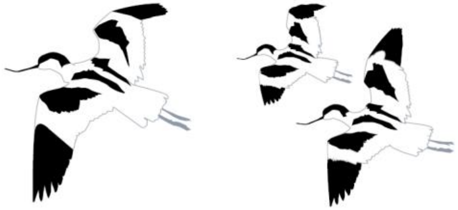
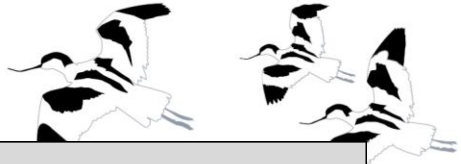


Figure 2. Figure 'South 4' from Devon Tidal Flood Warning Report (Halcrow, 2009); based on FRIS data.



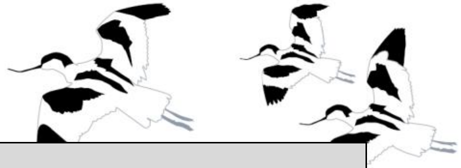
Annex A: List of Events

DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
1810	Flooding (Fluvial)	Dawlish	18	"…In straightening the [Dawlish Water] stream and altering its level, Manning has interfered with the free draining of water from the hills. In 1810 a flood, caused by the sudden melting of snow on Haldon, swept away lawns, banks, and two newly-built houses in Brooks Street."	Book: The book of Dawlish, Grace Griffith, 1984. pg39
18th October 1811	Storm (Tidal)	Exmouth	03	The tide on the Devonshire coast rose higher than has been witnessed in the memory of any person living; the wind was fortunately very moderate. Many houses near the sea deluged. The sand-beach at the town of Exmouth was completely metamorphorsed.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
18th October 1811	Storm (Tidal)	Budleigh Salterton	n/a	The new sea wall which was lately made at Budleigh Salterton was carried into the Ocean.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
11th October 1811	Storm	Exmouth and Budleigh Salterton	02, 03	No specific information provided within document	A historical record of coastal floods in Britain: frequencies and associated storm tracks.
20th January 1817	Storm	Dawlish Warren	17	Bad storm, 5 acres of the Warren swept away.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
January 1817	Storm	Dawlish Warren	17	5 acres of the Warren were washed away in a single storm	Carter 1976 (As cited in The History of Dawlish Warren Research document)

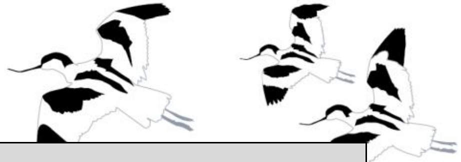


DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
1817	Storm	Dawlish Warren	17	5 acres of the Warren were washed away in a single storm	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
1817	Storm	Dawlish Warren	17	5 acres of the Warren were washed away in a single storm	Extract from Lost Devon, Creation, Change and Destruction over 500 years
30th November 1823	Flood / Storm	Dawlish Warren	17	Boats damaged and roofs pulled off many houses	Extract from Lost Devon, Creation, Change and Destruction over 500 years
23rd November 1824	Storm	Dawlish Warren	17	SW'ly Storm caused the River Otter to move quite considerably eastward. Breach caused through the Warren and was used for a short while by shipping until it silted up. Much sand thrown from the Warren into the Channel. An 1855 Engineer's Report to an Admiralty Inquiry asserted that the Exe had never recovered from the 1824 storm (31 years earlier). This led to a statement from E. A. G. Clarke, "This may have been the too generous estimate of the past, common among people past their middle age, accentuated by the rapid increase within their lifetime in the size of ships".	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
1824	Storm	Dawlish Warren	17	The Great Storm caused a breach through the Warren, used by ships for a short while until it silted up.	Exe History, as cited within e-mail received from Mr Williams-Hawkes 25/11/08
22nd November 1824	Storm	Dawlish Warren	17	Sea burst through the embankment and flooded some seventy acres Considerable damage to property	Extract from Lost Devon, Creation, Change and Destruction over 500 years

DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
				reported.	
November 1824	Storm	-	-	-	http://www.soton.ac.uk/~imw/chestorm.htm
February 1838	Storm	Dawlish Warren	17	Storm washed away up to one quarter of the Warren with exceptionally high tides	Extract from Lost Devon, Creation, Change and Destruction over 500 years
1844	Historical Observation	Dawlish Warren	17	Dawlish Warren covered 300 acres+	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
1855 and 1859	Storm	Teignmouth	n/a	Sea broke through the railway, a phenomenon not unknown today. Brunel, who designed the line, was said at the time to have been scornful of the danger of the sea and laughed at suggestions of potential problems.	Extract from Lost Devon, Creation, Change and Destruction over 500 years
1859	Storm	Dawlish Warren	17	25 foot high steep bluff at the end of the Warren swept away. Pilot Charles Wilson commented "The entrance of this harbour is almost blocked up with sand".	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
1862	Storm	Dawlish Warren	17	"…Even the physical appearance of the warren changed. In the 19th century it ended in a steep bluff of sand on its seaward side. This bluff, at least 25frt high, was washed away by a great storm in 1859"	Book: The book of Dawlish, Grace Griffith, 1984. pg87
1864	Flood (fluvial)	Dawlish	18	"Church bridge, the oldest bridge in town, was rebuilt and enlarged after with financial help from Devon County Council after a flood in 1864"	Book: The book of Dawlish, Grace Griffith, 1984. pg63
1867	Storm	Dawlish	18	Photo "damage to the seawall, 1867"	Book: The book of Dawlish, Grace Griffith,



DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
					1984. pg68
1869	Storm	Dawlish	18	"…in 1869 300 yards of rail track were washed away"	Book: The book of Dawlish, Grace Griffith, 1984. pg63
1st February 1869	Storm	Exmouth	03	Storm accompanied by thunder and lightning. Portion of the new docks washed away at Exmouth. The Exe Bight Fishery works suffered severely.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
1st February 1869	Storm	Dawlish Warren	17	Storm accompanied by thunder and lightning. Oyster beds covered with sand.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
1869	Storm	Dawlish Warren	17	A storm ripped through the Warren and closed an oyster farm	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
31st January and 1st February 1869	Storm	Dawlish	18	Spring gales and high tides coincided to devastate the coast. On the South Devon line a quarter of a mile east of Dawlish 150 yards of permanent way were washed away and a part of the Exmouth docks suffered similarly. More disastrously the Warren was seriously breached. Sand filled the oyster beds and chocked the breeding stock. It was estimated that 28,000 oyster were destroyed.	As cited within extract of the Devon and Cornwall Notes and Queries (page 362)
1st February 1869	Storm	Exeter	13, 14	Storm accompanied by thunder and lightning. 200 yards of the South Devon railway line about a mile and a half from St Thomas' Station under water.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08



DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
1st February 1869	Storm, Flooding (fluvial)	Exe and Creedy Valley	13, 14	Storm accompanied by thunder and lightning. Valleys of Exe and Creedy submerged.	Extreme storm & weather on the Exe “as bad as ever”, as cited within e-mail received from Mr Williams-Hawkes 28/11/08
1872/73	Storm and Breaches	Dawlish	18	Brunel's optimistic plan was that breakwaters would cause the accumulation of beach sand, and that the sea wall would not be touched by the sea except under severe gale conditions (Kay, 1991). However, the sea wall has long been under attack, particularly in the winter of 1872/1873, when there were major breaches. There was discussion about building a new line inland.	Website referencing: Rails along the Sea Wall. Kay , P. 1991). http://www.soton.ac.uk/~imw/Dawlish-Warren.htm
19th October 1875	Storm	Dawlish	18	No specific information provided within document	A historical record of coastal floods in Britain: frequencies and associated storm tracks.
1911	Storm	Dawlish Warren	17	‘The Gale’ washes away several homes	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
3rd January 1926	Flooding (Fluvial)	Exeter	13, 14	River Exe overflowed. Thousands of acres under water. Some Exeter streets 2 foot under water.	Extreme storm & weather on the Exe “as bad as ever”, as cited within e-mail received from Mr Williams-Hawkes 28/11/08
28th December 1928	Flooding (Fluvial)	Okehampton	n/a	River Exe rose 5½ foot above normal. Okehampton Street flooded.	Extreme storm & weather on the Exe “as bad as ever”, as cited within e-mail received from Mr Williams-Hawkes 28/11/08
5th October 1929	Flooding (Fluvial)	Exeter	13, 14	River Exe rose 4 ft. and houses in St Thomas flooded to a depth of nearly a foot.	Extreme storm & weather on the Exe “as bad as ever”, as cited within e-mail received from Mr Williams-Hawkes 28/11/08

DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
1930	Flooding	Dawlish Warren	17	Photo "Flooding [of the spit] 1930"	Book: The book of Dawlish, Grace Griffith, 1984. pg90
1937	Storms	Dawlish Warren	17	A series of storms and high tides removed bungalows on the Warren	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
1939	Storms	Dawlish Warren	17	"The whole of the warren was in danger. By 1939 most of the bungalows had disappeared from the spit of land which curved into the Exe Estuary"	Book: The book of Dawlish, Grace Griffith, 1984. pg88
1939/40	Storms	Dawlish Warren	17	Winter storms destroy more homes	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
1944-46	Storms	Dawlish Warren	17	"The storms of 1944-1946 washed away the end of the Warren…"	Newspaper article, E&E 23rd Nov 1949
21st December 1945	Storm	Dawlish Warren	17	"Worst for 50 years"?, Mines washed up on coast. Havoc was caused amongst beach huts at Dawlish Warren.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
21st December 1945	Storm	Starcross and Teignmouth	16	"Worst for 50 years"?, The railway line between Starcross and Teignmouth was deeply flooded. Ballast washed out from lines. Seats torn away from their fastenings on sea wall.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
21st December 1945	Storm	Starcross, Dawlish and Teignmouth	16, 18	No specific information provided within document	A historical record of coastal floods in Britain: frequencies and associated storm tracks.,
29th December 1947	Storm	Dawlish Warren	17	Strong winds caused rough seas. The River Exe rose so suddenly that four boats belonging to Tiverton sea cadets were carried away	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08

DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
10th December 1957	Storm	Starcross, Topsham	16, 12	No specific information provided within document	A historical record of coastal floods in Britain: frequencies and associated storm tracks.,
1959	Historical Construction	Dawlish Warren	17	Dawlish Urban District Council installed five timber groynes	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
Oct 1960	Flood Event	Exeter	13, 14	Severe flooding in Exeter resulted in flooding to more than 1000 properties. It was as a result of this flooding that the current flood alleviation scheme in Exeter was constructed.	The interaction of flood risk management in catchments, estuaries and the coast: a case study on the Exe Estuary, UK, (Dan Fox, Mike Kendon and Jonathan Rogers)
December 1960	Flood Event	Exeter	13, 14	Severe flooding in Exeter resulted in flooding to more than 1000 properties. It was as a result of this flooding that the current flood alleviation scheme in Exeter was constructed.	The interaction of flood risk management in catchments, estuaries and the coast: a case study on the Exe Estuary, UK, (Dan Fox, Mike Kendon and Jonathan Rogers)
8th October 1960	Storm	Exmouth	02, 03	No specific information provided within document	A historical record of coastal floods in Britain: frequencies and associated storm tracks.
Sept 1960	Flood Event	Lympstone	05	Large-scale floods in September 1960 caused problems in Lympstone – so severe that people had to use boats to move around the village.	Article "Exhibition to be held to mark 50th anniversary of Lympstone floods" By the Devon Week, on Wednesday, June 2, 2010, http://thedevonweek.newsandmediarepublic.org/2010/06/02/exhibition-to-be-held-to-mark-50th-anniversary-of-lympstone-floods/
Autumn 1960	Flood Event	Lympstone	05	"…flooding witnesses on Black Thursday in autumn 1960. This catastrophic flood was caused when 700 cumecs of flood water (some 30 – 50% above the river	Report " The Exe Estuary, National Cycle Network (NCN) Route 2, Exton to Lympstone, Flood Risk Assessment (no date), http://www.devon.gov.uk/extonlympstone-

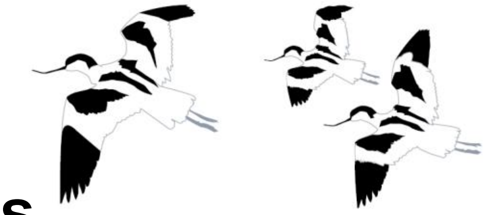
DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
				capacity) was generated by a period of rainfall over a ten week period… This 700 cumecs level of flooding is said to occur once in every 50 years.	floodriskassessment.pdf
Sept 1960	Flood Event	Lympstone	05	Large-scale floods in September 1960 caused problems in Lympstone - so severe that people had to use boats to move around the village.	Exhibition to be held to mark 50th anniversary of Lympstone floods 17 May 2010 http://www.devon24.co.uk/exmouthjournal/news/story.aspx?brand=EXJOnline&category=news&tBrand=devon24&tCategory=newsexj&itemid=DEED17%20May%202010%2011%3A55%3A19%3A407
27th Oct 1960	Flood Event	Alphington	14	On the next day, the 27th October, or 'Black Thursday', 700 cubic metres of water per second (cumec) rushed down between the banks of the Exe and overflowed the river from above Exwick down through St Thomas and towards the low lying parts of Alphington.	Article, The Exeter floods of the 1960s, Page updated 3 March http://www.exetermemories.co.uk/EM/exeter_floods.html2009
27th Oct 1960	Flood Event	Alphington	14	On the 27th October the River Exe overflowed the banks from Exwick, down through St Thomas and towards the low lying parts of Alphington. St David's Station was flooded on the east side of the river, but it was the western bank that took the brunt of the flooding.	Report: PROPOSED PARK & RIDE SCHEME ADJACENT TO A30 IDE INTERCHANGE, EXETER – FLOOD RISK ASSESSMENT REPORT, for Devon County Council by Parsons Brinkerhoff February 2009 http://www.devon.gov.uk/plandoc_94_3562.pdf
3rd Dec 1960	Flood Event	Exeter	13, 14	Five and a half weeks after the October flood, the waters surged back and on Sunday, 3 December a further 80mm of rain fell to swell the river waters and	Article, The Exeter floods of the 1960s, Page updated 3 March http://www.exetermemories.co.uk/EM/exeter_floods.html2009

DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
				again, flood 1,200 properties.	
11th March 1962	Historical Observation	Dawlish Warren	17	Sightseers swamped Dawlish Warren to see the extensive damage to chalets and beach huts. The lower Exe was awash with railway sleepers.	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
1962	Storm	Dawlish Warren	17	Newspaper article and accompanying photo appear to indicate that a winter gale caused damaged to the dune and required hard defences to be constructed.	Newspaper article dated 11.04.62
1962	Storm	Dawlish Warren	17	"Soon after World War II a great storm swept away the last of then [bungalows on the Warren spit] and the great storm of 1962 force the riparian authorities of Exe Estuary to sanction a join protection study"	Book: The book of Dawlish, Grace Griffith, 1984. pg88
8th February 1963	Breach (fluvial)	Upper Exe	13, 14	Upper Exe breaks banks	Extreme storm & weather on the Exe "as bad as ever", as cited within e-mail received from Mr Williams-Hawkes 28/11/08
1963	Storm	Dawlish Warren	17	Severe storms breached the Warren and dune heights were lowered	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
1969	Storm	Dawlish Warren	17	Severe storms breached the Warren and dune heights were lowered	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
January 1973	Storm	Dawlish Warren	17	Newspaper article and accompanying photograph appears to suggest that a winter storm caused damage to the recently completed sea defences.	Newspaper article dated 26.01.1973

DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
1974	Storm	Dawlish	18	One particular storm in 1974 washed away much of the down platform in the station[7].	http://en.wikipedia.org/wiki/Dawlish#cite_note-6
1989	Storms	Dawlish Warren	17	Storms damaged the revetments and emergency work was carried out by Teignbridge District Council	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
20th December 1989	Storm	Sidmouth, Dawlish, Budleigh Salterton, Lympstone	18, 05	No specific information provided within document	A historical record of coastal floods in Britain: frequencies and associated storm tracks.
1990	Storms	Dawlish Warren	17	Storms damaged the revetments and emergency work was carried out by Teignbridge District Council	National Rivers Authority (1993) and Barber (2001), (As cited within the extract of State of the Exe 2006)
1990	Storms	Dawlish Warren	17	Severe winter storms	Sims 1988 (As cited in The History of Dawlish Warren Research document)
8th December 2000	Flooding	Dawlish Warren	17	Torrential rain across Britain has triggered further flooding and nearly 100 new flood warnings, A caravan park at Dawlish Warren , Devon, had to be evacuated just before 1am today, police said.	Extreme storm & weather on the Exe “as bad as ever”, as cited within e-mail received from Mr Williams-Hawkes 28/11/08
26th and 27th October 2004	Storm	Dawlish Warren	17	Photograph showing how the rock gabions were exposed after the storm	Exe Estuary Management Partnership, (As cited within the extract of State of the Exe 2006)
26th and 27th October	Storm	Exe Estuary	01 - 18	In Torbay, it was described as a "once-in-25-years" storm by the Environment Agency.	http://www.bbc.co.uk/devon/news_features/2004/october_storms.shtml

DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
2004					
October 2004	Storm, Breach	Exmouth	02	In October 2004, severe south easterly storms coincided with high spring tides which caused the beach to be lowered and resulted in damage to both the Esplanade and Beach Gardens sea walls. During these storms the foundations of beach gardens were exposed and undermined sufficiently to cause partial subsidence of this section of wall. Rock armour was placed in front of this section as a temporary measure	www.eastdevon.gov.uk/exmouth_sea_wall_works.pdf
October 2004	Storm	Exmouth	02	Hard sea defences at Exmouth experienced a lot of damage (Photo provided). The resultant exposure of the timber foundation of the mid 19th century esplanade seawall increased the risk of failure of this defence structure. A section of the seawall failed, resulting in the partial subsidence of the Beach Gardens section of the seawall and subsidence, cracks and damage to the footpath behind.	Extract of State of the Exe 2006
2004	Storms	Dawlish Warren	17	“Major storms and erosion”	Coastal defence problems at Dawlish Warren, presentation by University of West of England, Dr Chris Spencer
10th March 2008	Storm and Breaching	Exmouth	02, 03	In Exmouth, the heavy winds and powerful waves meant water spilled on to some roads, making driving difficult.	Channel Coastal Observatory (2010) BBC News (with photograph)

DATE	DETAILS OF EVENT	LOCATION	FCRM Unit	IMPACT OF EVENT	REFERENCE
17th January 2009	Storm	Exmouth Dawlish Warren	02, 03, 17	'Tagged' by Plymouth Coastal Observatory in SANDS database as being a storm date which triggered a post-storm beach survey	Channel Coastal Observatory (2010)
19th October 2009	Storm	Exmouth Dawlish Warren	02, 03, 17	'Tagged' by Plymouth Coastal Observatory in SANDS database as being a storm date which triggered a post-storm beach survey	Channel Coastal Observatory (2010)
12th November 2009	Storm	Dawlish Warren	17	'Tagged' by Plymouth Coastal Observatory in SANDS database as being a storm date which triggered a post-storm beach survey	Channel Coastal Observatory (2010)
3rd March 2010	Storm	Dawlish Warren	17	'Tagged' by Plymouth Coastal Observatory in SANDS database as being a storm date which triggered a post-storm beach survey	Channel Coastal Observatory (2010)



5 Beach Profile Analysis

1 Introduction

This section details the steps taken as part of the beach profile analysis for the Exe Estuary Strategy. The purpose of the analysis is to provide understanding of how the beaches of Dawlish Warren and Exmouth respond and evolve in response to both typical and extreme wave and tidal conditions. Understanding the beach responses in these situations, when reviewed alongside other analysis of longer-term trends, will inform the development of the Exe Estuary conceptual model.

This analysis focuses on the beaches at Exmouth and Dawlish Warren and is concerned only with physical changes in the beaches, in terms of profile, area and volume changes and changes in plan shape positions. The analysis does not discuss implications for habitat change. The rest of this section is structured as follows:

- Section 2 – Data;
- Section 3 – Cross-Sectional Area and Volumes Analysis;
- Section 4 – Beach Position Analysis;
- Section 5 – Post-Storm Event Analysis; and
- Section 6 – Conclusions.

2 Data

The beach profile data used in this analysis originates from a number of sources, much of which was collated as part of the Exe Estuary Coastal Management Study (Halcrow, 2009). The main data used is:

- Two LiDAR profiles for May 1998 and December 2005; and
- South-West Regional Coastal Monitoring Programme (SWRCMP) profiles from Spring 2007 upto (in some places but not all) Spring 2010.

Figures 1(a) and 1(b) show the location and date range of all available beach profile data.

The data used for the analysis was largely copied from the SANDS ‘South Devon’ database and imported into the SANDS ‘DCDASP – Exe Estuary Strategy’ database. LiDAR profiles in this latter database are suffixed with ‘_L’. This copied data, which was used in the Exe Estuary Coastal Management Study, was then updated with the latest SWRCMP profile data that were downloaded as part of this analysis from the Channel Coastal Observatory website on Friday 4th June 2010. The LiDAR profiles have the same origin as the SWRCMP profiles and so, in order to extend the profile data sets in SANDS and to make analysis simpler, the LiDAR profile data was subsequently re-imported to be assigned to the same profile id as the relevant SWRCMP profile locations. The information in Figures 1(a) and 1(b) shows both the origin of all profile data available but also the range of dates that the profile data covers at each point.

In addition, a recent report by University of Plymouth (Esteves and Williams, 2010) looking at shoreline evolution of Dawlish Warren has been reviewed. Comparison between the findings of that report and the findings of the analysis undertaken as part of this strategy is provided at appropriate points within this section relating to Dawlish Warren.

2.1 Defining Beach Profile Analysis Units

From a review of the available profile data, it was decided to only analyse data for which several years of data were available. As some areas have more data available than others, it was also decided to group those areas with the same periods of data coverage into separate Beach Profile Analysis Units in SANDS (NB: these are referred to as Coastal Process Units in SANDS, but for clarity in the context of the rest of this strategy, are referred to as Beach Profile Analysis Units in the rest of this section). In addition, Beach Profile Analysis Units have been established for Post-Storm Surveys along both frontages. This has resulted in a number of Beach Profile Analysis Units being defined along both the Exmouth and Dawlish Warren frontages as follows:

- ‘Exmouth 1’ = all profiles along Exmouth frontage with profiles between April 2007 and February 2010. This equates to 14 profiles in total (Figure 2);
- ‘Exmouth 2’ = Profiles along the westernmost part of the Exmouth frontage where LiDAR data extends profile range to May 1998. This equates to 13 profiles in total (Figure 3);
- ‘Dawlish Warren 1’ = all profiles along Dawlish Warren frontage with profiles between May 1998 and March 2010. This equates to 19 profiles in total (Figure 4);
- ‘Dawlish Warren 2’ = all profiles along Dawlish Warren frontage with profiles between May 1998 and April 2007. This equates to 54 profiles in total (Figure 5);
- ‘Exmouth Storms’ = post-storm profile locations with data relating to storm events that are assumed to have occurred within a few days of the post-storm survey dates of 22/01/2009 and 20/10/2009 (Figure 6); and
- ‘Dawlish Warren Storms’ = post-storm profile locations with data relating to storm events that are assumed to have occurred within a few days of the post-storm survey dates of 13/03/2008, 23/01/2009, 23/10/2009, 29/11/2009 and 06/03/2010 (Figure 7).

It should be noted that based upon the review of profile data, it was decided not to carry out analysis along the Dawlish frontage to the south-west of Langstone Rock as only very limited profile data is currently available, making any meaningful analysis very limited at this time. Continued monitoring of this area over the coming years will eventually allow this area to also be analysed in greater detail.

2.2 Assigning Tide Levels

Tide levels were assigned to all beach profiles to be used for analysis. The values were taken from the 2010 Admiralty Tide Tables (United Kingdom Hydrographic Office, 2009) for Exmouth Approaches. These are:

- MHWS = +2.16mOD;
- MHWN = +0.96mOD;
- MSL = +0.07mOD;
- MLWN = -0.74mOD; and
- MLWS = -1.94mOD.

2.3 Defining Master and Design Profiles

In order to undertake analysis of profile changes, it is necessary to define reference profiles. For this analysis, two reference profiles have been defined. The Master Profile has been defined for each profile analysed to encompass the entire active beach area. The Design Profile has been defined to encompass the beach area that lies between MHWS and MLWS.

For Dawlish Warren the Master Profile has been defined at its landward limit as being the highest part of the dunes where, upon visual inspection, relatively small (if any) changes in profile have occurred over time. At the seaward end of each profile, the Master Profile is taken as far as necessary to encompass the MLWS tide level.

For Exmouth, the Master Profile has been defined at its landward limit as being the hard defence line that is clearly visible on each profile. At the seaward end of each profile, the Master Profile is taken as far as necessary to encompass the MLWS tide level.

For both Dawlish Warren and Exmouth, the Design Profile is defined as the area between MHWS and MLWS. It should be noted however, that the way in which SANDS calculates beach area and volumes means that where profiles are either above the MHWS level or fall short of the MLWS level, the values calculated can be over or under estimated. From a review of the profile data used in this analysis, volumes stated may be under or over estimated by up to approximately 1,000m^3. Whilst this margin of error does not significantly affect the analysis, this does need to be borne in mind when viewing volumes stated within the rest of this section.

Figures 8 and 9 illustrate the application of the Design and Master Profiles to beach profiles at Exmouth and Dawlish Warren respectively.

3 Cross-Sectional Area and Volumes Analysis

The profile data in each of the Beach Profile Analysis Units was analysed to derive beach volume and beach cross-sectional area data. Beach volumes were derived for two different reference profiles in order to allow assessment of how beach volume has changed over time along both the Dawlish Warren and Exmouth frontages, and to attempt to identify if different parts of the beach show different changes in beach volume. Cross-sectional area trend data has been assessed to identify the overall trends in beach movement along each beach profile.

3.1 Beach Volume Changes

(a) Exmouth Beach

The analysis of volume changes along the Exmouth Beach frontage is split into two parts, reflecting the different date ranges of data available. The first part looks at volume changes between 1998 and April 2007 for the western-most part of the frontage between Profiles 6a01809 and 6a01821, which is backed along its length by a seawall. Here, review of the volumes calculated shows that the volume reduced between 1998 and 2005 with profiles losing between -750m^3 and -6,655m^3. Although some of these changes are within the error margin of volume assessment, it is note worthy that the changes are consistent along the whole of the frontage, implying that the observed erosion is a real occurrence.

The Exe Estuary Coastal Management Study (Halcrow, 2009) concluded the majority of the reduction in volume was likely to have occurred as a result of a single storm event in 2004, although there is no profile data around that period to analyse to confirm this. From 2005 to April 2007, review of the volumes calculated shows that there was continued erosion and reduction in volume (-62m^3 and -1,117m^3). The rate of volume loss (-315m^3 and -1,120m^3) at the western end of this western-most part of Exmouth Beach (Profiles 6a01814 to 6a01821) was at a similar amount as between 1998 and 2005. This is in contrast to the eastern part of this section (Profiles 6a01809 to 6a01813) where volumes changed very little (-114m^3 and -231m^3) between 2005 and 2007. These volume changes are within the error margin of the assessment, however, changes are consistent over the frontage implying the observed erosion is a real occurrence.

Over the whole period between 1998 to April 2007, there was a net loss of volume between Profiles 6a01809 and 6a01821, with profiles losing between -1,160m^3 and -6,887m^3 over 12 years. The greatest loss of volume occurred at the eastern end of this section (Profile 6a01809; -6,887m^3 loss) with the amount of loss reducing along the frontage towards Profile 6a01821 (-1,343m^3 loss), as shown in Figure 10.

Figure 11 demonstrates the volume changes over the past 3 years along the frontage. This shows there is a clear loss of volume and erosion trend along the eastern half of the Exmouth Beach frontage with greatest loss occurring along The Maer frontage (-9,860m^3).

Erosion has continued to occur along the western-most part of the frontage (Profiles 6a01809 to 6a01821; -310m^3 to -1,040m^3,) but to a relatively less amount than the eastern half of Exmouth Beach (-51m^3 to -9,860m^3). Here though, slightly greater erosion has continued to occur towards 6a01809 (-1,040m^3) with volumes lost reducing along the frontage to 6a01821 (-310m^3). This is a continuation of the trends observed above between 1998 and April 2007 along this part of the frontage.

Accretion has, however, occurred along the Beach Gardens section of the Exmouth Beach frontage (Profiles 6a01792 to 6a01808; +1,590m^3 to -5,778m^3). This area is slightly indented and forms a very small embayment area within which this data suggests sediment accumulates.

Despite this accretion though, the net volume balance over the whole frontage over the last 3 years continues to be negative (-17,712 m^{3}loss) – erosion is ongoing.

(b) Dawlish Warren

The analysis of volume changes along the Dawlish Warren frontage is split into two parts, reflecting the different date ranges of data available.

The first part looks at volume changes between 1998 and April 2007. Figure 10 shows the volume changes along Dawlish Warren over this period.

Over this period the changes in beach volume occurred in three sub-sections along Dawlish Warren:

- the distal end which showed accretion (Profiles 6b00001 to 6b00017; +212,141m^3):
- the central part which showed erosion (Profiles 6b00018 to 6b00046; -330,989m^3): and
- the proximal end which also showed erosion but with greater amounts of fluctuation (Profiles 6b00047 to 6b00054; -19,341m^3).

At the distal end net accretion occurred between 1998 and 2005 over all profiles (+239,781m^3), but between 2005 and 2007 there was more variability along this part of Dawlish Warren, with some profiles eroding whilst others continued to accrete. These fluctuations however, were not sufficient to impact on an overall net accretion between 1998 and 2007. This is in agreement with the findings of the University of Plymouth research (Esteves & Williams, 2010).

Along the central part of Dawlish Warren there has been net erosion over the whole period from 1998 to 2007 with most profiles along this part of the spit reducing by between -4,676m^3 and -26,533m^3 over the period. The University of Plymouth research (Esteves & Williams, 2010) found similar trends of erosion of this part of Dawlish Warren over a longer period since 1890 (the earliest record analysed by University of Plymouth). They also found that the rate of retreat along

this central part has reduced since construction of the groynes in the 1960's when rates of MHW retreat from 1964 to 2010 are compared to rates of MHW retreat between 1890 and 1955.

The proximal end of Dawlish Warren has also experienced net erosion over the period 1998 to 2007 (-19,341m^3) to a similar degree as the central part in terms of relative volumes. However, the volumes in this area have fluctuated, with most loss of volume occurring between 1998 and 2005 (-15,050m^3) but a general pattern of (slight) accretion over this proximal end between 2005 and 2007 (+2,515m^3).

Overall, from 1998 to 2007, there was a net reduction in the volume of material along Dawlish Warren of -138,188m^3).

Moving on to look at the most recent 3 years of data covering April 2007 to February 2010, Figure 13 shows the volume changes along Dawlish Warren over this period in relation to the changes seen over the longer term back to May 1998.

The assessment of volume changes over this more recent period is limited to fewer profiles in total compared to the assessment for 1998 to 2007 above. However, despite utilising fewer profiles, the pattern of volume changes along Dawlish Warren between April 2007 and March 2010 is very similar to that observed between 1998 and 2007. Whilst there have been fluctuations between erosion and accretion over this period, the net changes show:

- continued accretion of the distal end (+6,999m^3);
- net erosion of the central (-128,610m^3); and,
- net erosion proximal parts of Dawlish Warren (-4,189m^3).

Overall from April 2007 to March 2010, there has continued to be a net reduction in volume along Dawlish Warren (-125,800m^3). This erosion has occurred on the central and proximal parts of Dawlish Warren, and although accretion has occurred at the distal end, the volume accreted does not exceed the volume eroded overall. This is corroborated by the findings of both the University of Plymouth research (Esteves & Williams, 2010) and the South-West Regional Coastal Monitoring Programme (Plymouth Coastal Observatory, 2010) which analysed the same data set.

3.2 Cross-Sectional Area Trends

(a) Exmouth Beach

Along Exmouth Beach, the CSA trends between Profiles 6a01767 and 6a01796 for the period April 2007 to February 2010 is for erosion at varying rates of loss. The greatest rate of loss (-51m^2) is at 6a01780. If this trend were to continue then the beach CSA above MLWS would decrease to zero within 10 to 20 years. This implies the complete loss of beach (assuming no intervention). This estimate is provided purely for indicative purposes and is based upon extrapolation of the recent trend in CSA reduction from the data available and does not include reference to actual underlying bedrock levels. If bed rock forms part of the CSA above MLWS then the volume of sediment would be smaller and would be lost sooner than 10 years.

Along profiles 6a01796 to 6a01804 the trend is for accretion (+82m^2) between April 2007 and February 2010. These profiles are around an indentation in the coast that forms a slight embayment. Accretion trends here suggest this slight embayment encourages deposition.

Along the western part of the Exmouth Beach frontage (Profiles 6a01809 to 6a01821) data is available from 1998 to February 2010 along a number of profiles. The CSA trends in these areas suggest that very little change (+4m^2) to a slight trend of erosion (-12m^2) has occurred. However, the profiles in this area have a relatively small CSA compared to profiles along the rest of

Exmouth Beach and if the CSA trends were to continue into the future (assuming no intervention) then there could be complete loss of beach along this area within 5 to 15 years. If bed rock forms part of the CSA above MLWS then the volume of sediment would be smaller and would be lost sooner than 10 years.

(b) Dawlish Warren

CSA trends along Dawlish Warren for the period May 1998 to March 2010 vary along the length of the spit. Profile 6b00007 at the distal end of the spit shows an accretionary trend (+1,492m^2), whilst 6b00009 also at the distal end shows very little change over this period.

Moving along Dawlish Warren, there is an overall CSA trend for erosion (-105 to -319m^2) along much of the spit with erosion appearing to occur over the whole beach from the highest part of the dune crest to the MLWS level.

The rate of erosion in the CSA trends reduces towards the proximal end of the spit. Taking the March 2010 CSA values along Dawlish Warren and projecting the CSA trends forward (assuming no intervention), suggests that the most vulnerable parts of the frontage are around profiles 6b00019, 6b00021, 6b00024 and 6b00030.

4 Beach Position Analysis

Data for each profile has been analysed by level (the tide levels defined above in Section 2.2) to identify where each tide level intersects each individual profile line at each location. The beach position data analysed for this purpose was for the surveys of:

- May 1998;
- April 2007;
- Feb/March 2008;
- Feb/March 2009; and,
- Feb/March 2010.

The changes in beach position between these periods were analysed to determine if the position of MHW and MLW has advanced or retreated over time, and whether the beach slope has steepened or flattened. This information was then used to assess the Foreshore Change Parameter (FCP) – defined below.

4.1 Foreshore Change Parameter

The FCP was originally developed by Halcrow for the Anglian Coastal Management Atlas (Halcrow, 1988) and was also used to assess foreshore change around the coast of England and Wales as part of the Futurecoast project (Halcrow, 2002). It assesses the movement of MHW, MLW and rotation of beach slope (inter-tidal gradient) to classify beach movement using a 13 point classification system, as shown in Table 1.

FCP	**MHW**	**MLW**	**Inter-tidal (gradient)**
+6	Advance	Advance	Flattening
+5	Advance	Advance	No Rotation
+4	Advance	Advance	Steepening

FCP	MHW	MLW	Inter-tidal (gradient)
+3	Advance	No Movement	Steepening
+2	Advance	Retreat	Steepening
+1	No Movement	Advance	Flattening
0	No Movement	No Movement	No Rotation
-1	No Movement	Retreat	Steepening
-2	Retreat	Advance	Flattening
-3	Retreat	No Movement	Flattening
-4	Retreat	Retreat	Flattening
-5	Retreat	Retreat	No Rotation
-6	Retreat	Retreat	Steepening

Table 1 Foreshore Change Parameter Classification System.

Based on the classification shown in Table 1, a classification mode of '-6' indicates an unhealthy beach trend, whereas '+6' indicates a healthy beach trend. The following discusses these results, first for Exmouth Beach (Section 4.2) and then for Dawlish Warren (Section 4.3).

4.2 Exmouth Beach

For the eastern part of the frontage between Orcombe Rocks and Beach Gardens (Profiles 6a01767 to 6a01808), only data between April 2007 and February 2010 was analysed. This is a relatively short data-set on which to make long-term assessments and therefore discussion of the results in the following should be treated with a degree of caution.

The majority of locations between Profiles 6a01767 to 6a01808 show an erosionary trend, with FCP typically around -3 (within a range of -1 to -5) indicative of a moderately unhealthy beach. There has been particular retreat of the MHW position (8 out of 11 profiles show MHW retreat) but relatively less movement of the MLW position (3 out of 11 profiles show retreat; 5 show no movement). Along this part of the frontage the back of beach is defined by hard defences and the MHW position lies in front of these. The retreat of the MHW position therefore shows a narrowing of the upper beach. In areas where this is coupled with the advance or stability of the MLW position, this means that beach profiles are flattening between MHW and MLW. Taking this as a whole, the upper part of the beach along much this section appears to be narrowing and lowering. The latter point is supported by visual inspection of the beach profile data in SANDS which shows the level of the beach near the hard structures is lower in the more recent surveys compared to earlier surveys (although levels do fluctuate).

This retreat of the MHW position is broadly in agreement with analysis of historic mapping undertaken for Futurecoast (Halcrow, 2002) which concluded (for location 'S226') net retreat of MHW and MLW had occurred over the period from the 1880's to 2000. The lack of MLW retreat in some areas differs to the longer term trends observed by Futurecoast. These differences can be explained by several factors:

(a) the location of the Futurecoast analysis point;

(b) the short term data set analysed not being representative of longer term trends but more seasonal variations, or

(c) a combination of (a) and (b).

The exception to this erosionary trend in the 3 years of data analysed is at the area around Beach Gardens (Profiles 6a01800 and 6a01804). This area is an indented part of the coast and appears to be relatively healthier compared to the rest of this section. MHW and MLW have both advanced over this 3 year period and the overall slope of the beach is steepening. Futurecoast (Halcrow, 2002) historic mapping analysis concluded (for location ‘S227’) a similar trend over a longer time period for this area.

In addition to the 3 years of data, a longer period of data was available for the westernmost part of the frontage (Profiles 6a01809 to 6a01821). Here, data for all profiles covered surveys in 1998, 2005 and April 2007, whilst 3 locations also have data from April 2007 to February 2010. This longer time-series of data allows longer-term trends to be observed with a higher level of confidence than the analysis only looking at 3 years of data.

Over the period from 1998 to April 2007, the trend here is for erosion with retreat of MHW and MLW and steepening of the beach. The FCP is typically -6, indicating a very unhealthy beach. Where data extends to February 2010 it is observed that there has been relatively little (if any) movement of note over the past 3 years along two profiles, but that at location 6a01812 the FCP continues to be high with ongoing retreat of both MHW and MLW.

4.3 Dawlish Warren

Analysis of beach position movements along the Dawlish Warren frontage benefits from having data covering the period from 1998 to April 2007 along all profiles, and a number of profiles that extend that data to March 2010.

The analysis of the data along Dawlish Warren is discussed in 3 sub-units, covering the:

(a) distal end;

(b) central portion; and

(c) proximal end.

It should be noted that the University of Plymouth research (Esteves & Williams, 2010) also presents the results of their analysis in 3 sub-units aligned to those determined as part of this strategy work.

(a) Distal End (Profiles 6b00001 to 6b00020)

Between 1998 and April 2007 the trend along this part of Dawlish Warren is for accretion, with advance of MHW and retreat of MLW, with overall steepening of the beach slope. The FCP over this period is positive indicating a relatively healthy beach over the period. More recent data from April 2007 to March 2010 suggests this situation has altered in the past 3 years, with overall FCP values being negative indicating an unhealthy beach at the present time. This recent reverse of the previous positive trend is associated with net retreat of MHW and MLW and some steepening of the beach slope, although both MHW and MLW positions still show periods of advance within this recent net trend.

The historical analysis presented in the University of Plymouth research (Esteves & Williams, 2010) concluded that the distal end of Dawlish Warren has historically experienced periods of both erosion and accretion, but that in recent decades (1964 to 2010) the trend has been for accretion and advance of the MHW position.

This broadly corroborates the analysis undertaken for this strategy. The recent net retreat observed in the strategy analysis may possibly be a short-term fluctuation within longer term trend, although without a longer period of data to analyse this is an uncertainty.

(b) Central (Profiles 6b00021 to 6b00046)

The overall trend between 1998 and April 2007 is for erosion of this part of Dawlish Warren, with retreat of both MHW and MLW and steepening of the beach slope. FCP values are mostly negative and typically -6, indicating an unhealthy beach. This is in agreement with the of historic mapping undertaken for Futurecoast (Halcrow, 2002) for a location along this central portion of Dawlish Warren.

This trend has continued between April 2007 and March 2010 with continued retreat of MHW and MLW and steepening of the beach slope. FCP values are all negative and mostly at -6, indicating an unhealthy beach.

This pattern of MHW and MLW retreat was also observed in the analysis of historical mapping between the 1880's and 2000 (for location 'S228') undertaken as part of Futurecoast (Halcrow, 2002). This finding is corroborated by the findings of the University of Plymouth research (Esteves & Williams, 2010).

(c) Proximal End (Profiles 6b00047 to 6b00054)

Between 1998 and April 2007 the trend at the western-most part of Dawlish Warren was erosionary, with retreat of MHW and MLW and steepening of the beach slope. This pattern of erosion has reduced in the recent data with profiles from April 2007 to March 2010 suggesting that there has been no movement of MHW over the past 3 years and at Profile 6b00051 the MLW position has advanced and the beach slope has flattened.

This area is backed by hard defences and visual inspection of the profile data suggests that MHW has not moved, a finding corroborated by the University of Plymouth research (Esteves & Williams, 2010). This is because the MHW position is at the hard defence and so cannot move further. The flattening of the slope is therefore likely attributable to the beach being drawn down in front of the hard defence.

5 Post-Storm Event Analysis

This section has reviewed recent impacts of storm events on shoreline evolution through analysis of post-storm survey data available from Plymouth Coastal Observatory. The analysis is split between Exmouth Beach, for which only 2 post-storm surveys are available to analyse, and Dawlish Warren, for which there are 5 post-storm surveys available to analyse.

The analysis has primarily focussed on the visual inspection of changes to the beach from comparison of post-storm surveys to the most recent pre-storm survey. Comparison to the subsequent survey is also made to assess recovery of the beach post-storm.

This section may also be read in conjunction with the Natural Events Review section above that discusses historical impacts of storm events around the Exe Estuary.

5.1 Exmouth Beach

Two post-storm surveys are available for analysis for the following dates:

- 22nd January 2009; and
- 20th October 2009.

The key storm parameters relating to these two events are presented in Table 2 below. Wave data is from the Plymouth Coastal Observatory monitoring data, notably the Start Bay wave buoy (for wave data) and the Teignmouth Pier tide gauge (for tide level data).

Storm date	Highest Significant wave height (m)	Maximum wave height (m)	General Wave direction (degN)	Approximate Direction spread (deg)	Tide Level (mOD)	Residual tide level (surge, m)
17/01/2009	2.5	4.53	180	+/- 20	1.07	+0.33
19/10/2009	1.95	2.97	140	+/- 30	0.54	+0.1

Table 2. Key parameters relating to the storms that triggered post storm surveys at Exmouth.

The most recent ‘pre-storm’ survey prior to the January 2009 storm is for February 2008 – nearly 1 year before. Therefore changes observed in the post-storm survey may not be a reliable reflection of the beach response to the storm event. In general, the analysis of beach profiles suggests that the January 2009 storm resulted in a reduction in beach levels around the MHW area and an increase in beach levels around the MLW area. Such a profile response is consistent with sediment being eroded from the upper beach and being deposited on the lower beach during storm conditions. The direction of cross shore movement appears to vary along the frontage and is likely to be related to the orientation of the profiles in respect of the wave direction. In this case, the wave direction in January 2009 was from a southerly direction so more perpendicular to the shoreline; a situation that would be expected to generate more cross-shore than long-shore sediment movement. In the normal cycle of beach response one would expect this period of upper beach erosion to be followed by periods of accretion during which material is moved back up the beach profile under more fair weather wave conditions. In the study area, recovery of the profiles appears to have been partial in the next survey 1 month later. Review of volume changes associated with this storm event suggests that full recovery to about the pre-storm volume took several months.

The response of the beach to the October 2009 storm are compared to a survey only 1 month previous and so are likely to be a reliable reflection of the impact of the storm. Figure 14 shows an example profile response for this event. In general the storm caused a reduction in beach levels around the MHW area and an increase in beach levels around the MLW area. Such a profile response is consistent with sediment being eroded from the upper beach and being deposited on the lower beach during storm conditions . In the normal cycle of beach response one would expect this period of upper beach erosion to be followed by periods of accretion during which material is moved back up the beach profile under more fair weather wave conditions. However, at this site there is little evidence of recovery in the next survey of February 2010 – in fact further erosion is evident. It is known that a large storm occurred in November 2009 and this further erosion/lack of recovery following the October storm may be a result of that event, although no post-storm survey for November 2009 appears to have been triggered. It may also be possible that the south-easterly direction of the waves during this event may have moved material alongshore once it was moved down the beach.

In summary, storms appear to move sediment in a cross-shore direction along Exmouth Beach, and in most areas this is in an offshore direction. It is uncertain if material moved offshore during storms is also moved alongshore, depending on wave angle to the shoreline, and in what proportions these cross-shore and long-shore transport processes operate. Recovery of the beach is then a gradual process taking several months.

5.2 Dawlish Warren

Five post-storm surveys are available for analysis for the following dates:

- 13th March 2008;
- 23rd January 2009;
- 23rd October 2009;
- 29th November 2009; and
- 6th March 2010.

The key storm parameters relating to these five events are presented in Table 3 below. Wave data is from the Plymouth Coastal Observatory monitoring data, notably the Start Bay wave buoy (for wave data) and the Teignmouth Pier tide gauge (for tide level data).

Storm date	Highest Significant wave height (m)	Maximum wave height (m)	General Wave direction (degN)	Approximate Direction spread (deg)	Tide Level (mOD)	Residual tide level (i.e. Surge) (m)
10/03/2008	3.17	6.72	185	+/- 30	n/a	n/a
17/01/2009	2.5	4.53	180	+/- 20	1.07	+0.33
19/10/2009	1.95	2.97	140	+/- 30	0.54	+0.1
12/11/2009	1.94	3.15	185	+/- 20	1.02	+0.35
03/03/2010	2.45	4.48	095	+/- 20	1.11	+0.1

Table 3 Key parameters relating to the storms that triggered post storm surveys at Dawlish Warren

It should be noted that the University of Plymouth research (Esteves & Williams, 2010) analysed only 3 of these 5 storm events (March 2008, October 2009 and March 2010), and only considered 5 of the 11 available post-storm survey profile locations.

In the case of the March 2008 storm, the most recent pre-storm survey was September 2007. For the January 2009 storm the pre-storm survey is from September 2008. For the late 2009 storms, the pre-storm survey was carried out in mid-October 2009, just a few days before the October 2009 storm. The pre-storm survey for the March 2006 storm was also carried out just a few days before the event (on 2nd March 2010). As such, there is greater confidence in the storm response assessments for the October, 2009, November 2009 and March 2010 storms compared to the other two storm events, simply by virtue of the relatively short period between pre- and post-storm survey dates.

For the March 2008 storms, particularly at the distal and proximal ends of the spit, there was a general trend for erosion around MHW and accretion around MLW. This suggests the cross shore movement sediment from MHW towards MLW under storm conditions. At this site beach profiles were seen to recover over the following 6 months. However, the central part of the spit experienced erosion over the whole profile, including erosion of dunes in some places. In these areas the evidence does not suggest accretion lower down the beach slope; a finding corroborated by the University of Plymouth research (Esteves & Williams, 2010). As there is no obvious coincident accretion alongshore, then it is thought most likely that this lack of accretion is more indicative of sediment being transported further offshore beyond the extent of beach profile surveys.

The January 2009 storm again appears to have resulted in sediment eroding from the upper beach and moving down the beach slope to be deposited towards MLW. There are varying levels of recovery from none to partial evident in the survey 2 months later, suggesting recovery (if any) takes several months to occur. The October 2009 storm again shows some evidence of moving sediment down the beach from MHW towards MLW. However, there is no obvious erosion of the backing dunes – a finding which is corroborated by the University of Plymouth research (Esteves & Williams, 2010). With no obvious coincident accretion alongshore, then (as above) it is thought most likely that this lack of accretion is more indicative of sediment being transported further offshore beyond the extent of beach profile surveys.

The next survey is for the November 2009 storm and this shows even more erosion along the whole frontage. In places this storm caused erosion of the fore dune. Evidence in some profiles also indicates sediment moved down the beach towards MLW. However, as above, in places this evidence is not present and with no obvious coincident accretion alongshore, then it is thought most likely that this lack of accretion is more indicative of sediment being transported further offshore beyond the extent of beach profile surveys. The combined impact of the October and November 2009 storms resulted in a net loss of beach volume of around 40% compared to the pre-storm volume.

By early March 2010 the distal end shows some signs of partial recovery, although the central part of Dawlish Warren has continued to erode. In places the main dune is eroded along its front face. The impact of the March 2010 storm is generally minimal, causing some further erosion and moving sediment down the beach slope from MHW towards MLW. These findings appear to be corroborated by the findings of the University of Plymouth research (Esteves & Williams, 2010) which notes dune erosion and beach accretion as a result of this storm event.

Figure 15 shows an example of the beach profile responses to the November 2009 and March 2010 events along one point of Dawlish Warren.

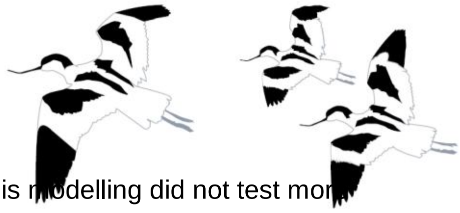
In summary, along Dawlish Warren it appears that the typical response of the beach to storm events is for sediment to cause erosion on the upper beach and accretion on the lower beach. This implies that material is moved down the beach profile. The degree of erosion of the upper beach is dependant on the wave and water levels. Under moderate storms waves erode the beach around MHWS level, but under more severe events waves erode the dunes as well. During particularly severe storms that material that is eroded from the dunes and upper beach is not deposited on the lower beach. During these events the material is either being moved:

- further offshore than is covered by the surveys, or;
- further alongshore.

It is uncertain which process occurs, or if a combination of these processes, in what proportions material moved during storms is moved alongshore and cross-shore.

Post storm recovery does occur, but is very slow, taking several months and not always recovering to the same level as previously. This incomplete recovery suggests that some material may be permanently lost from the beach system. These findings are in agreement with those of the University of Plymouth research (Esteves & Williams, 2010).

The University of Plymouth research (Esteves & Williams, 2010) also concluded that Dawlish Warren is most impacted by south-easterly storms, with storms from this direction causing most damage (erosion) compared to south-westerly storms. This conclusion is based on review of 3 storm events, two of which were from east and south-easterly direction, and supported by XBeach modelling that suggests localised erosion of the dunes in the vicinity of the groynes along Dawlish Warren is caused by water circulation cells set-up between the groynes moving sediment offshore



under easterly storm wave conditions. It should be noted that this modelling did not test more southerly wave directions.

The work that has been undertaken in the present report confirms that south-easterly storm conditions, that are perpendicular to the shoreline at Dawlish Warren, are likely to promote draw-down of sediment in a cross-shore direction within the groyne bays. However, the work that has been undertaken here also suggests that south-westerly storms can be produce similar changes. This conclusion therefore differs to that reached by the University of Plymouth which analysed a smaller number of storms.

6 Conclusions

Along Exmouth Beach, there is a clear pattern from the various analyses undertaken that most of the frontage is eroding. The exception to this is in the area around Beach Gardens, where the beach is relatively healthy, stable and accreting. Despite this area of accretion, the frontage as a whole is losing material and could potentially experience gradual loss of beach along parts of the frontage over the next 5 to 20 years if no intervention occurs, based upon extrapolation of recent trends in reduction of beach cross-sectional area.

Along Dawlish Warren, the trends can be considered in 3 sub-sections:

- The distal end shows a trend of accretion since 1998 (+212,141m^3) and is relatively healthy, although more recently this area has shown signs of experiencing fluctuations between periods of erosion and accretion. This is in line with the findings of the University of Plymouth research (Esteves & Williams, 2010) which found accretion of the distal end has occurred since 1964, although between 1890 to 1955 periods of both erosion and accretion have occurred.
- The central part of Dawlish Warren is in an unhealthy state and has experienced ongoing erosion over a long period of time since 1890 (and loss of -330,989m^3 since 1998), although the rate of erosion since the 1960's appears to have reduced since the introduction of groynes along this part (Esteves & Williams, 2010). Despite this, the beach along this central part is retreating landwards and the slope is steepening. The latest surveys show erosion of the fore and main dunes is currently occurring.
- The proximal end of Dawlish Warren is also eroding (loss of -19,341m^3 since 1998). However, due to this area being backed by hard defences, the beach levels in this area are already reduced and the response of the beach in this area is to lower and produce a flatter beach slope rather than retreat landwards (as retreat is constrained by the hard defences).,

It should be noted that the conclusions drawn from this analysis are based upon volume changes that have a margin of error of approximately +/- 1,000m^3. Whilst this margin of error does not significantly affect the analysis (as most changes exceed this tolerance level), this does need to be borne in mind when viewing volumes stated within this section.

In terms of beach response to storm events, along Exmouth Beach storms appear to move sediment in a cross-shore direction, and in most areas this is in an offshore direction. Recovery of the beach is then a gradual process taking several months. This appears to occur in response to waves from both south-easterly and southerly directions, although the limited data available means there remains significant uncertainty about this.

Along Dawlish Warren it appears that the typical response of the beach to storm events is for sediment to move down the beach slope. Recovery does occur but is very slow, taking several months and not always recovering to the same level as previously. From the limited data analysed

it is apparent that this response of the beach along Dawlish Warren occurs under wave conditions from easterly, south-easterly and southerly directions.

Along both frontages, it appears that sediment sometimes either moves further offshore, or is moved alongshore. There is uncertainty as to which process dominates, and in what relative proportions alongshore and cross-shore sediment transport occurs during storm (and typical) conditions. This is due to a lack of temporal (i.e. only a limited number of storm events have been recorded) and spatial data (i.e. profiles do not extend far enough offshore).

The findings of this analysis, which is based upon recent beach movement over a very short period of time, are to be used in developing the Exe Estuary conceptual model and should be used in conjunction with longer-terms trends analysis to provide a fuller picture of the evolution of both Dawlish Warren and Exmouth.

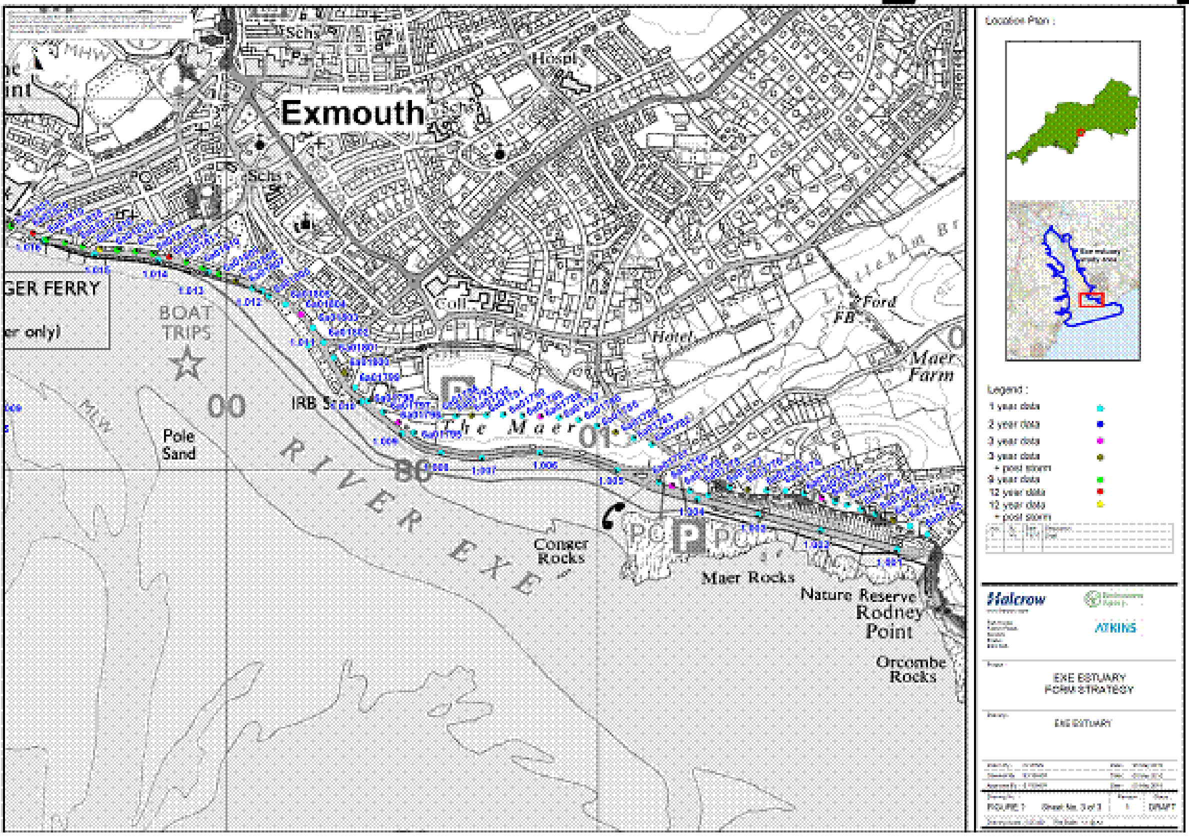


Figure 1(a) Available beach profile data along Exmouth frontage

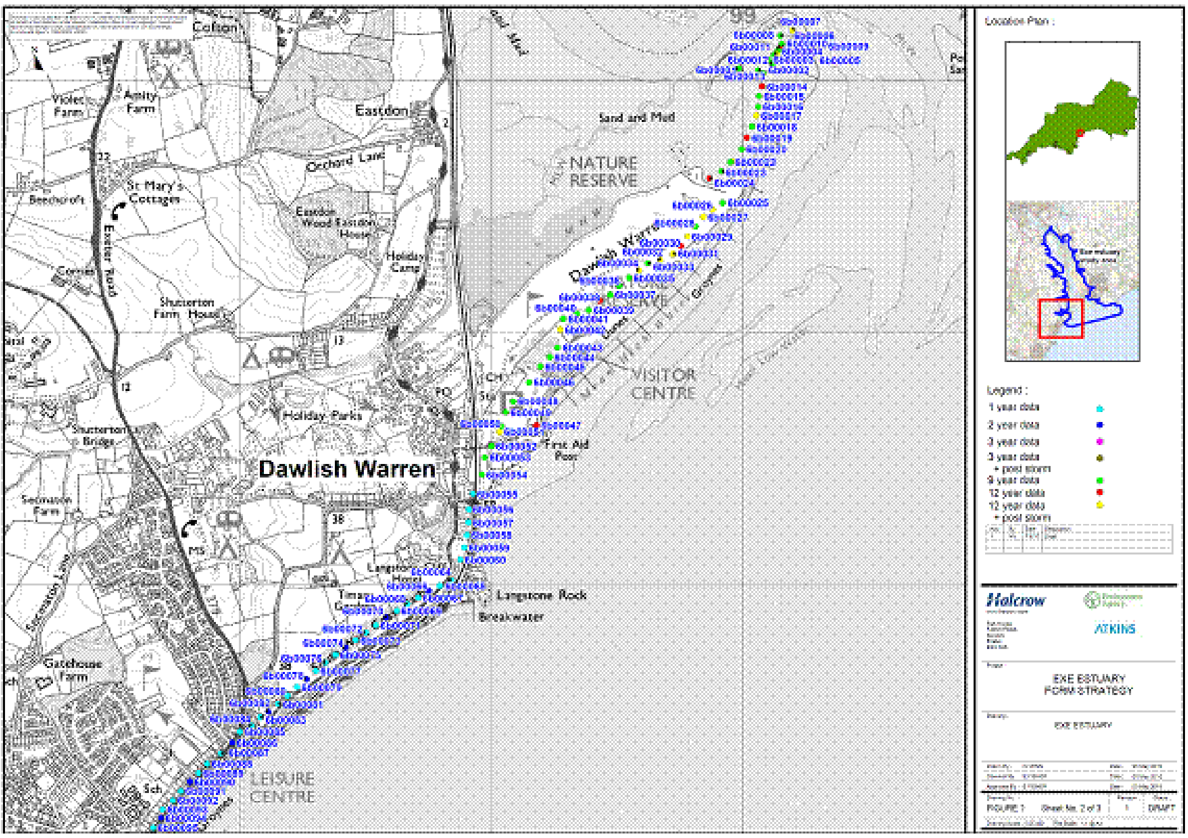


Figure 1(b) Available beach profile data along Dawlish Warren frontage

Figure 2 ‘Exmouth 1’ Beach Profile Analysis Unit.

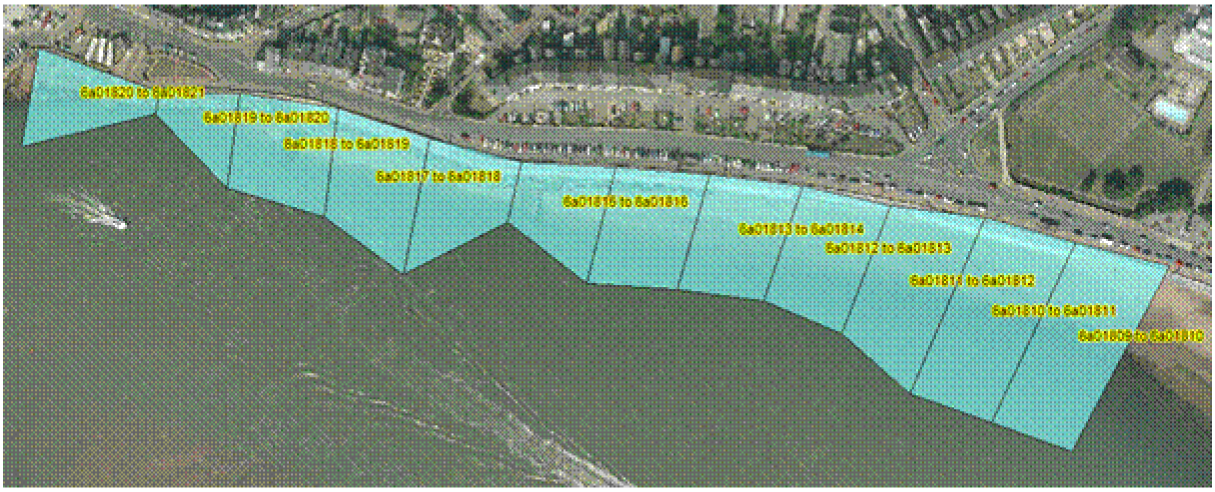


Figure 3 ‘Exmouth 2’ Beach Profile Analysis Unit.

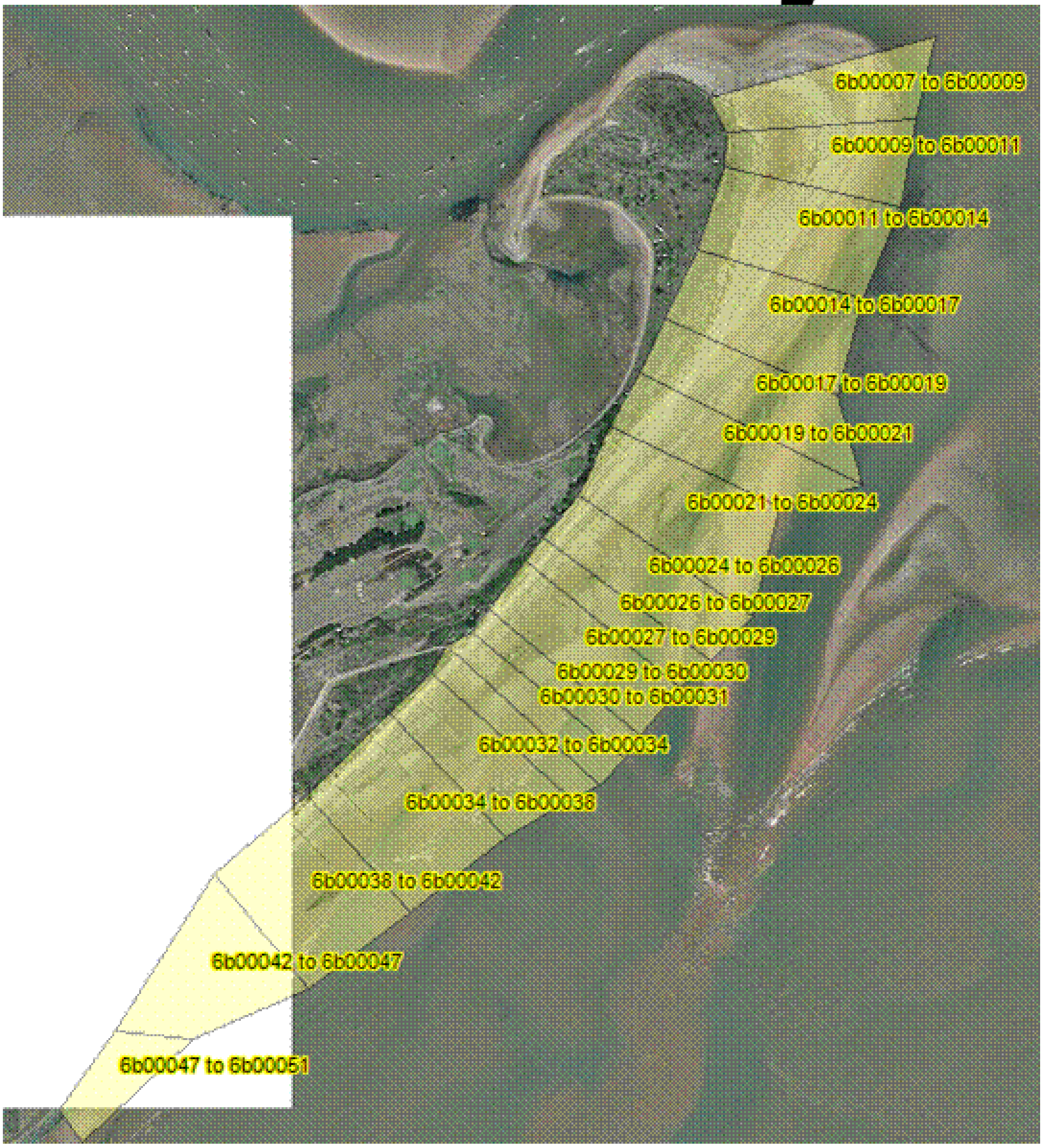


Figure 4 'Dawlish Warren 1' Beach Profile Analysis Unit.

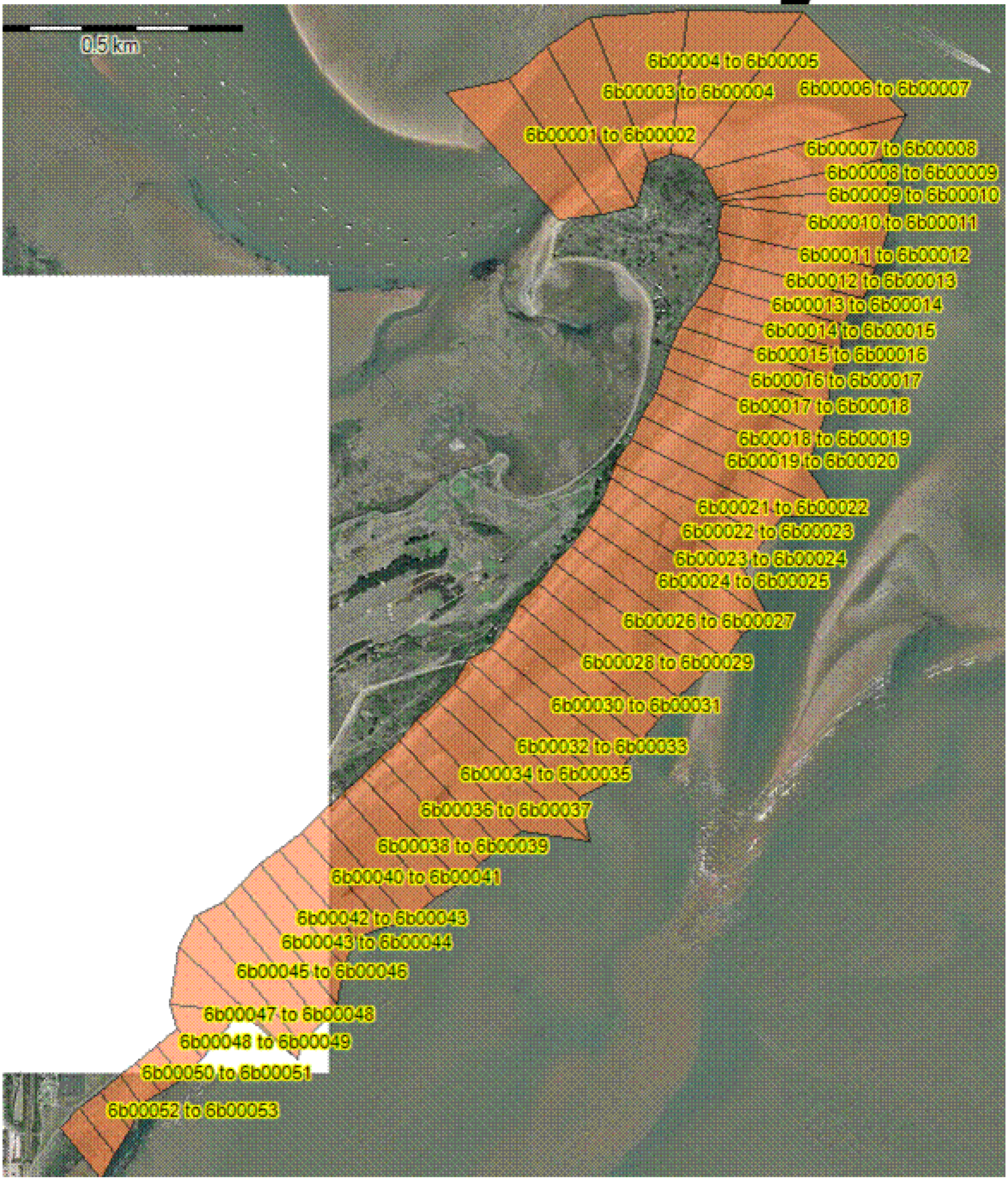


Figure 5 ‘Dawlish Warren 2’ Beach Profile Analysis Unit.

Figure 6 ‘Exmouth Storms’ Beach Profile Analysis Unit.

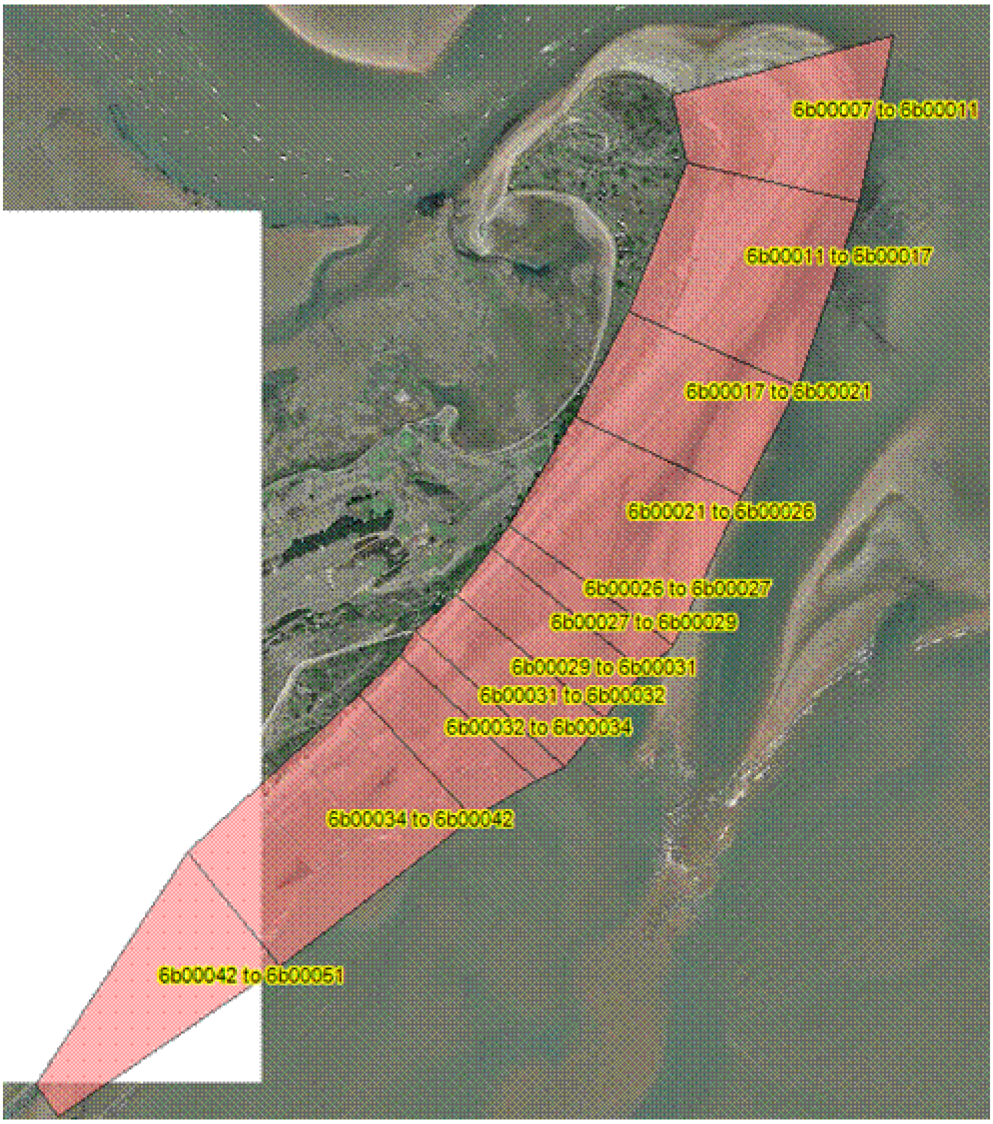


Figure 7 ‘Dawlish Warren Storms’ Beach Profile Analysis Unit.

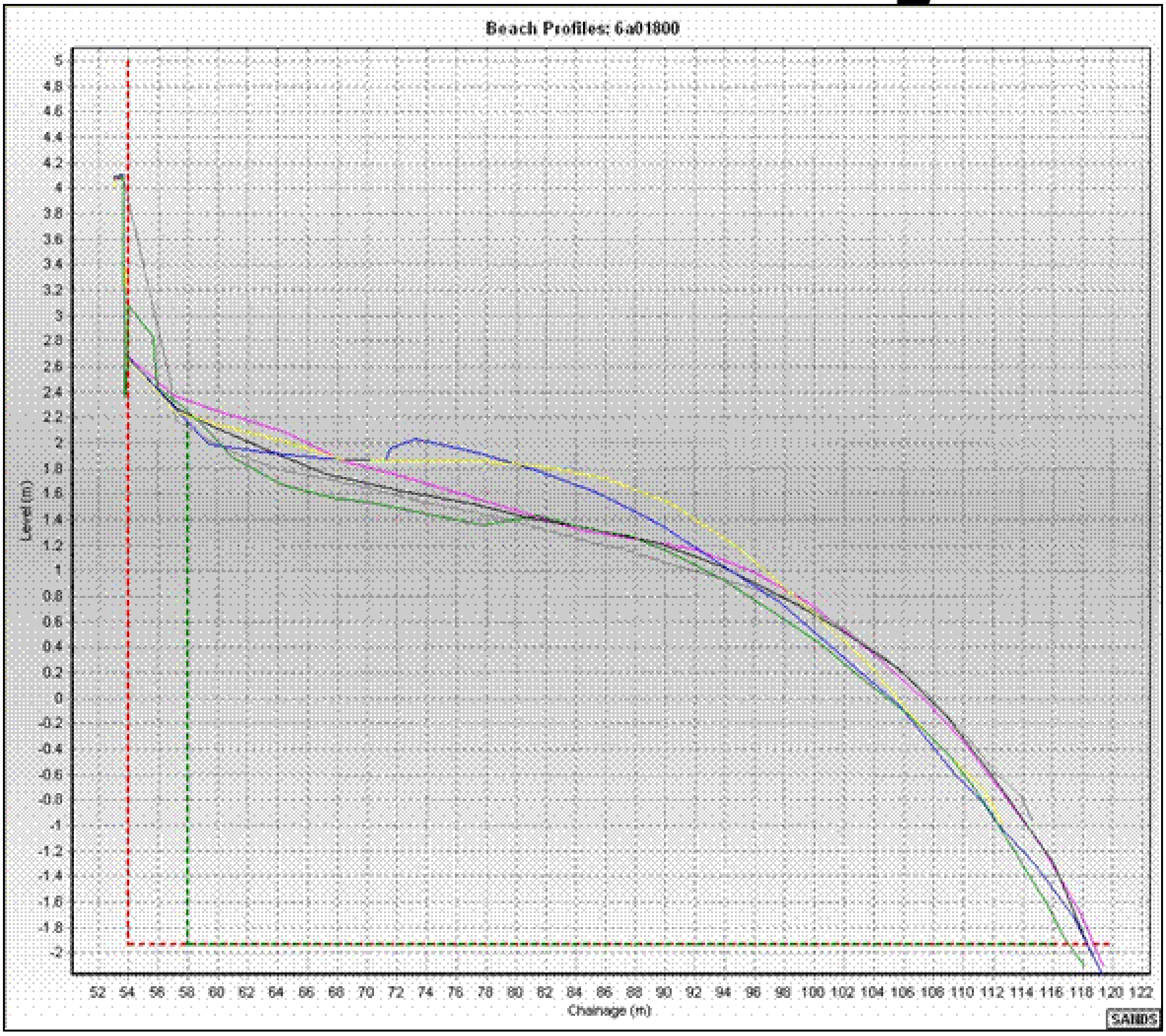


Figure 8 Example ‘Design’ (red dashed line) and ‘Master’ (green dashed line) profiles assigned to a profile location along the Exmouth frontage.

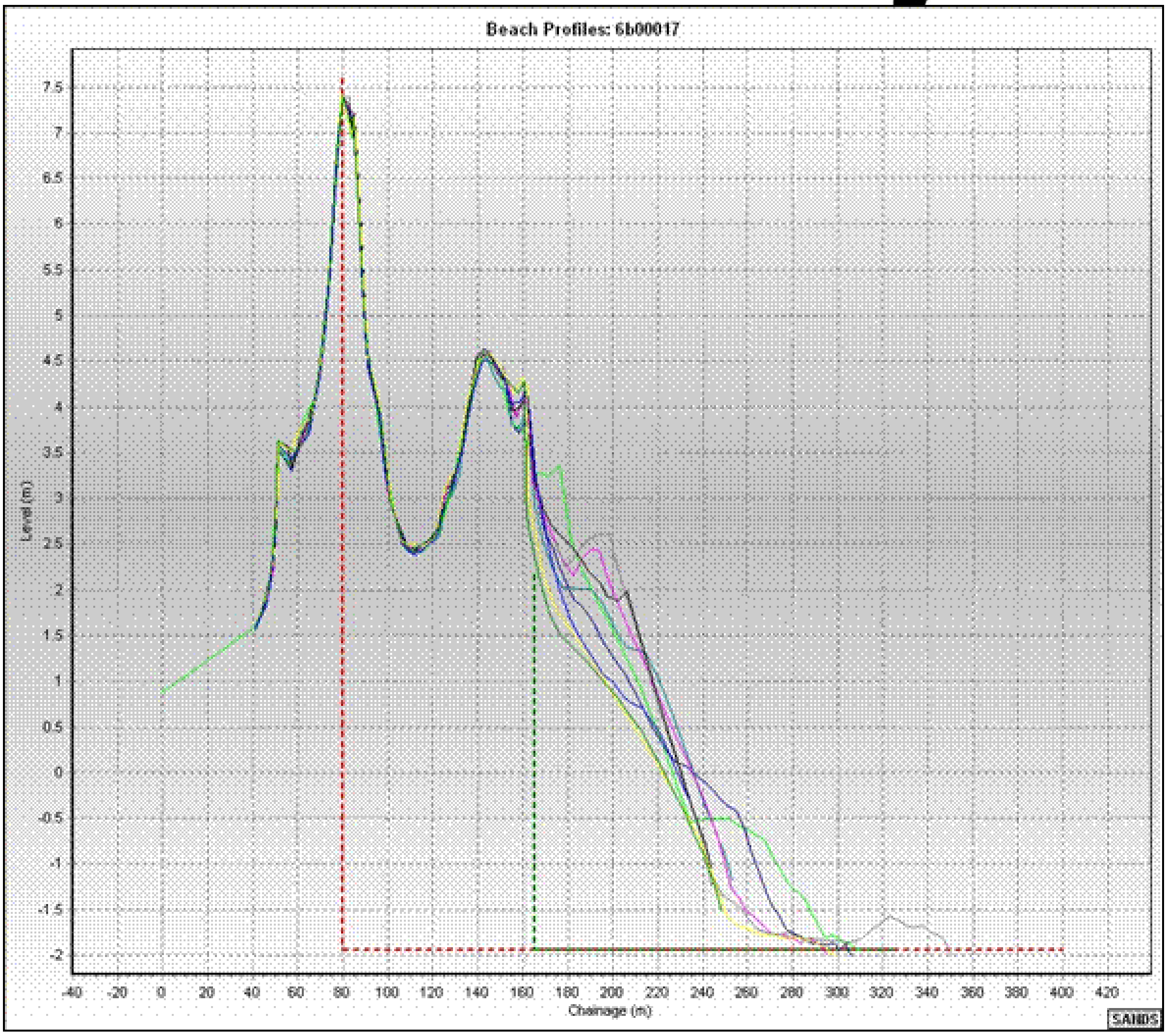
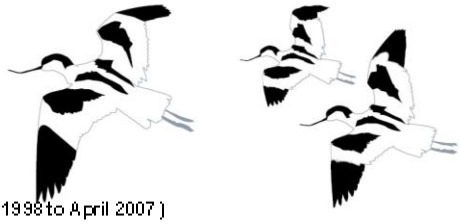


Figure 9 Example 'Design' (red dashed line) and 'Master' (green dashed line) profiles assigned to a profile location along the Dawlish Warren frontage.



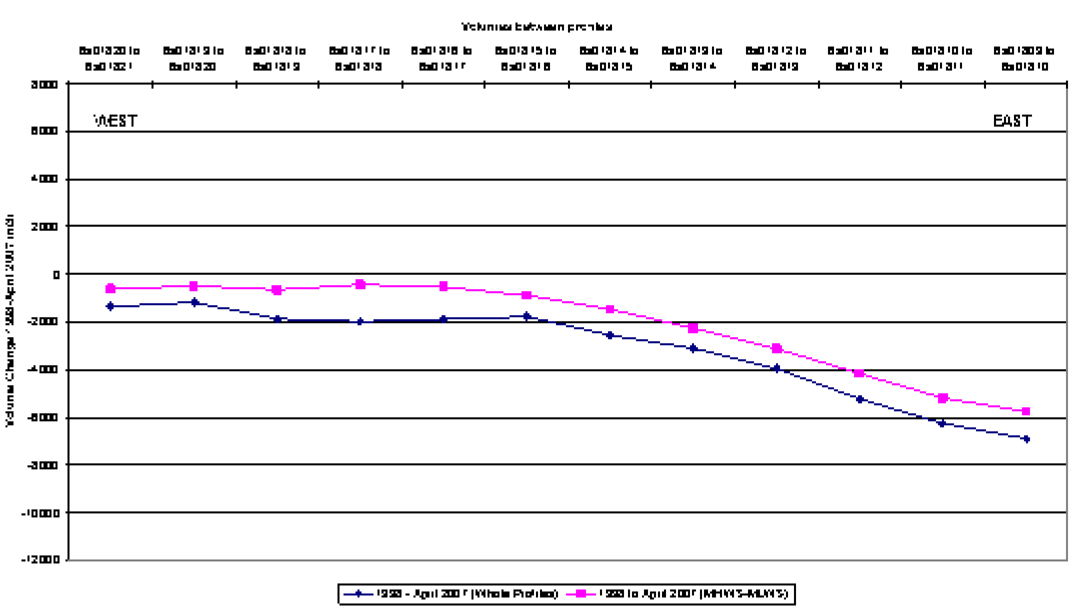


Figure 10 Beach volume changes 1998 to April 2007 along western-most part of Exmouth Beach (Profiles 6a01809 to 6a01821).

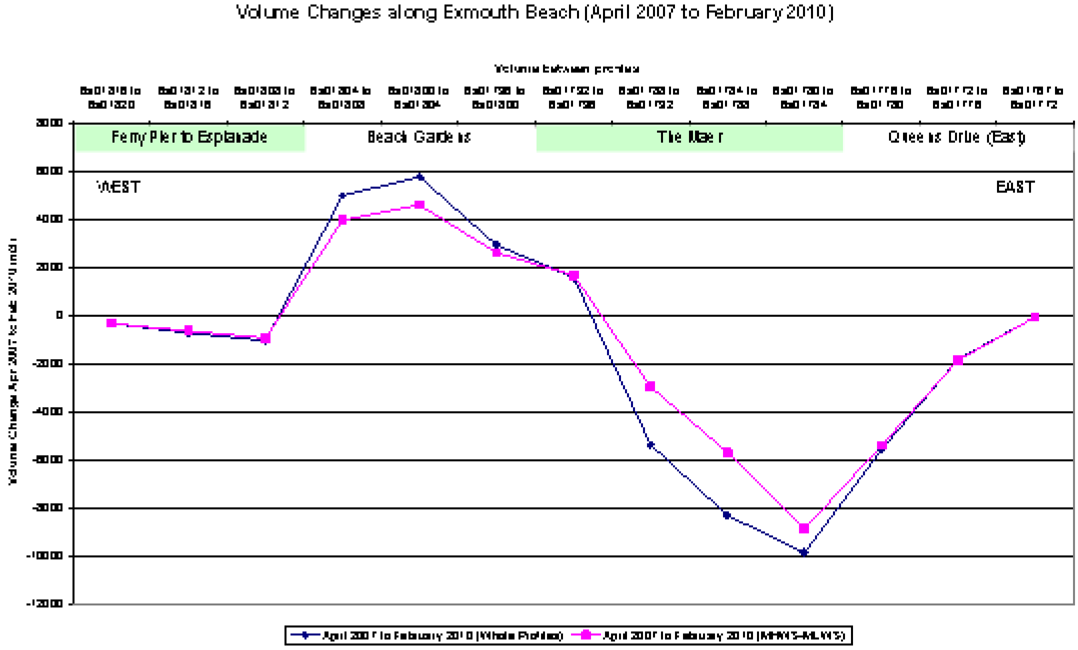
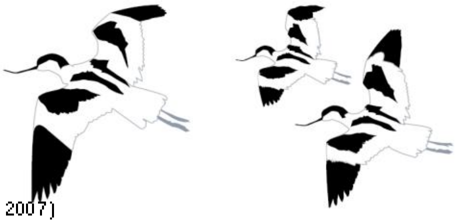


Figure 11 Beach volume changes April 2007 to February 2010 along Exmouth Beach.



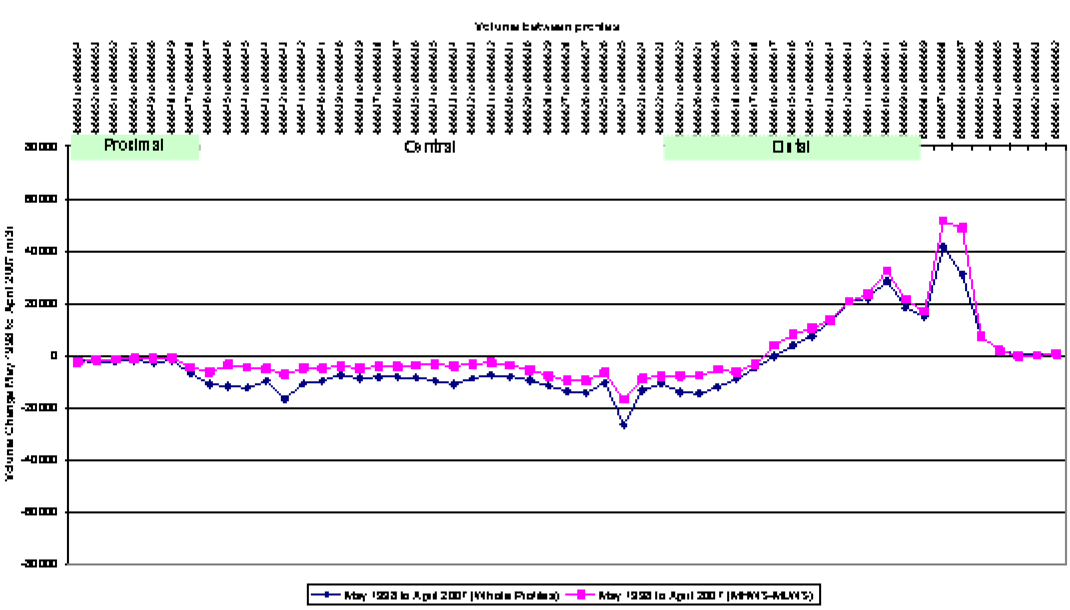


Figure 12 Beach volume changes May 1998 to April 2007 along Dawlish Warren.

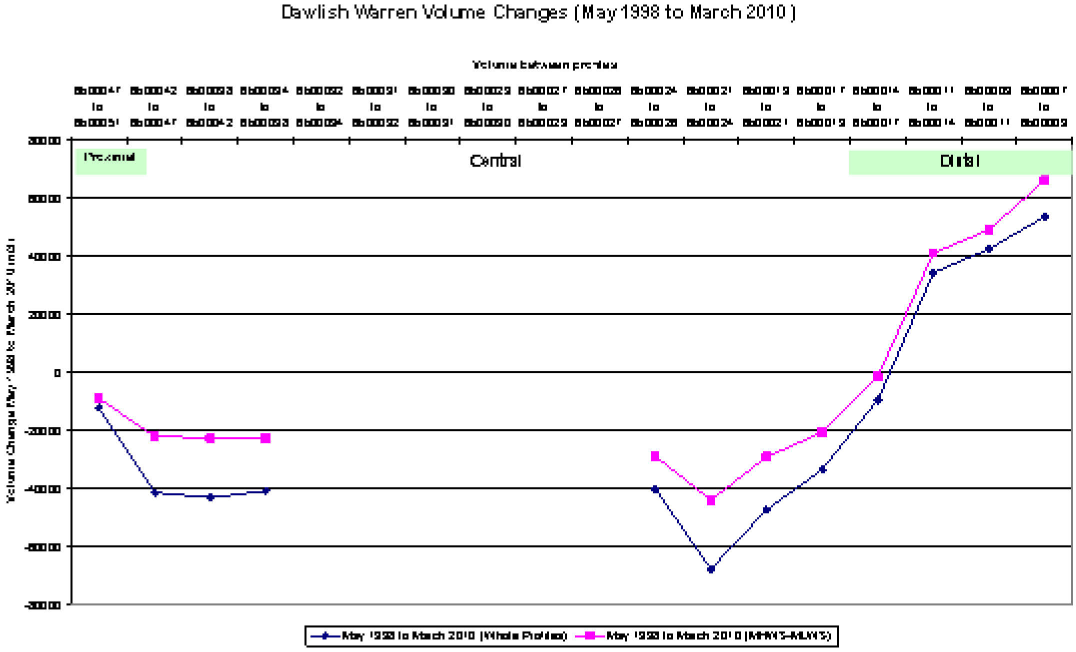


Figure 13 Beach volume changes May 1998 to March 2010 along Dawlish Warren.

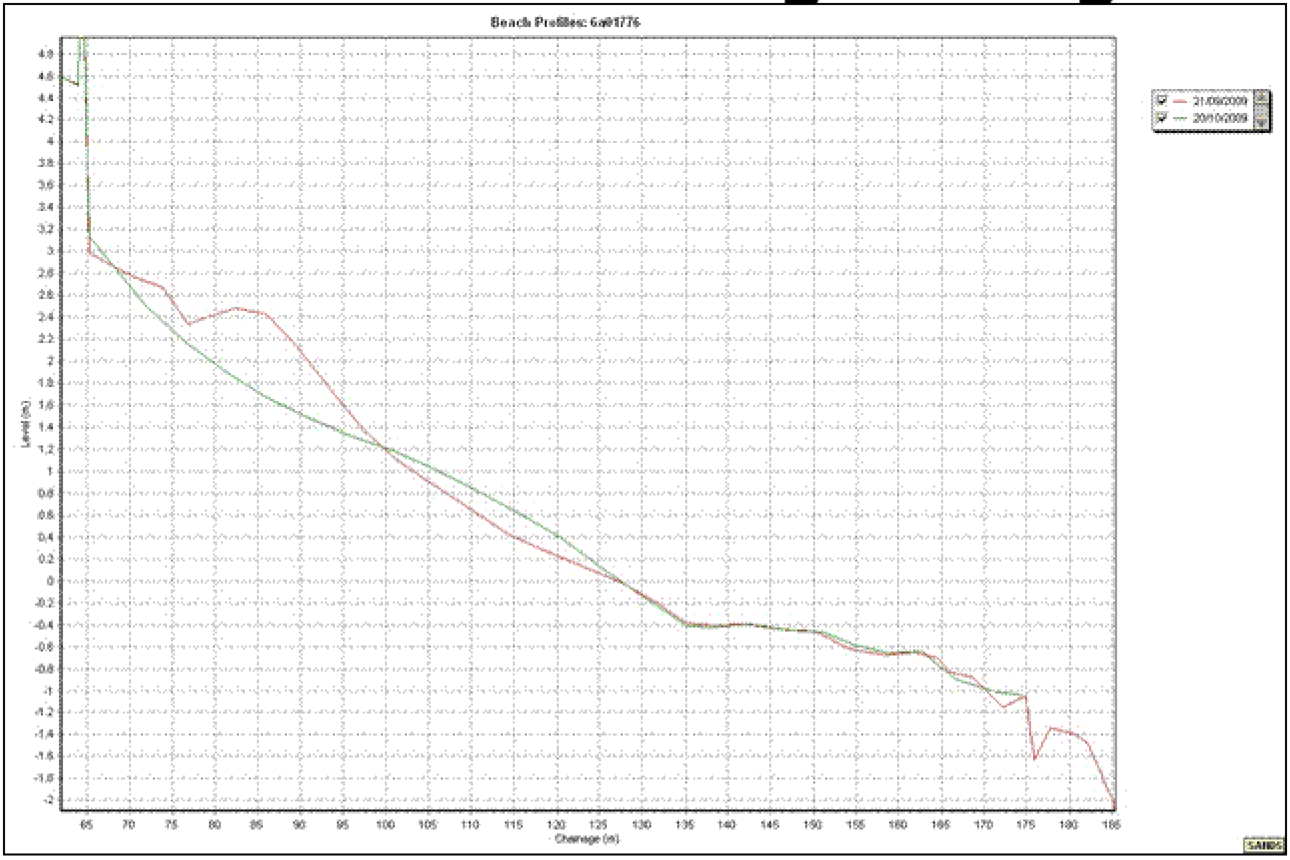


Figure 14 Example of the October 2009 beach profile storm response along the Exmouth frontage.

Figure 15 Example of the November 2009 and March 2010 beach profile storm responses along the Dawlish Warren frontage.

6 Historic Spatial Analysis

1 Purpose

This section documents the steps taken as part of the historic Ordnance Survey (OS) mapping and aerial photography analyses.

The rationale for undertaking this work is that this will provide information on long term historic trends and events that have occurred since the 18th century. As noted previously, understanding how the estuary has developed in the past provides and insight into how it might develop in the future.

This section details the It is structured as follows:

- Summary of collection of historic OS maps and vertical aerial photography.
- Analysis of historic OS mapping.
- Analysis of vertical aerial photography.

2 Data Collection

Historic OS maps were received from the Environment Agency for the 1880-90s, 1900s and 1930s, with coverage summarised in Figure 1. These datasets were supplied in geo-referenced format.

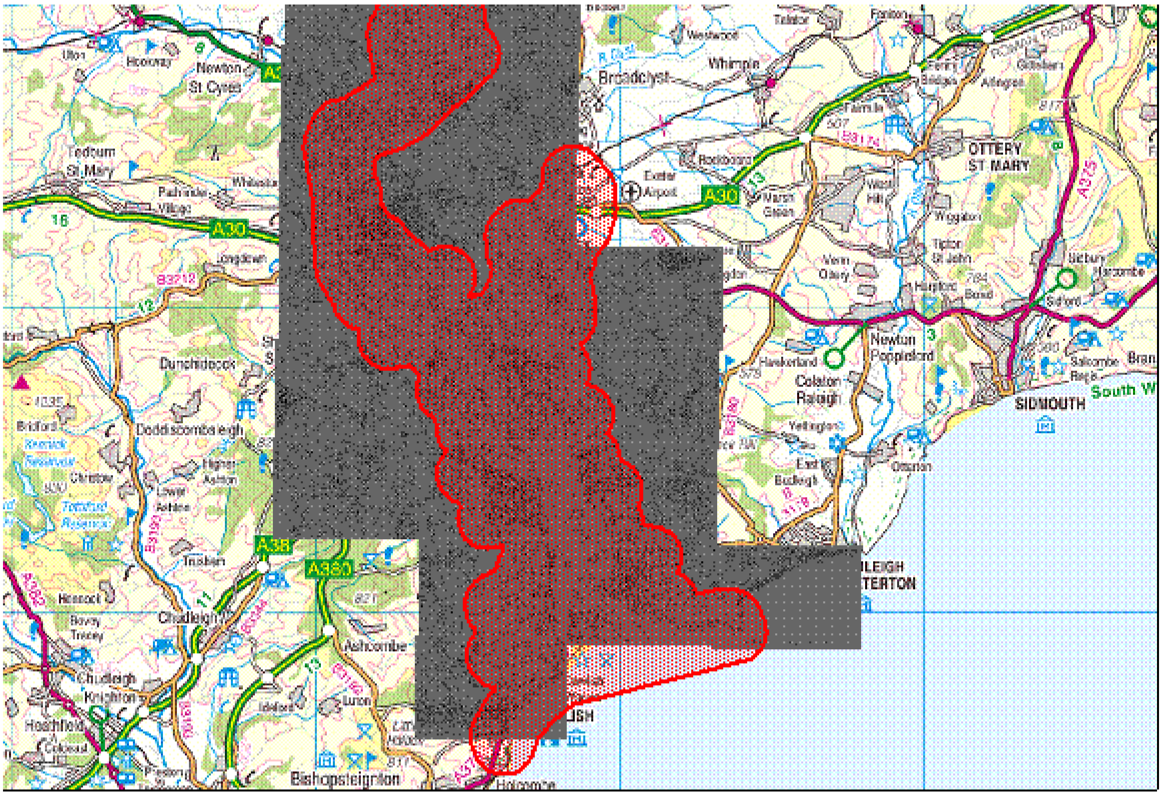


Figure 1. Coverage of historic OS maps.

Vertical aerial photography was sourced from the National Monuments Record archive, as described in detail in AHA (2010a). The collected datasets are summarised in Table 1.

Year	No. on short list	No. eliminated	No. of suitable photos
1941	57	20	37
1946	78	48	30
1950	58	30	28
1960	49	2	24
1969	47	19	28
1979	33	8	25
1988	22	10	12
TOTAL	344	137	184

Table 1. Historic vertical aerial photography collected from NMR.

The collected aerial photographs were geo-referenced using MapInfo, applying a general minimum of 4 spatial reference points. The estimated spatial accuracy of the geo-referencing process for each set of photographs is summarised in Table 2, including the most recent photographic dataset for reference.

Year	Horizontal accuracy (order of magnitude, m)
1941	10
1946	
1950	
1960	
1969	1
1979	
1988	
2000	

Table 2. Estimated spatial accuracy of geo-referenced photographs.

3 Historic OS Mapping

A number of features were mapped from the historic OS maps. These were:

- Low Water Mean Ordinary Tide (LWMOT)
- High Water Mean Ordinary Tide (HWMOT), and
- saltmarsh.

These were also compared to present day OS mapping, although this maps Mean Low Water (MLW) and Mean High Water (MHW) which may not be exactly the same as LWMOT and HWMOT. The hard coastline was also mapped, but did not show any clear changes over time and often coincided with HWMOT and MHW. The outlines of these features are given in Figures 2, 3, and 4. Quantified observations are given in Tables 3 and 4. The analysis focuses on the estuary mouth as this is where significant changes have occurred.

The LWMOT features show clear changes. At Dawlish Warren, whilst the mapping is intermittent, it is apparent that the central and distal sections moved in-estuary with the rate reducing from 7m/yr (1900-1930) to 2m/yr (1930-2000). At the main body of Pole Sands, the spatial area reduces and then increases by 26-37%. Bull Hill banks experiences large changes in shape and location, generally drifting westwards until 1930, and then moving eastwards again. The spatial area reduces and then increases by 25-30%.In 1890 Pole Sands LWMOT was linked to the Dawlish Warren LWMOT, however by 1900 this had separated, and by 1930 a clear LWMOT channel exists between Dawlish Warren and Pole Sands of up to 350m. By 2000 this LWMOT channel is still present, but less coherent spatially: this trend of change appears to be generally corroborated by Esteves & Williams (2010), although they note a possible cyclical change with loss of the LWMOT channel observed from OS mapping in 1955.

The HWMOT and saltmarsh features show smaller changes. The proximal section of Dawlish Warren has remained static, as corroborated by a similar MHW analysis by Esteves & Williams (2010). The central section moved in estuary with a reducing rate from 7 to 1 m/yr, which again is corroborated by Esteves & Williams (2010), who note the influence of groyne construction in the 1960s on reducing the in-estuary rate of movement. The distal section has moved in-estuary by a total of 270m, and both extended and retreated north-eastwards. This general movement of the distal end is again corroborated by Esteves & Williams (2010), who suggest that this is due to the growth of the ebb delta (Pole Sands); whilst spatially Pole Sands appears to have reduced in size, there were volumetric increases as note in the historic volumetric analysis. The north-eastwards movement narrowed the estuary mouth and may have resulted in increased tidal velocities. Whilst the distal end changed shape, the spatial area remained relatively constant until after 1930, when it reduced by around 50% to the present day. Saltmarsh features are only recorded in the lee of Dawlish Warren, and have not varied significantly in coverage.

Feature	1890-1900	1900-1930	1930-2000
Dawlish Warren in-estuary movement	NA	200m	140m
Pole Sands spatial area change	-40Ha	-17Ha	30Ha
Bull Hill Banks westward movement	200m	300m	-300m
Bull Hill Banks spatial area change	-2Ha	-3Ha	9Ha

Table 3. LWMOT observed changes.

Feature	1890-1900	1900-1930	1930-2000
Dawlish Warren central section in-estuary movement	70m	70m	50-100m
Dawlish Warren distal end in-estuary movement	NA	120m	150m
Distal end spatial area change	2Ha	-3Ha	-8Ha
Saltmarsh spatial area change	7Ha	-2Ha	1Ha

Table 4. HWMOT and saltmarsh observed changes.

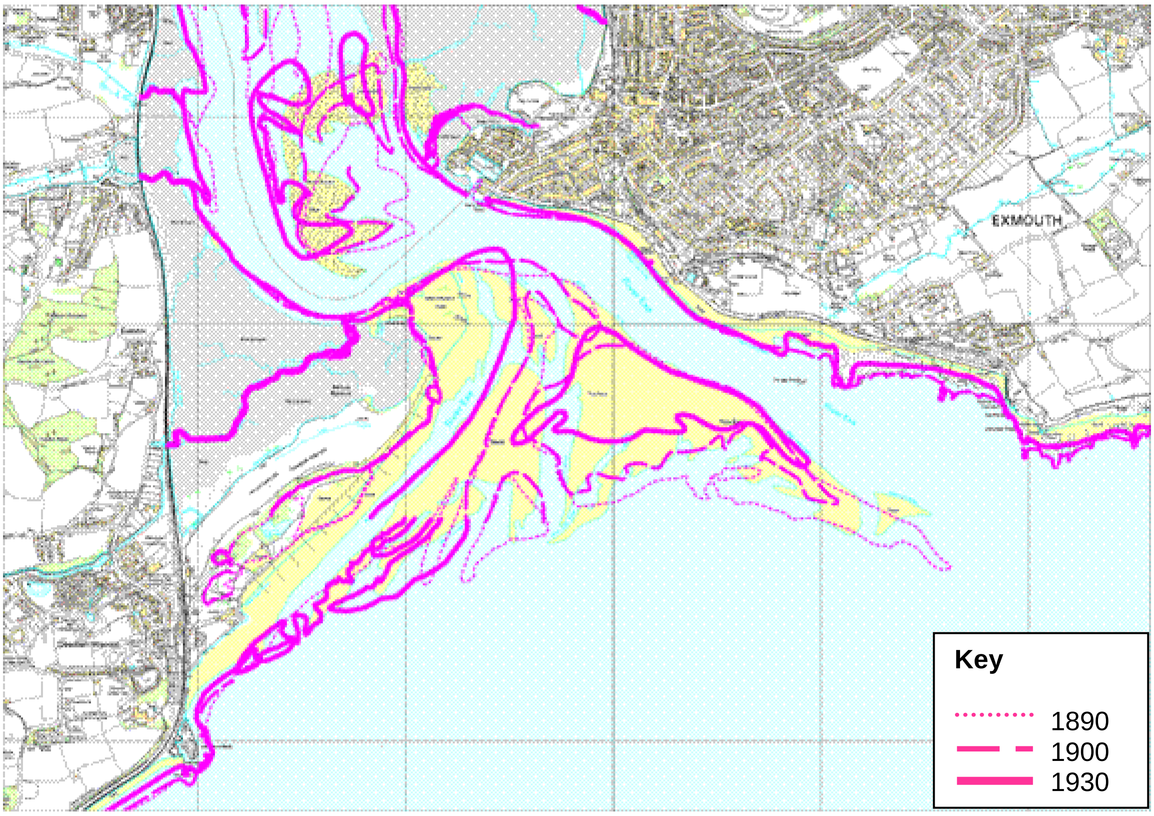


Figure 2. LWMOT between 1890 and 1930.

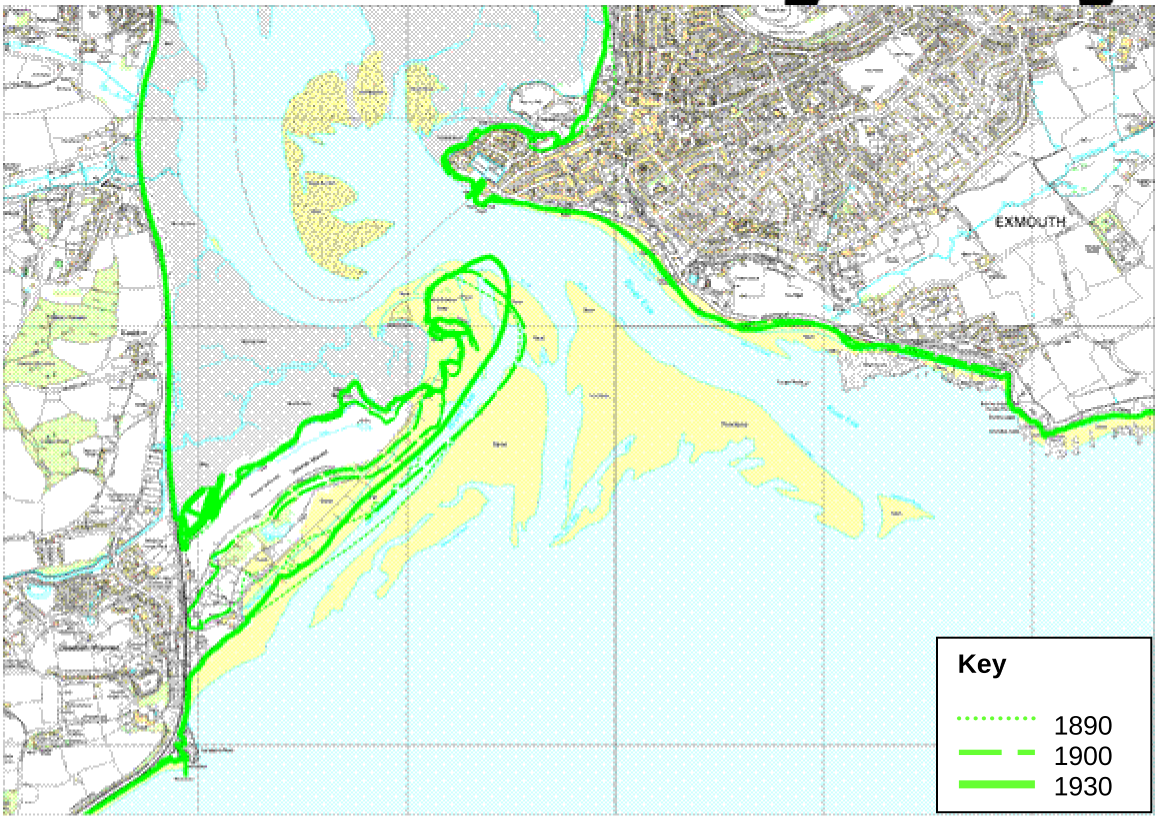


Figure 3. HWMOT between 1890 and 1930.

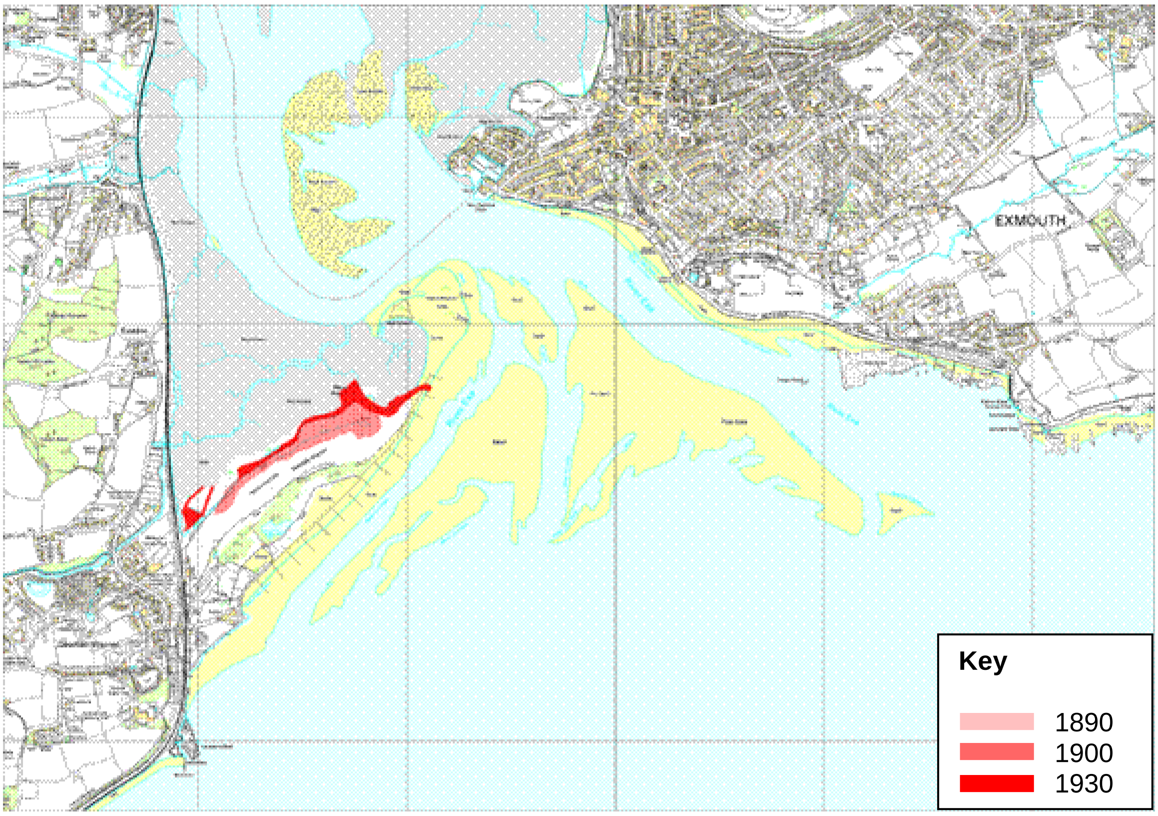


Figure 4. Saltmarsh between 1890 and 1930.

4 Vertical Aerial Photography Mapping

Vertical aerial photography provides a more detailed source of visual information than historic OS maps, however the mapping of features is not as clear cut. Different aerial sorties will be carried out at different tidal states, meaning that mapping of low water is difficult and unlikely to be quantitatively correct. However, other features are more easily mapped, such as intertidal or terrestrial vegetation extent, or more detailed assessment of regeneration and damage to natural or man-made structures. Again, commentary will be focussed around the estuary mouth where measurable (whether quantitative or qualitative) changes have occurred. As Bull Hill Banks and Pole Sands are low water features rather than high water, and therefore at least partially submerged in the photographs, the focus will furthermore be on the evolution of Dawlish Warren, and specifically its response to storms. In particular, the dataset has captured the response of Dawlish Warren to the series of storms in the 1940s, and the related recovery from the late 1940s onwards. Summary images of the photography are provided in Figures 5 to 13.

The 1941 set of aerials show Dawlish Warren with its distal end intact but damaged; the remains of the buildings on the distal end can be seen. By April 1946 it can easily be seen that the distal end has been seriously damaged, and become partially detached (dependent on tidal state) as a relatively small island. This was in response to a well documented series of storms in the intervening period (refer to Natural Events Review). By November 1946, 7 months later, the island had reattached, and possibly lowered (due to lack of vegetation) and become more active, with evidence of sand recurves. By 1950 the distal end had grown significantly, although still unvegetated, The April to June 1960 aerial set shows evidence of human intervention at the distal end, with a linear structure apparent with around north-south orientation. By 1969 revegetation of the distal end is occurring, which expands consistently through to 1999.

In addition to the large-scale changes at the distal end, the proximal to central section shows clear expansion seawards. In 1941 it is apparent that there is a seaward vegetated frontage to Dawlish Warren that is relatively unmanaged. By 1946, this area has become more clearly defined, with internal groynes present. By 1969 this area is terrestrial and has some buildings constructed on it. These buildings are no longer present by 1988, and the vegetated area is the present day gabion protected dunes and the Dawlish Warren nature reserve. Throughout the time period 1946 and 1999 there is no clear measurable movement in the seaward extent of this area.

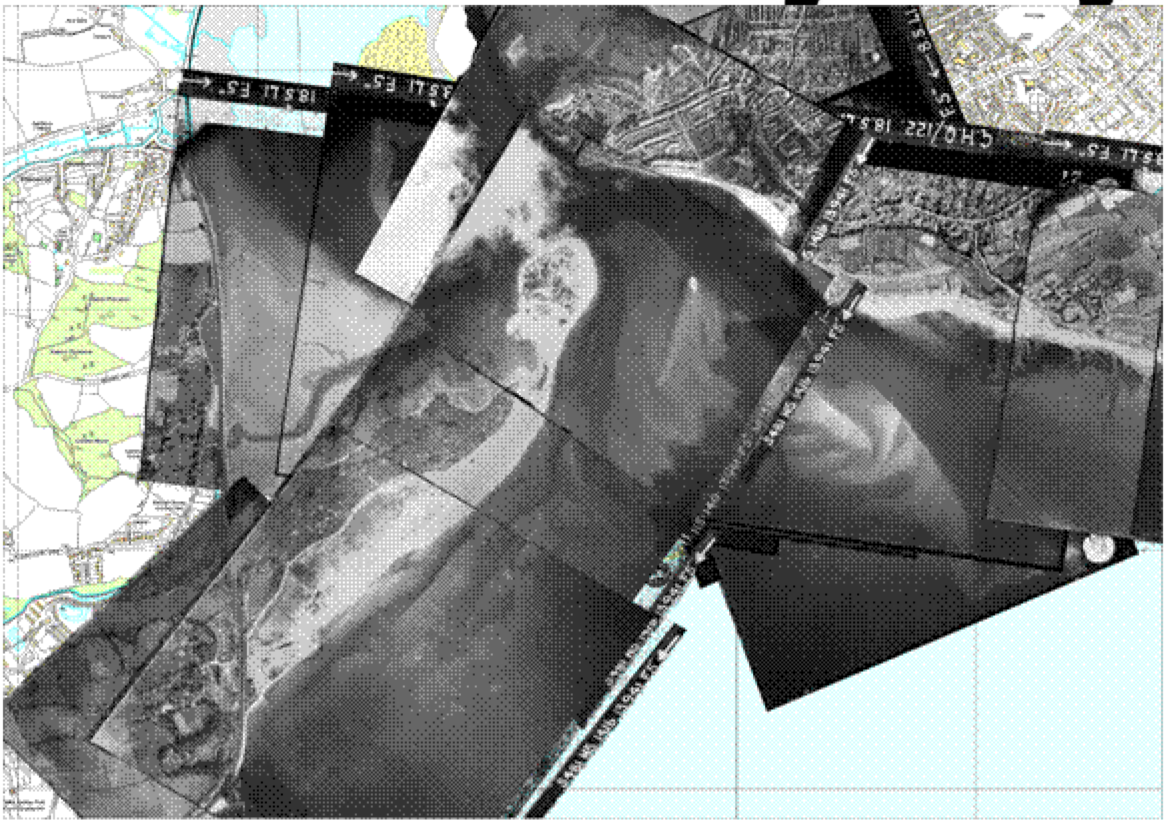


Figure 5. Dawlish Warren in May to September 1941.

Figure 6. Dawlish Warren in April 1946.

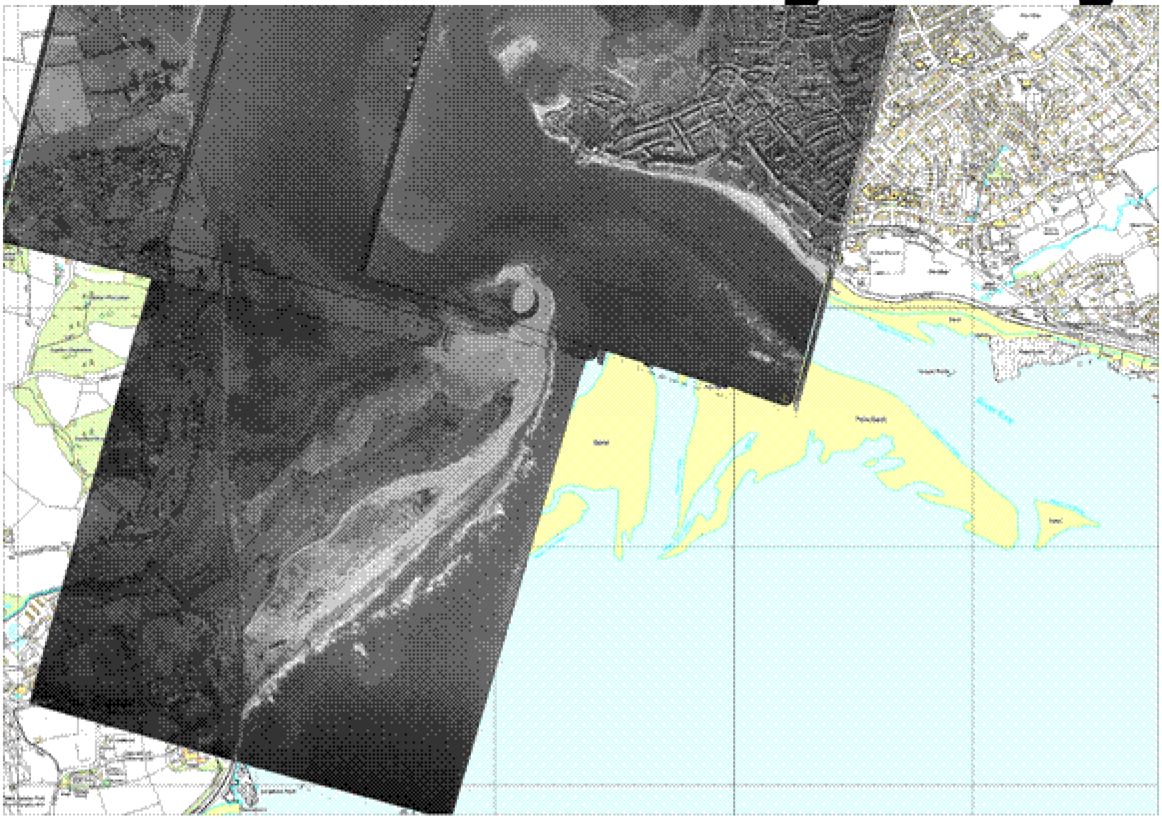


Figure 7. Dawlish Warren in November 1946.

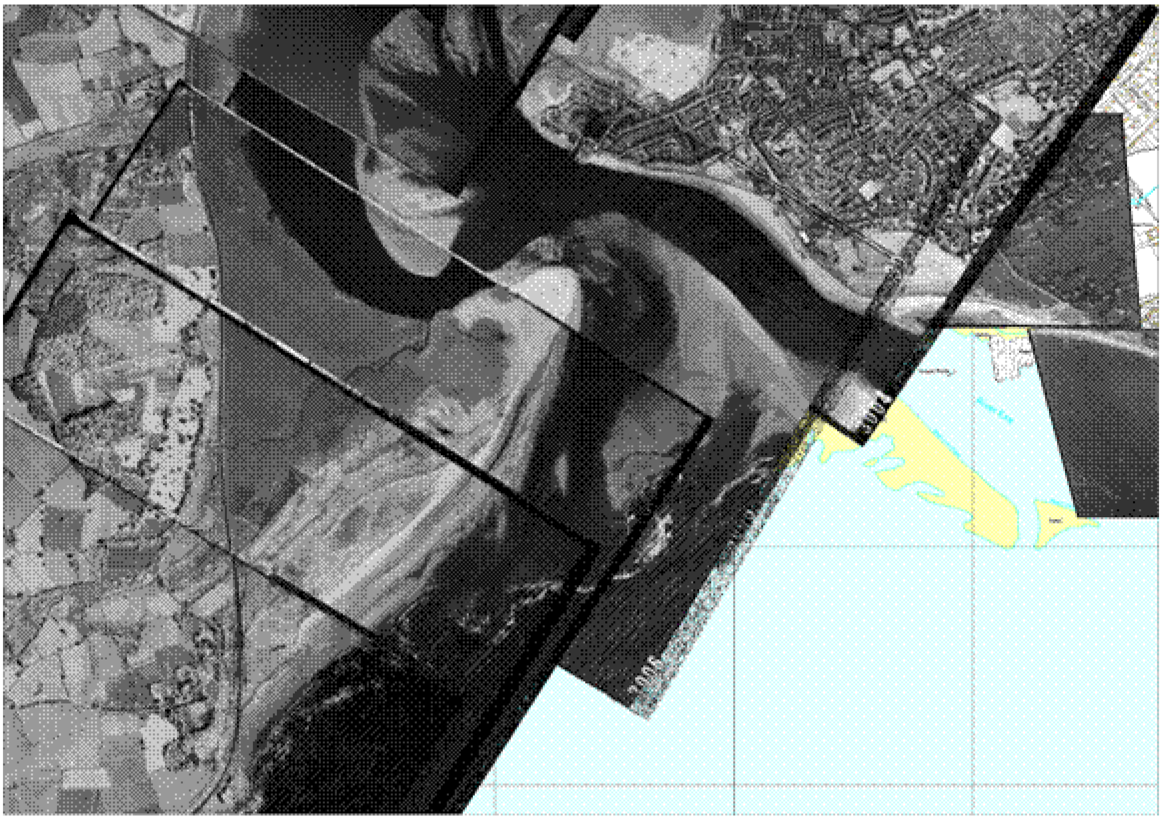


Figure 8. Dawlish Warren in February to May 1950.

Figure 9. Dawlish Warren in April to June 1960.

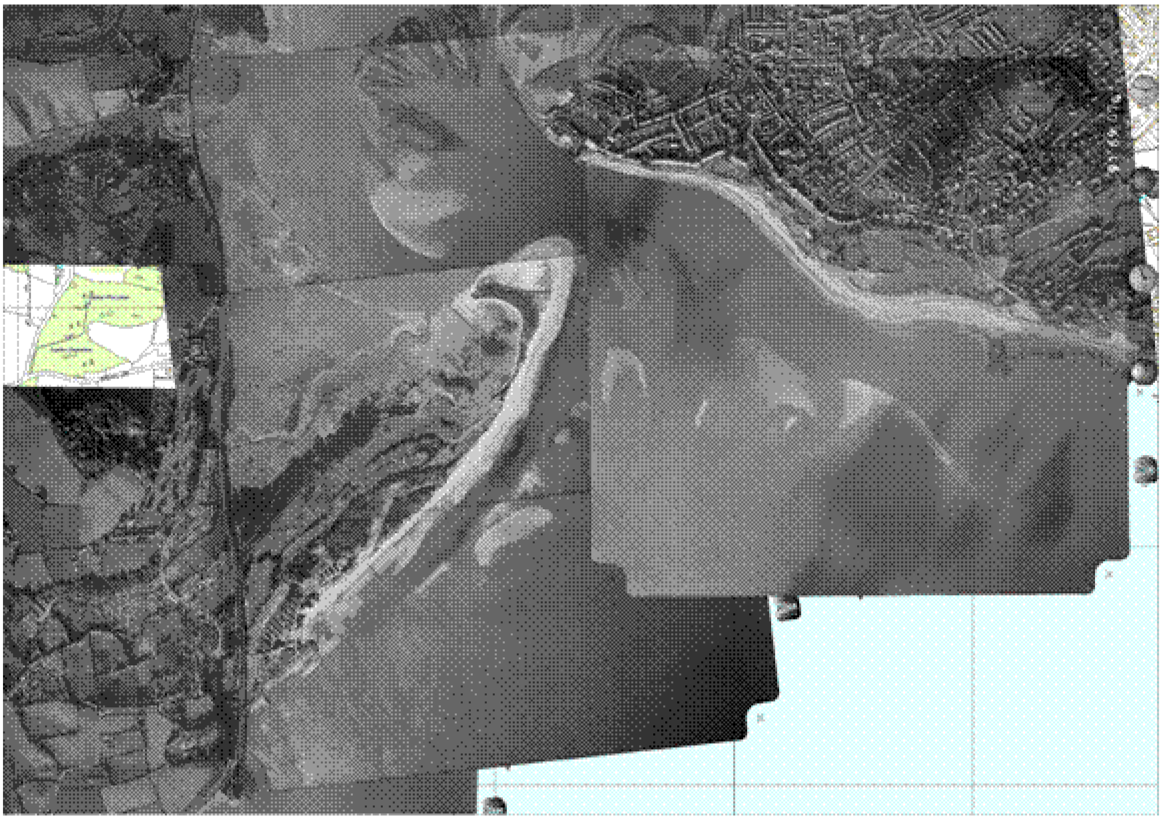


Figure 10. Dawlish Warren in November 1969.

Figure 11. Dawlish Warren in August 1979.

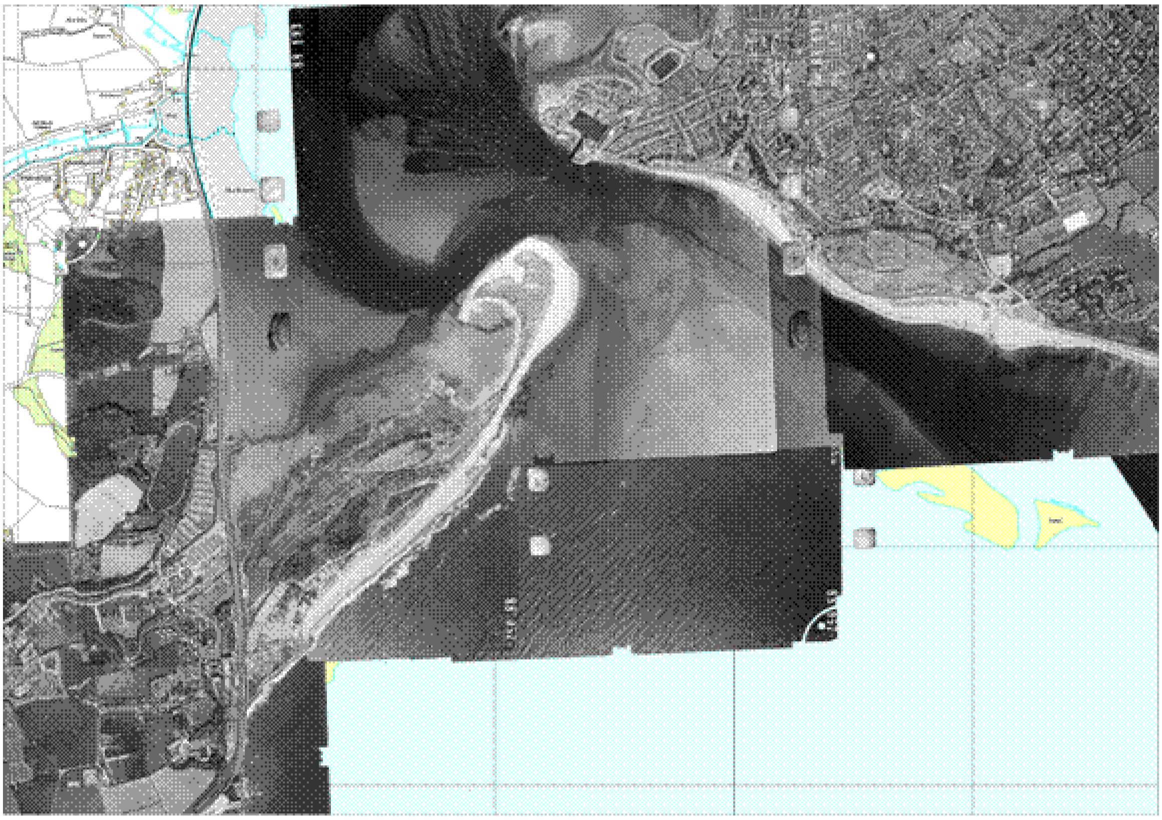
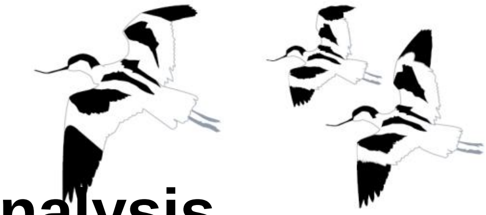


Figure 12. Dawlish Warren in April 1988.

Figure 13. Dawlish Warren in April 1999.



7 Historic Volumetric Analysis

1 Purpose

This section documents the analysis of volumetric changes since the 18th Century. The rationale for undertaking this work is that this will provide information on long term historic trends and events that have occurred since the 18th century, and more particularly provide supporting information to improve understanding of the sediment budget. As noted previously, understanding how the estuary has developed in the past provides and insight into how it might develop in the future.

This section details the analysis of volumetric changes from two datasets:

- Historic UKHO bathymetry surveys, for the years 1830, 1890 and 1930.
- More recent LiDAR surveys, for the years 1998 and 2007.

The information in the UKHO dataset covers the estuary mouth area, whereas the LiDAR dataset covers the whole estuary.

2 UKHO Bathymetry Surveys

Bathymetry surveys in paper format were collected from UKHO offices in Taunton; coverage is shown in Figure 1. The paper surveys were geo-referenced, and depth points digitised in GIS. This process allowed depth grids and surfaces to be generated for comparison, applying the IDW method for interpolating and extrapolating. Elevation difference maps were generated between the three datasets, as shown in Figures 2 and 3.

As the 1830 dataset is predominantly a line rather than a dataset covering an area any observations are necessarily very low in confidence. Figures 2 and 3 show the difference between the 1890-1930 and 1930-2007 (LiDAR) datasets, which have much more spatial overlap. Volumetric changes have been estimated for the key features at the estuary mouth, and are given in Table 1, although to some extent this is subjective dependent on the area considered. These changes indicate that Bull Hill Banks appears to have increased in volume since 1830 to the present day, with a rate of 19,600m^3/yr for 1890 to 1930, slowing to 14,800m^3/yr for 1930 to 2007. Pole Sands appears to have grown by 11,100m^3/yr for 1890 to 1930, and marginally reduced by 700m^3/yr for 1930 to the present day.

Feature	1890-1930 volumetric change (m^3)	1890-1930 rate of volumetric change (m^3/yr)	1930-2007 volumetric change (m^3)	1930-2007 rate of volumetric change (m^3/yr)
Bull Hill Banks	783,000	19,600	592,000	14,800
Pole Sands	444,000	11,100	-55,000	-700

Note: positive numbers indicate volumetric increase as time passes, negative numbers indicate volumetric decrease as time passes.

Table 1. Estimated volumetric changes for Bull Hill Banks and Pole Sands.

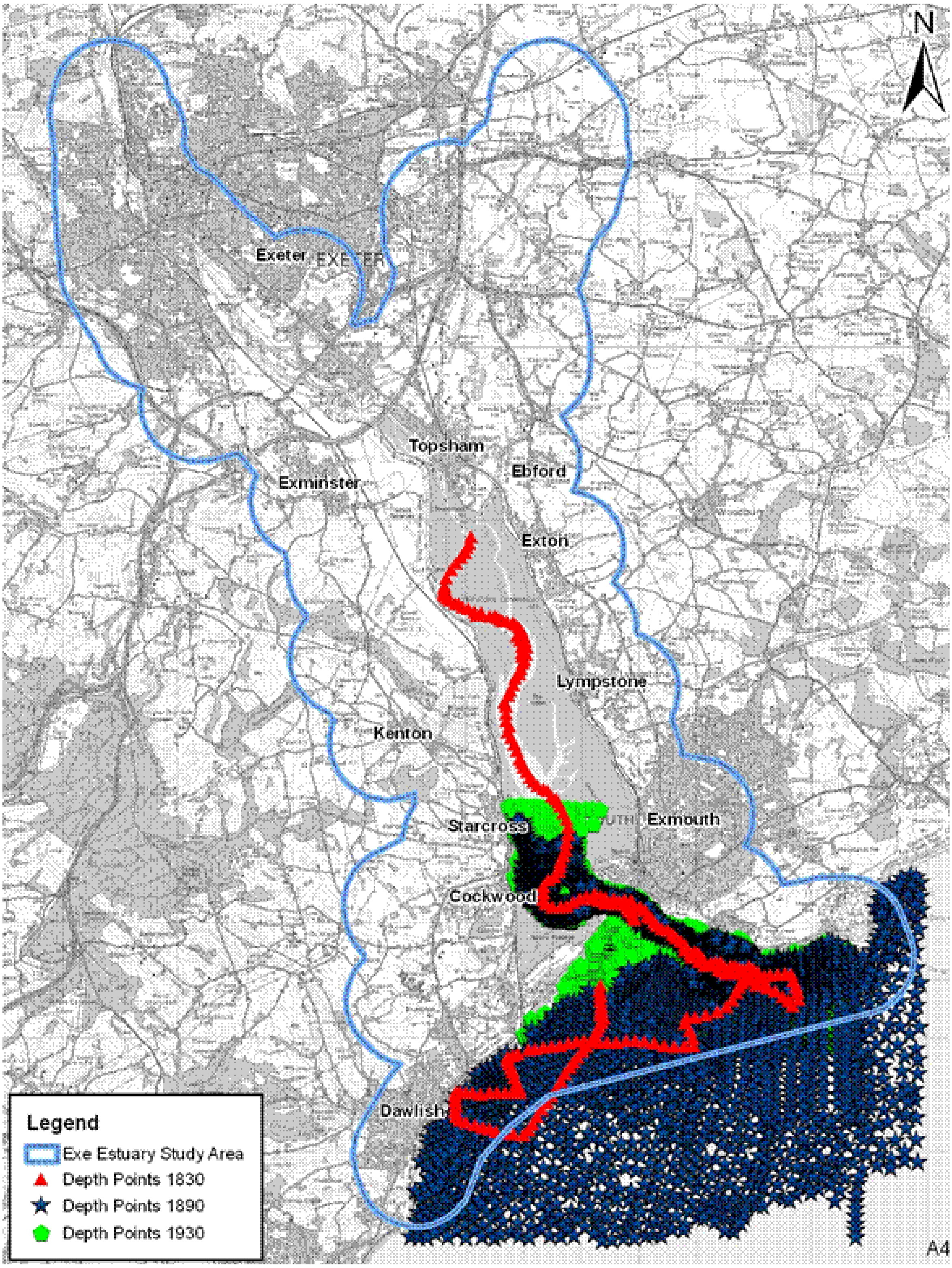


Figure 1. Coverage of bathymetry surveys.

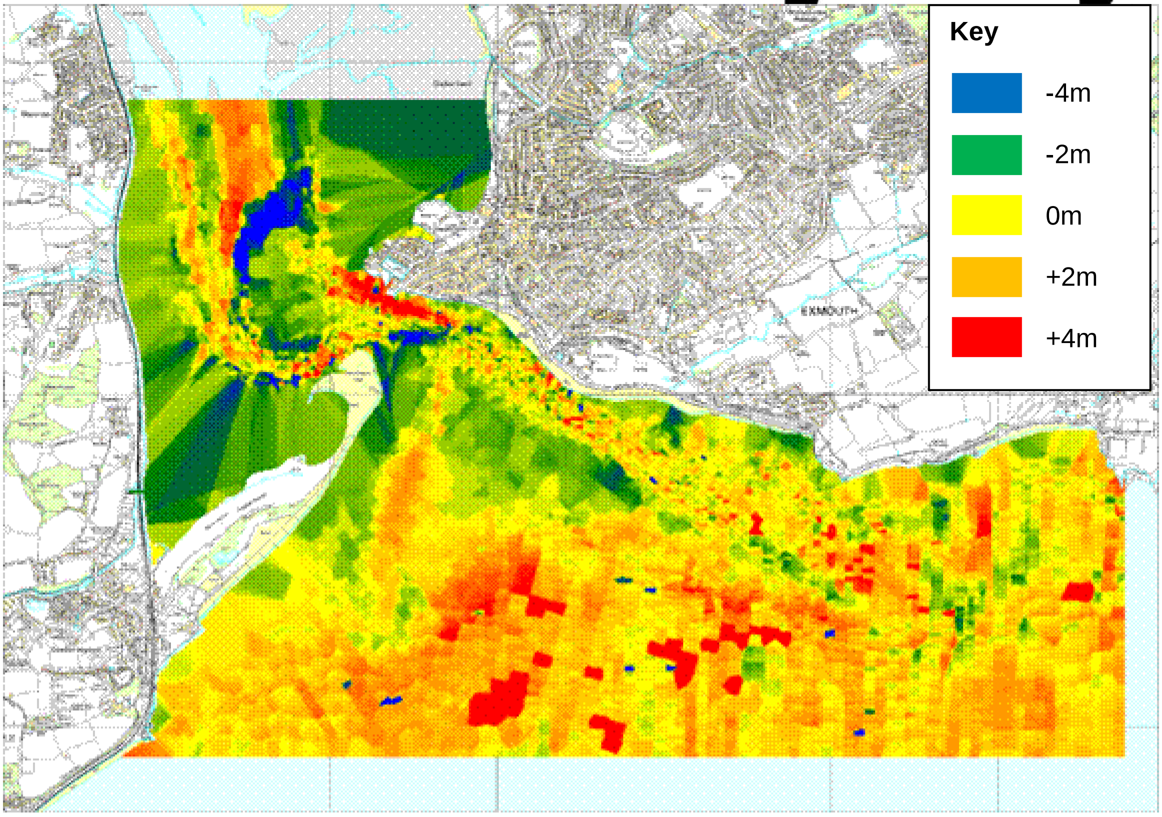


Figure 2. Elevation difference between 1930 and 1890.

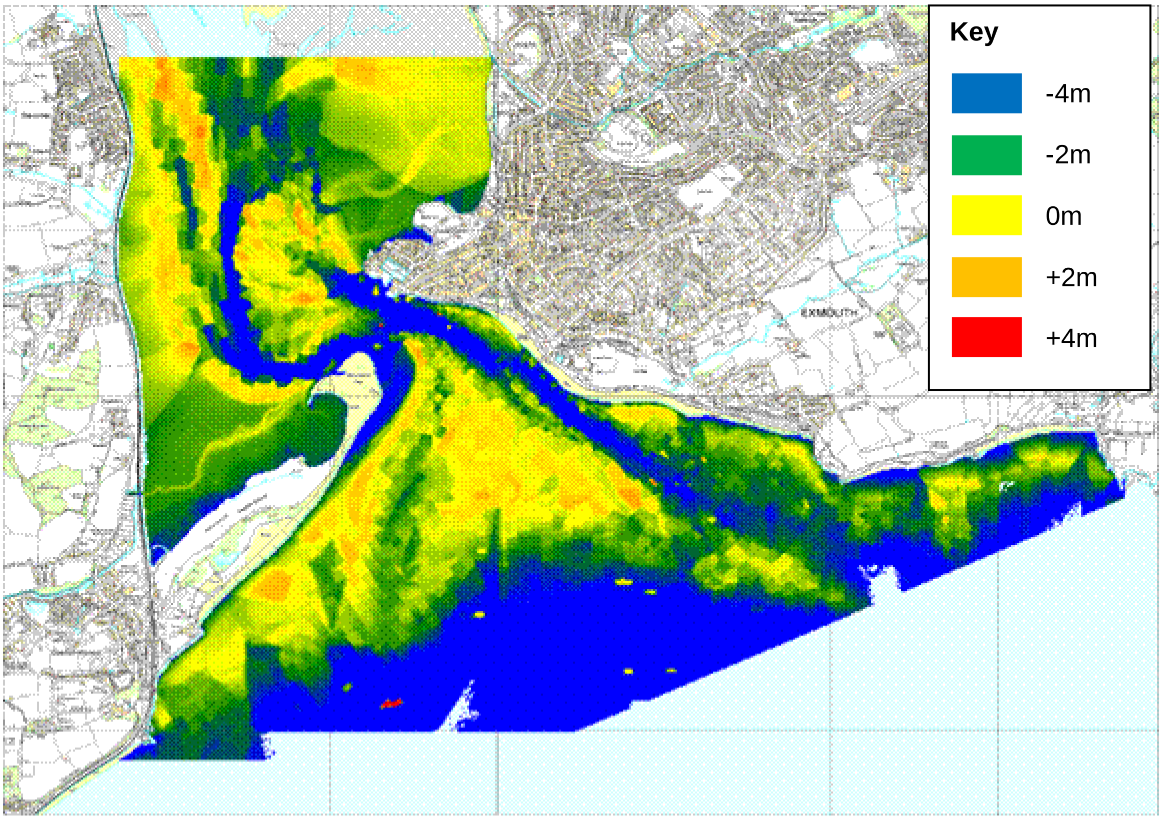


Figure 3. Elevation difference between 2007 and 1930.

3 LiDAR surveys

LiDAR surveys were received from the Environment Agency and Channel Coastal Observatory for the years 1998 and 2007. Whilst the two LiDAR datasets represent a relatively short term time interval compared to the UKHO datasets, they do have the benefit of covering a much wider area. The 1998 and 2007 LiDAR datasets were compared to generate an elevation difference map. This is shown in Figure 4.

LiDAR surveys are currently considered to have an accuracy of ±0.1m, although with a comparative analysis of LiDAR surveys it could be considered the comparative accuracy would be improved by an order of magnitude i.e. ±0.01m. From Figure 4 it can be seen that the variation between 1998 and 2007 are generally of the order of ±0.1m, and notably the differences in the (presumably vertically static) floodplains are of a similar order. This implies that the majority of differences could be related to a change in the LiDAR ‘datum’ rather than actual changes in the level of the estuary intertidal area. Overall inspection of Figure 4 does however allow some broad conclusions to be made:

- Within the 1997-2008 timeframe, the inner estuary (between MHW and MLW i.e. excluding sub-tidal channels and sand banks) has accreted by the order of 0.005m as a spatial average, equating to around 40,000m^3 (4000m^3/yr); this has order of magnitude agreement with SCOPAC (2004). It should be noted that this level of change may not be significant in relation to the comparative LiDAR accuracy of ±0.01m, but does indicate a limited overall bathymetric change.
- Bull Hill Banks does indicate some local extreme accretion of up to 0.5m in places.
- The main channel appears to have eroded up to 0.5m, although this may well be a spurious feature generated by standing water.
- The distal end of Dawlish Warren has accreted by over 0.5m. There is evidence of erosion of the Dawlish Warren proximal and central section beaches of up to 0.4m.
- Pole Sands appears to have lowered generally by 0.1-0.4m, although this may well be a spurious feature generated by standing water.

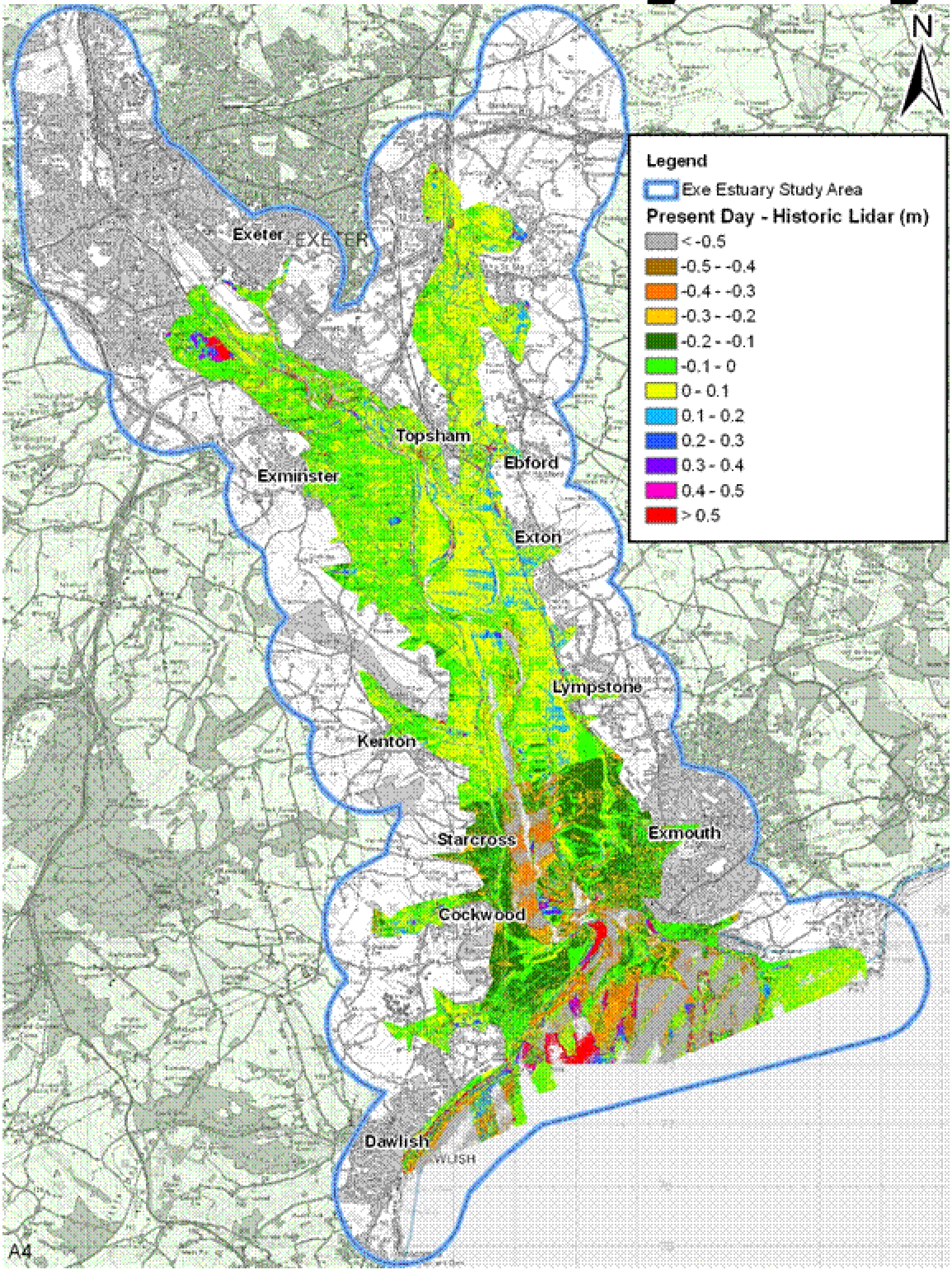


Figure 4. Elevation difference between 2007 and 1998.

8 Breach Analysis at Dawlish Warren

1 Purpose

This section describes the assessment of potential breach at Dawlish Warren. This is a significant concern in the Exe Estuary as Dawlish Warren is considered to provide some measure of shelter from offshore waves, and there is clear evidence of breaches having occurred in the past. Understanding the conditions under which Dawlish Warren could breach will provide information on when significant morphological changes could occur, and when the inner estuary could be exposed to a more energetic wave and tide climate.

2 Methodology

Breach of Dawlish Warren has been considered in light of Hartley and Pontee (2008), which sets out 3 definitions:

- Level 1. A level 1 breach has a basal level around mean high water spring tides. The breach may be temporary and may either (I) infill through a combination of longshore drift and the accretion of barriers on the foreshore around successive high water marks; or, (ii) deepen to form a level 2 breach.
- Level 2. A level 2 breach has a basal level around mean low water tides. The breach may be more permanent than a level 1 breach, but may still infill or may deepen to form a permanent inlet.
- Permanent inlet. A permanent inlet has a basal level at/or below mean low water spring tides and is a permanent feature subject to tidal flows on a daily basis.

The breach assessment described subsequently refers to the Level 1 breach definition. Breach mechanisms have also been considered in light of Bradbury (2000) and EC (2007), with Table 1 showing the EC (2007) mechanisms. The relevant mechanisms are:

- Erosion of cover of inner slope by overflow (Aa1.1)
- Erosion of seaward face of sand by waves (Aa2.1a)
- Overwashing (Bradbury, 2000)

These mechanisms were assessed and are described below. An assessment of the change in elevation above MHWS was also made. To inform the analyses topographic information along Dawlish Warren was analysed to find low and/or thin points along the coastal frontage. The key locations where this occurred are shown in Figure 1.

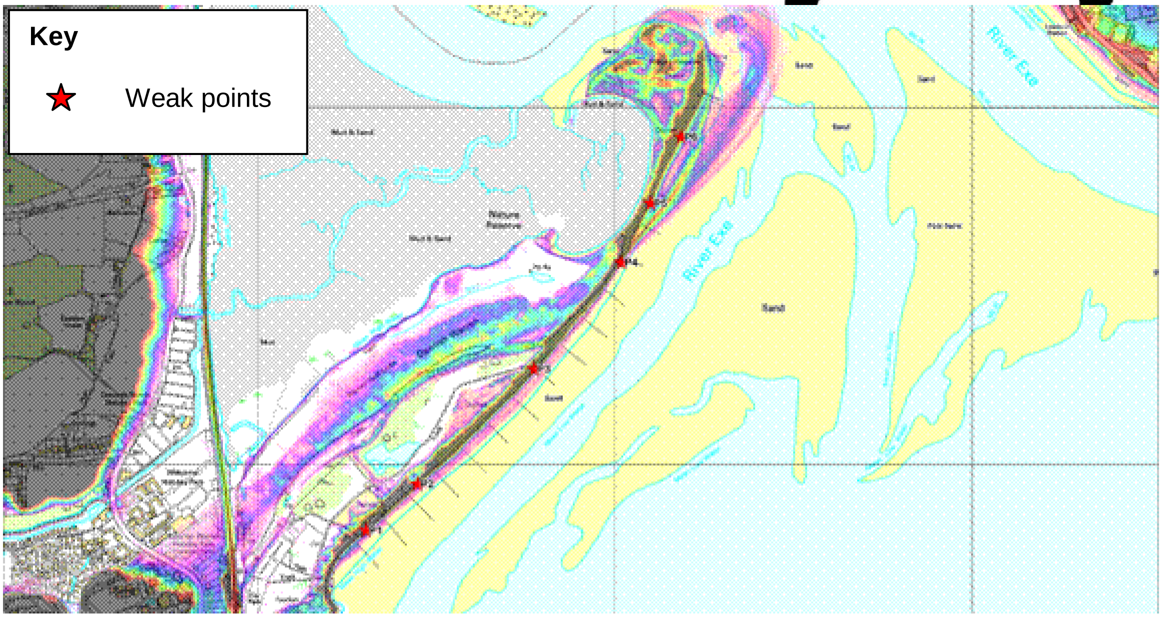


Figure 1. Location of weak points along Dawlish Warren.

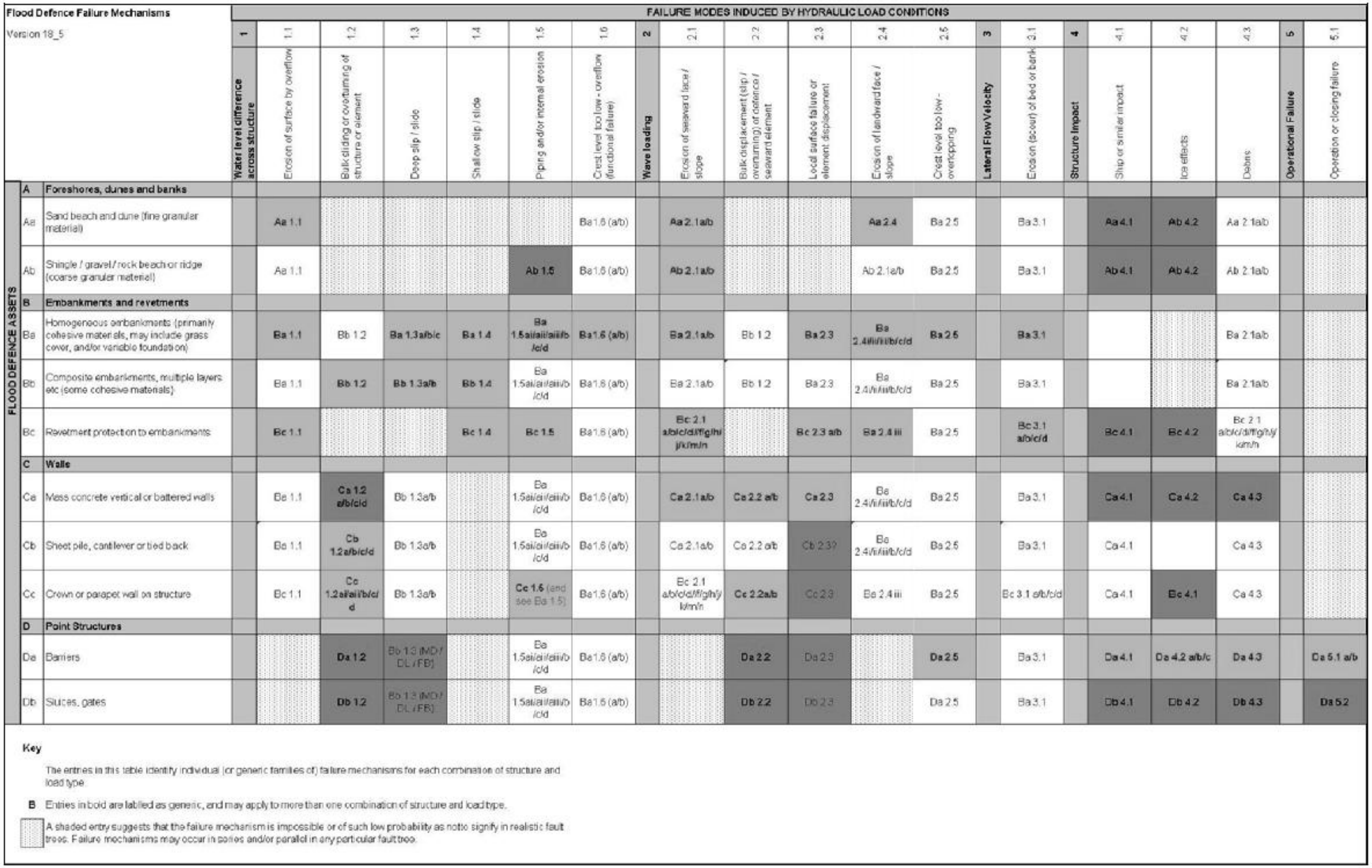
3 Overwashing analysis (Bradbury, 2000)

Varying definitions and prediction techniques for breaching have been used in the context of barrier beaches, however these have generally focussed on shingle features. Whilst not directly transferable to sand features (such as Dawlish Warren), Bradbury (2000) does provide a method for assessing overwashing risk to shingle barrier beaches, which would likely underestimate the same risk for sand features. Bradbury (2000) described breaching as the short-term lowering of the barrier crest, resulting from wave induced overwashing. The conceptual approaches outlined by Bradbury have been developed to examine the short-term profile response, by reference to the wave climate, storm peak static water level datum, barrier freeboard R_c and the barrier cross-section-area above this datum. When combined, the two latter variables provide a barrier inertia grouping, which can be non-dimensionalised by wave height, to provide the dimensionless barrier inertia parameter (Bi), described by

$$B_i = R_c B_a / H_s^3$$

Where R_c(m) is the barrier freeboard, B_a(m^2) is the cross-sectional area of the beach above still water level and H_s (m) is the significant wave height. The barrier inertia parameter is plotted against a dimensionless wave steepness parameter, which provides a measure of the combined wave height and period; H_s/L_m where; wavelength, $L_m = gT_m / 2\pi$, and T_m is the mean wave period. If $B_i < -153.1 (H_s/L_m) + 10.9$ then overwashing will occur for the range $0.01 < H_s/L_m < 0.06$. This relationship is shown in Figure 2, sourced from EC (2007).

This method was applied to the previous weak locations along Dawlish Warren (except for P1 which has hard defences as part of the profile), shown in Figures 3, 4, 5, 6 and 7. These results are also summarised in Table 2, giving the SoP against breach caused by overwashing.



Flood Defence Failure Mechanisms			FAILURE MODES INDUCED BY HYDRAULIC LOAD CONDITIONS																				
Version 18_5			1	1.1	1.2	1.3	1.4	1.5	1.6	2	2.1	2.2	2.3	2.4	2.5	3	3.1	4	4.1	4.2	4.3	5	5.1
			Water level difference across structure	Erosion of surface by overflow	Bulk sliding or overturning of structure or element	Deep slip / slide	Shallow slip / slide	Piping and/or internal erosion	Crest level too low - overflow (functional failure)	**Wave loading**	Erosion of seaward face / slope	Bulk displacement (slip / overturning) of defence / seaward element	Local surface failure or element displacement	Erosion of landward face / slope	Crest level too low - overtopping	**Lateral Flow Velocity**	Erosion (scour) of bed or bank	**Structure Impact**	Ship or similar impact	Ice effects	Debris	**Operational Failure**	Operation or closing failure
FLOOD DEFENCE ASSETS	A	**Foreshores, dunes and banks**																					
	Aa	Sand beach and dune (fine granular material)		**Aa 1.1**	▨	▨	▨	▨	Ba1.6 (a/b)		**Aa 2.1a/b**	▨	▨	**Aa 2.4**	Ba 2.5		Ba 3.1		**Aa 4.1**	**Ab 4.2**	Aa 2.1a/b		▨
	Ab	Shingle / gravel / rock beach or ridge (coarse granular material)		Aa 1.1	▨	▨	▨	**Ab 1.5**	Ba1.6 (a/b)		**Ab 2.1a/b**	▨	▨	Ab 2.1a/b	Ba 2.5		Ba 3.1		**Ab 4.1**	**Ab 4.2**	Ab 2.1a/b		▨
	B	**Embankments and revetments**																					
	Ba	Homogeneous embankments (primarily cohesive materials, may include grass cover, and/or variable foundation)		**Ba 1.1**	Bb 1.2	**Ba 1.3a/b/c**	**Ba 1.4**	**Ba 1.5ai/aii/aiii/b/c/d**	**Ba1.6 (a/b)**		**Ba 2.1a/b**	Bb 1.2	**Ba 2.3**	**Ba 2.4i/ii/iii/b/c/d**	**Ba 2.5**		**Ba 3.1**			▨	Ba 2.1a/b		▨
	Bb	Composite embankments, multiple layers etc (some cohesive materials)		Ba 1.1	**Bb 1.2**	**Bb 1.3a/b**	**Bb 1.4**	Ba 1.5ai/aii/aiii/b/c/d	Ba1.6 (a/b)		Ba 2.1a/b	Bb 1.2	Ba 2.3	Ba 2.4i/ii/iii/b/c/d	Ba 2.5		Ba 3.1			▨	Ba 2.1a/b		▨
	Bc	Revetment protection to embankments		**Bc 1.1**	▨	▨	**Bc 1.4**	**Bc 1.5**	Ba1.6 (a/b)		**Bc 2.1 a/b/c/d/f/g/h/j/k/m/n**	▨	**Bc 2.3 a/b**	**Ba 2.4 iii**	Ba 2.5		**Bc 3.1 a/b/c/d**		**Bc 4.1**	**Bc 4.2**	Bc 2.1 a/b/c/d/f/g/h/j/k/m/n		▨
	C	**Walls**																					
	Ca	Mass concrete vertical or battered walls		Ba 1.1	**Ca 1.2 a/b/c/d**	Bb 1.3a/b	▨	Ba 1.5ai/aii/aiii/b/c/d	Ba1.6 (a/b)		**Ca 2.1a/b**	**Ca 2.2 a/b**	**Ca 2.3**	Ba 2.4i/ii/iii/b/c/d	Ba 2.5		Ba 3.1		**Ca 4.1**	**Ca 4.2**	**Ca 4.3**		▨
	Cb	Sheet pile, cantilever or tied back		Ba 1.1	**Cb 1.2a/b/c/d**	Bb 1.3a/b	▨	Ba 1.5ai/aii/aiii/b/c/d	Ba1.6 (a/b)		Ca 2.1a/b	Ca 2.2 a/b	Cb 2.3?	Ba 2.4i/ii/iii/b/c/d	Ba 2.5		Ba 3.1		Ca 4.1		Ca 4.3		▨
	Cc	Crown or parapet wall on structure		Bc 1.1	**Cc 1.2ai/aii/b/c/d**	Bb 1.3a/b	▨	**Cc 1.6** (and see Ba 1.5)	Ba1.6 (a/b)		Bc 2.1 a/b/c/d/f/g/h/j/k/m/n	**Cc 2.2a/b**	Cc 2.3	Ba 2.4 iii	Ba 2.5		Bc 3.1 a/b/c/d		Ca 4.1	**Bc 4.1**	Ca 4.3		▨
	D	**Point Structures**																					
	Da	Barriers		▨	**Da 1.2**	Bb 1.3 (MD / DL / FB)	▨	Ba 1.5ai/aii/aiii/b/c/d	Ba1.6 (a/b)		▨	**Da 2.2**	Da 2.3	▨	**Da 2.5**		Ba 3.1		**Da 4.1**	**Da 4.2 a/b/c**	**Da 4.3**		**Da 5.1 a/b**
	Db	Sluices, gates		▨	**Db 1.2**	Bb 1.3 (MD / DL / FB)	▨	Ba 1.5ai/aii/aiii/b/c/d	Ba1.6 (a/b)		▨	**Db 2.2**	Db 2.3	▨	Da 2.5		Ba 3.1		**Db 4.1**	**Db 4.2**	**Db 4.3**		**Da 5.2**

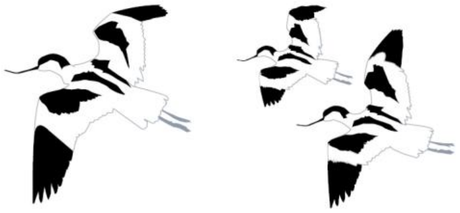
Key

The entries in this table identify individual (or generic families of) failure mechanisms for each combination of structure and load type.

B Entries in bold are labled as generic, and may apply to more than one combination of structure and load type.

▨ A shaded entry suggests that the failure mechanism is impossible or of such low probability as not to signify in realistic fault trees. Failure mechanisms may occur in series and/or parallel in any particular fault tree.

Table 1. Failure mechanisms for a variety of features (EC, 2007).



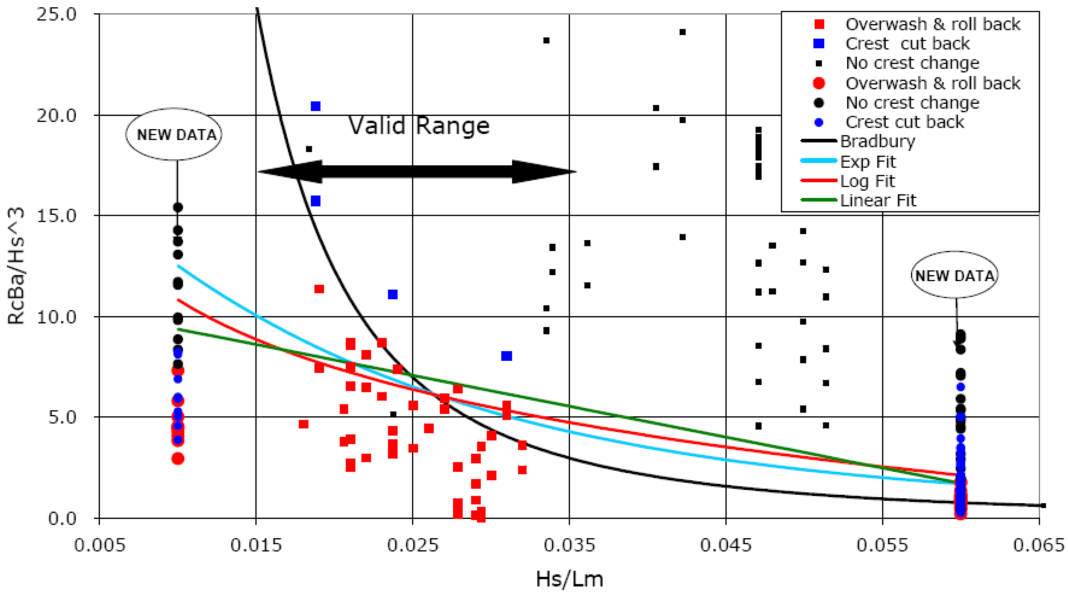


Figure 2. Barrier inertia threshold graph.

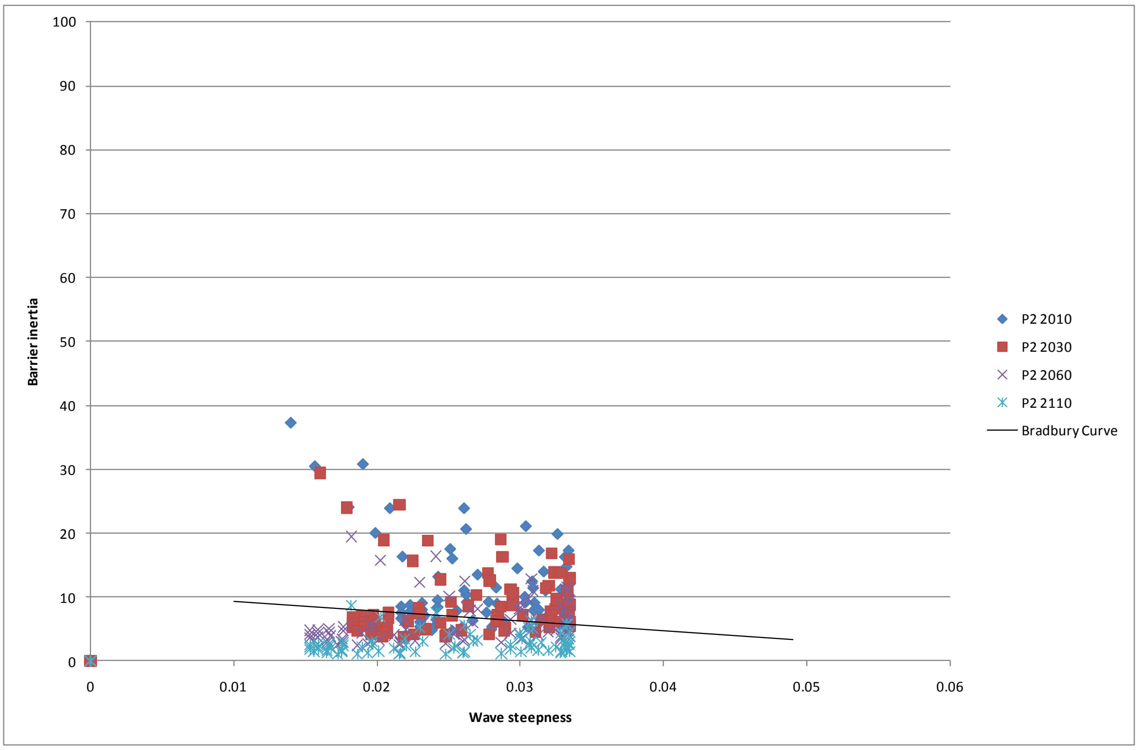


Figure 3. Results for P2.

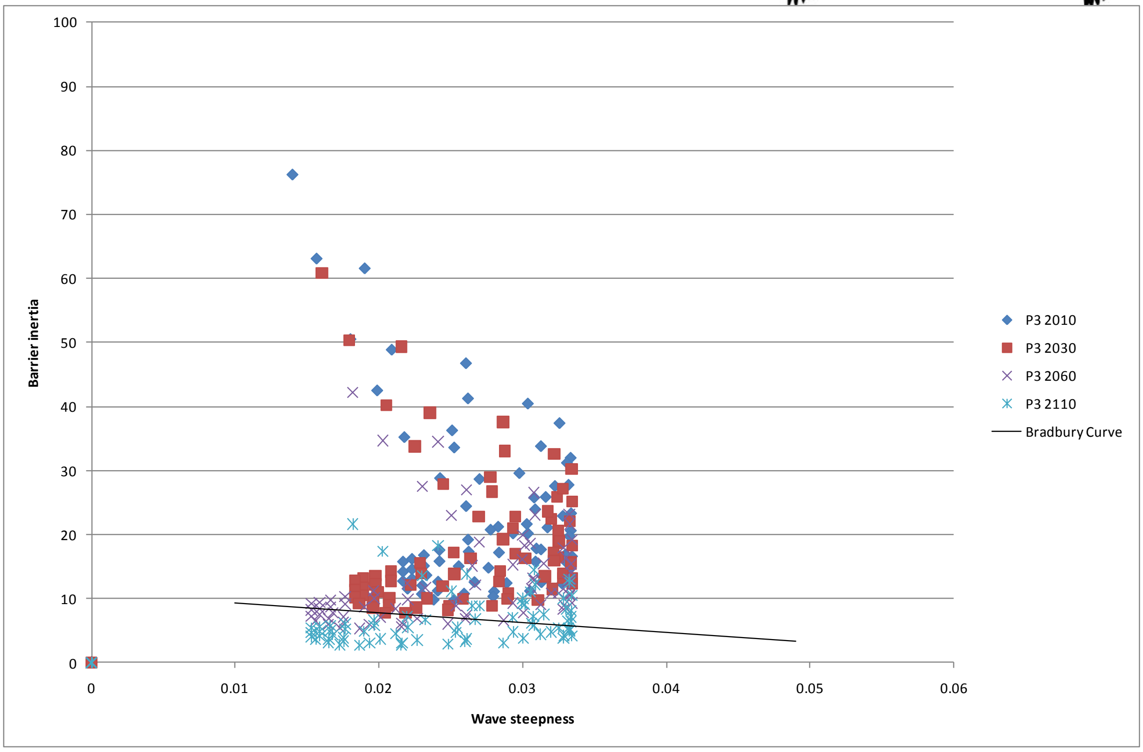


Figure 4. Results for P3.

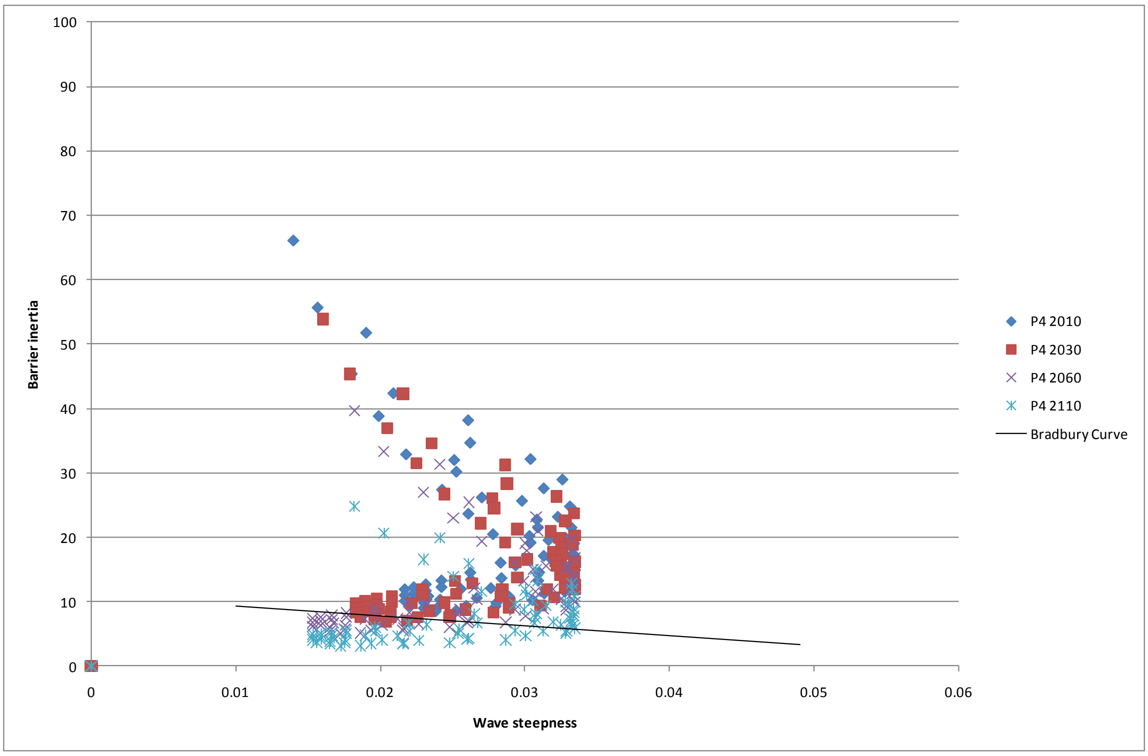


Figure 5. Results for P4.

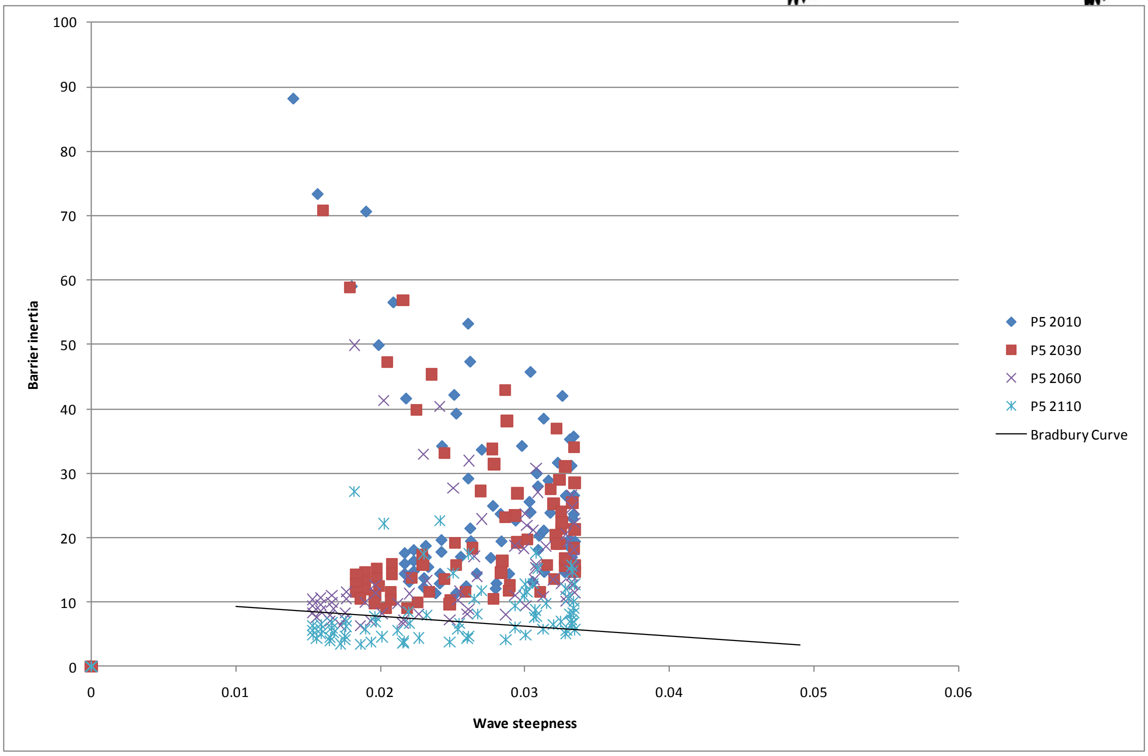


Figure 6. Results for P5.

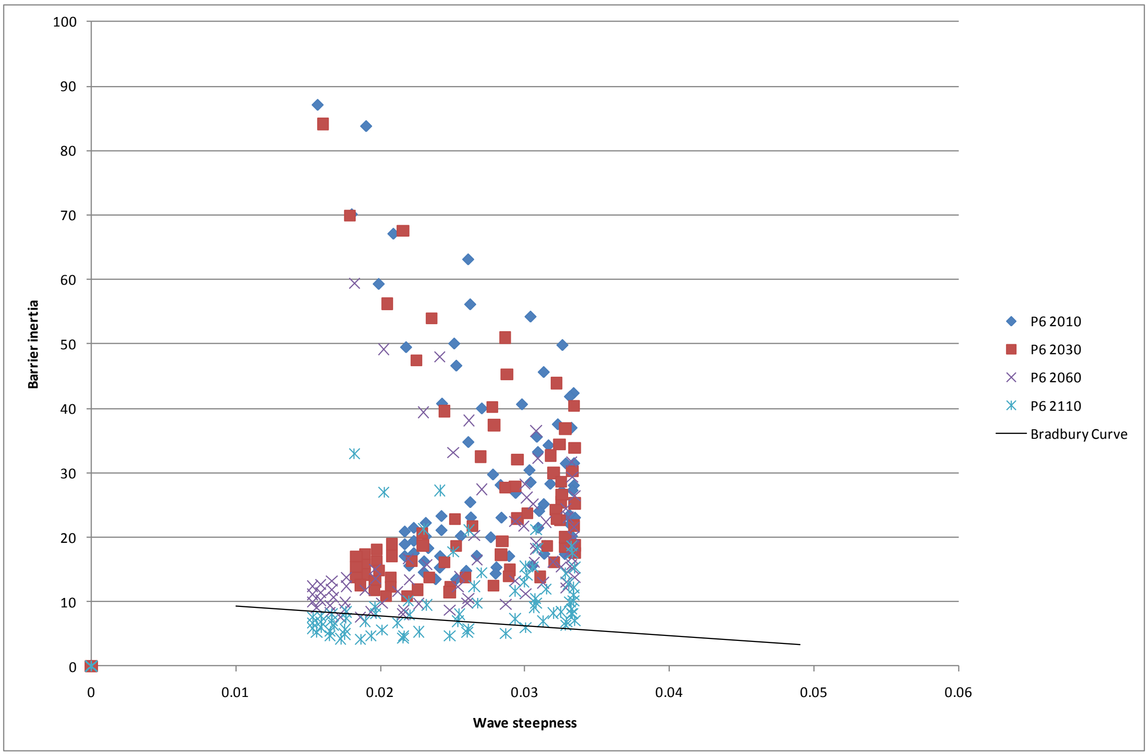
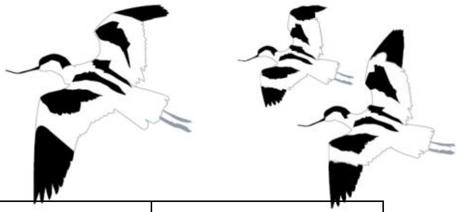


Figure 7. Results for P6.



Weak Point	Year 2010 SoP (%AEP)	Year 2030 SoP (%AEP)	Year 2060 SoP (%AEP)	Year 2110 SoP (%AEP)
P2	1	4	10	100
P3	0.1	1	4	10
P4	0.1	2	4	10
P5	0.1	0.5	4	10
P6	0.1	0.1	2	4

Table 2. Summary of overwashing risk.

4 Erosion of cover of inner slope by overflow (EC, 2007)

The EuroTOP method (EC, 2007) was applied to the points of interest along Dawlish Warren, to estimate overtopping rates over Dawlish Warren during storms. Analysis of the Dawlish Warren sand dune geometry in conjunction with the failure mechanism described in Aa1.1 indicates critical overtopping rates in the range of 0.1-1 m^3/s/m, which would cause serious erosion of the inner slope. Comparison of the predicted overtopping rates for extreme conditions with the critical overtopping rate indicates that location P4 is sensitive to this failure mechanism, with the critical overtopping rate being exceeded under the 0.5% AEP, 2% AEP and then 20-100% AEP events for 2010, 2030 and 2060-2110 respectively.

5 Erosion of seaward face of sand by waves (EC, 2007)

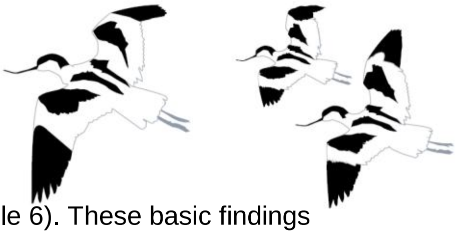
The beach profile analysis described earlier herein has indicated that around 40% of the pre-existing beach volume along Dawlish Warren was temporarily removed due to the October to November 2009 storm events, with evidence of fore dune erosion. Esteves & Williams (2010) carried out Xbeach modelling for a limited variety of conditions, particularly of note events that are asserted to correspond to the October/November 2009 storms (which on comparison with joint probability analysis would imply they were individually around a 20% AEP joint probability event i.e. annual), and a more extreme combination of wave and tide which is considered herein to be approximately equivalent to a joint probability event of 1% AEP. The XBeach model runs indicated fore dune erosion of up to 1m, although it is noted that the extreme 1% AEP event test was limited to a duration of 0.5 hours.

Considered in totality, the above findings do indicate qualitatively that:

- 20% AEP events can cause serious beach erosion, with some fore dune erosion.
- 1% AEP events could cause serious fore dune erosion.
- As minimum fore dune widths at Dawlish Warren are around 10-20m, events more extreme or longer duration than 1% AEP could form a temporary breach in the fore dunes.

6 Dawlish Warren sand spit volumetric analysis

LiDAR data from 2007 has been assessed to create a Digital Elevation Model of Dawlish Warren sand spit. These have been analysed in GIS to calculate the volume above MHWS, MLWS and the intertidal volume. The analysis has been repeated for future tide levels assuming an increase in level caused by sea level rise. The resulting values show a reduction in the inter/supra-tidal



volume of Dawlish Warren sand spit from 2010 to 2110 (see Table 6). These basic findings indicate that the volume above MLWS will reduce by 20% by 2110. If the sediment budget model is used to estimate the potential decrease in inter-supra-tidal volume then the reduction in volume is increased (see Table 7), with a 15%, 55% and then 100% loss of volume above MLWS in 2030, 2060 and 2110 respectively.

Percentage reduction in volume	**Year 2010**	**Year 2030**	**Year 2060**	**Year 2110**
Above MHWS	0%	10%	20%	45%
Above MLWS	0%	0%	10%	20%
Between MHWS and MLWS	0%	0%	5%	15%

NB percentages rounded to nearest 5%.

Table 6. Change in volume at Dawlish Warren sand spit (without geomorphological evolution).

Percentage reduction in volume	**Year 2010**	**Year 2030**	**Year 2060**	**Year 2110**
Above MHWS	0%	25%	65%	100%
Above MLWS	0%	15%	55%	100%
Between MHWS and MLWS	0%	15%	50%	100%

NB percentages rounded to nearest 5%.

Table 6. Change in volume at Dawlish Warren sand spit (with geomorphological evolution).

7 Summary

The above analyses, considered together, indicate that serious erosion of the fore dunes at Dawlish Warren, and potentially temporary breach, could occur during 4% AEP storm events in the present day, although temporary breach would have a greater likelihood of occurring during a 1% AEP event. The locations of P2 and P4 are particularly found to be susceptible, and these are close to the previously documented breach occurrences in 1962 and 1946 respectively. The area analysis also highlights that the wider coherency of Dawlish Warren as a spit would not be significantly changed until after 2060, assuming no geomorphological change.

9 Conceptual Model

1 Introduction

This section aims to synthesise the various sub-tasks, and consider them in conjunction to develop a conceptual model. The intention is that this will provide a fuller and more robust understanding of how the Exe Estuary has changed historically and how it may change into the future, to support the definition of baseline scenarios, and how interventions may affect the estuary system. The studies undertaken extend and improve the understanding developed in the EECMS (Halcrow, 2008), due to the more detailed and extensive data collected and analyses carried out. In particular:

- The historic and ongoing evolution of Dawlish Warren has been confirmed, noted as erosion of the proximal and central sections and accretion of the distal end, and the historic anti-clockwise rotation.
-
- Quantified rates of exchange have been defined for the majority of sediment transport pathways, enabling a sediment budget model to be developed.

2 Previous Studies

Previous studies have developed conceptual models, most notably Posford Duviver (1998), SCOPAC (2004) and Halcrow (2008). The graphical representation of these conceptual models is shown in Figures 1 to 4. In summary, the conceptual understanding of sediment pathways within the study area is relatively well developed. The key areas where improvement can be made are:

- Quantification of sediment transport rates where possible to build a more complete sediment budget model.
- Prediction of future evolution for the whole estuary and particularly the function of Dawlish Warren.

These previous conceptual models have been reconsidered, and transposed into a sediment budget model (Figure 5) that allows simple identification of transport rates and volumetric changes. This forms the framework within which the quantified future behaviour of the estuary can be set, in conjunction with other predictive techniques.

In summary, the conceptual understanding of sediment pathways within the study area is relatively well developed. The key areas where improvement can be made are:

- Quantification of sediment transport rates where possible to build a more complete sediment budget model.
- Prediction of future evolution for the whole estuary and particularly the function of Dawlish Warren.

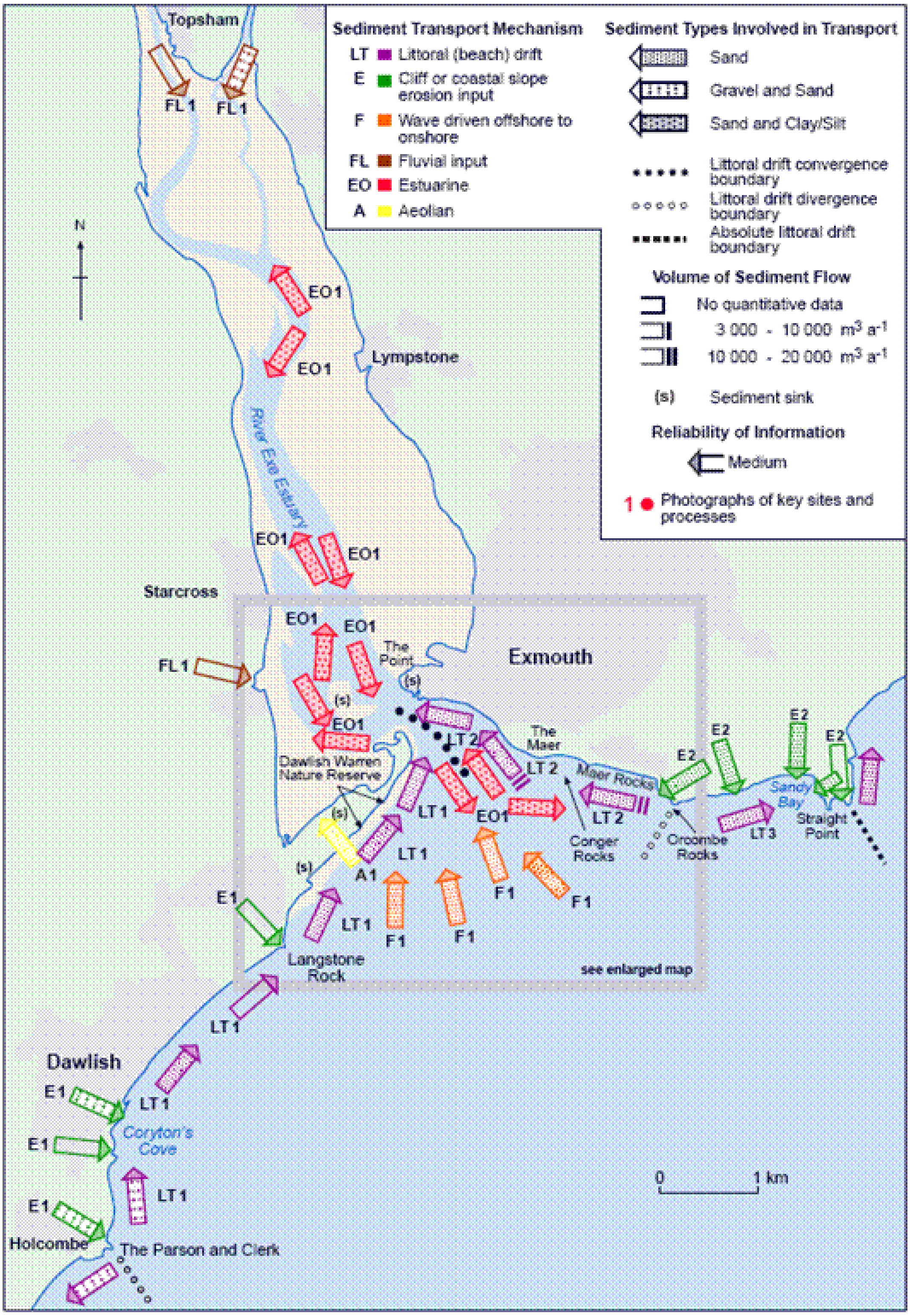


Figure 1. Sediment Transport in and around the Exe Estuary.

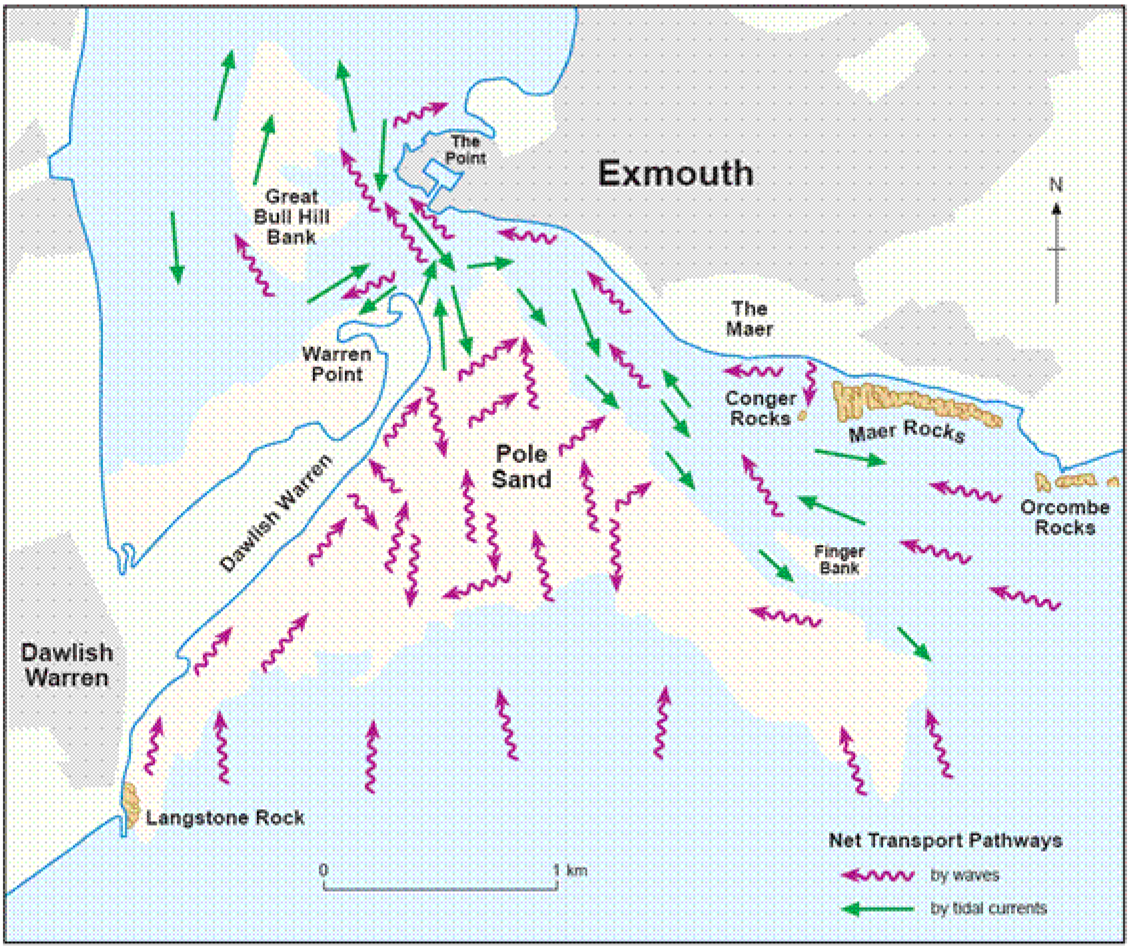


Figure 2. Outer Exe Estuary transport vectors (SCOPAC, 2003).

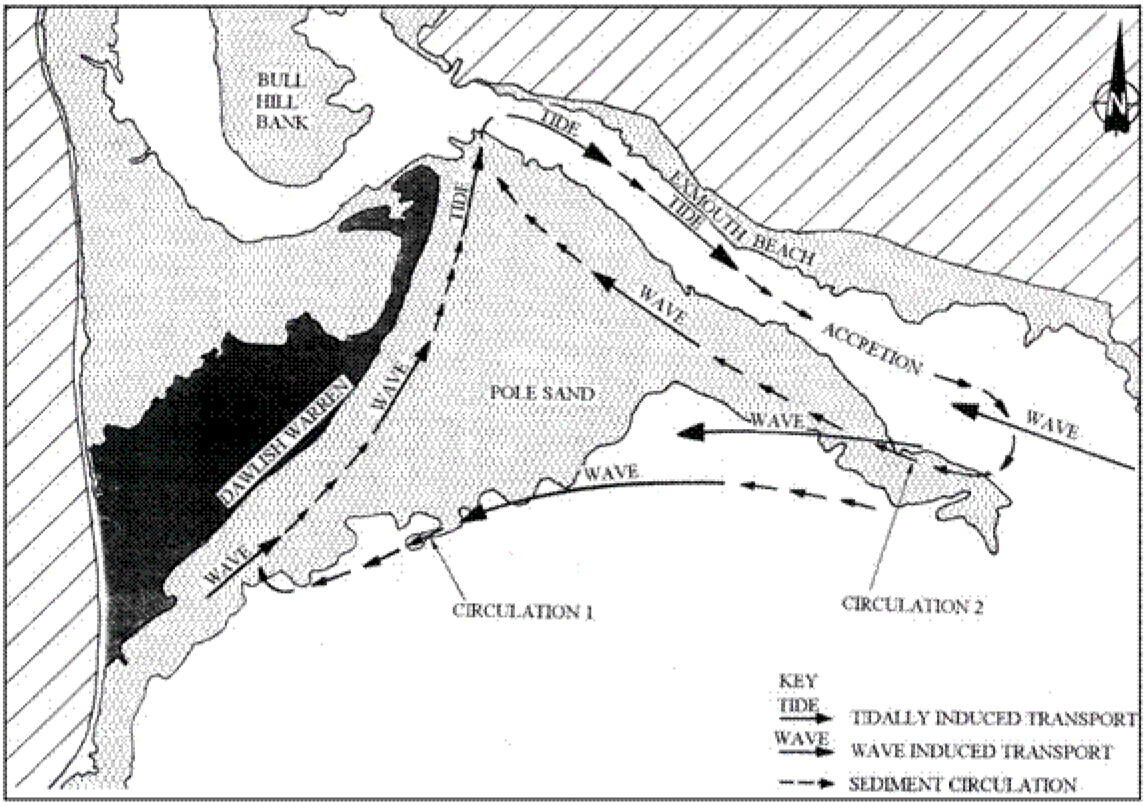


Figure 3. Sediment circulation within Exmouth approach channel and over Pole Sand (Posford Duvivier, 1998).

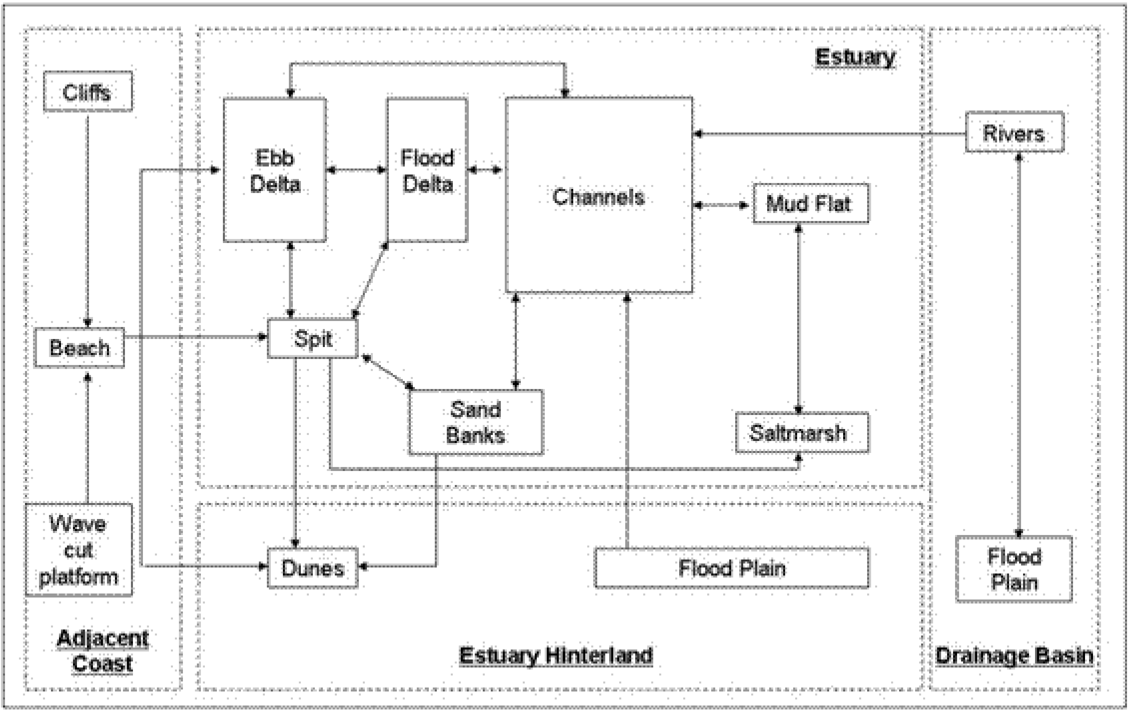


Figure 4. Preliminary conceptual model of the Exe Estuary (Halcrow, 2008).

3 Conceptual Model

3.1 Formation of the Exe Estuary

The historic and present day dynamics of the Exe Estuary and surrounding coast is described in detail in SCOPAC (2004). The Exe Estuary basin is considered a long established feature, potentially dating from the late Tertiary period. In the estuary basin, Holocene channels at a level of -50 to -30mAOD exist, and as sea level rose these channels were filled in by fluvial gravel. Subsequent to this (in the Weichselian) the gravels were re-excavated to a depth of 9m. The channels then subsequently infilled with both sand and mud sediments. The formation of the Dawlish Warren and Exmouth spits is considered to have occurred in the early to mid Holocene period, and were formed by shoreward movement of fluvially or periglacially deposited sand, and longshore drift of these sediments. Subsequent to this the weight of opinion suggests that any offshore reservoir of sand was exhausted or made inaccessible over the last 2-3000 years, effectively implying the existing outer estuary sediment budget is finite, with new inputs limited cliff erosion and extreme storm events.

From the mid to late Holocene, once submergence of the lower Exe valley created the present day estuary, fine-grain sedimentation the estuary basin is considered to have been continuous. The estuary therefore represents a sink for fine sediment, with sand and gravel being deposited temporarily close to the estuary entrance. Inputs come from both fluvial and marine sources, with fluvial sources now limited in comparison to the past.

3.2 Present Day System

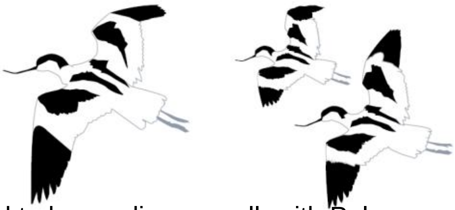
The Exe Estuary is a macro-tidal estuary, with current speeds varying between 1-3m/s at the entrance. Penetration into the estuary from offshore waves is limited due to the presence of Dawilsh Warren spit and to a lesser extent Exmouth spit. Internally generated waves are both fetch and depth limited, with the head of the estuary experiencing larger waves due to the increase north-south fetch. Extreme water levels in the estuary basin are caused by tidal surges, rather than fluvial flows. However, extreme fluvial flows are important, although not dominant as compared to tidal surges, in the lower reaches of the rivers Exe and Clyst and the inner estuary.

Intertidal areas in the estuary basin are composed of mud and sand flats, with both temporary and permanent intertidal habitat (such as saltmarsh and eel grass). Sedimentation in the estuary basin (excluding the flood delta and sub-tidal channels) prior to 1930 was of the order of 40,000m^3/yr, however since then this appears to have slowed by an order of magnitude to 4,000m^3/yr.

The movement of sediment around the outer estuary is complex, with details of recent conceptual understandings presented in Posford Duvivier (1998), SCOPAC (2004), with further details in Halcrow (2008). In essence, it is suggested by Posford Duvivier (1998) and SCOPAC (2004) that there are two distinct linked circulations of bedload sediment transport (as shown in Figure 3):

- Wave driven net onshore and longshore movements across Pole Sands towards Dawlish Warren. Flood tidal currents combine with waves to introduce sediment into the estuary mouth.
- Dominant ebb tidal transport south-eastward from the estuary mouth to accreting sand banks flanking the tidal channel along Exmouth beach. Offshore movement of the sediment is reversed by wave action eventually, pushing the sediment back north-westward towards Pole Sands.

These circulations have been set in the context of the understanding gained from Halcrow (2008) and the studies herein, particularly in relation to historic movement of Dawlish Warren and Exmouth beach. These studies have confirmed the long term trend that Dawlish Warren is rotating anti-clockwise into the estuary, and that the central and proximal sections are eroding, whilst the



distal end is accreting. In addition to this, Exmouth beach is found to be eroding overall, with Pole Sands more recently exhibiting a marginal erosional trend. Related to this, Bull Hill Banks is found to be accreting, with the likelihood that the estuary mouth is also accreting (historically addressed by capital and maintenance dredging). Looking at the outer estuary system as a whole, the present day trend appears to be for transport of sediment from the adjacent coast and ebb delta towards the estuary mouth and flood delta, suggesting an overall movement of sediment in-estuary.

3.3 Summary of Conceptual Model

In summary, the conceptual model indicates that:

- Atmospheric surges are important in generating high water levels, with extreme water levels in the range of 3-4mAOD. The main fresh water inputs to the Exe estuary are the rivers Exe, Clyst and Kenn. Freshwater flows show a strong seasonality with an annual mean flow of 23m^3/s, and maximum flows of the order of 300m^3/s. These inputs supply around 1,9000m^3/yr of sediment which is comparable to the marine sediment supply. This suggests that freshwater inputs are significant in the maintenance of intertidal habitats in the inner estuary.
- Beach profiles along Dawlish Warren show a net erosion of the intertidal. Despite the fact that the distal end is accreting, this accretion is less than the volume of erosion of the proximal and central areas. The volumes trends are consistent with a net transport of material from south west to north east. Dawlish Warren presently has no littoral sediment supply from the west. Some material may move onshore to the proximal and central areas of Dawlish from nearshore banks, however this is insufficient to offset the net erosion trend.
- The beaches along Exmouth are eroding. The mechanism for beach erosion is wave action during storms which cause the erosion of the upper beach and the transport of material alongshore and offshore. This material either passes into the estuary mouth and thence into the sub-tidal banks or is combed down into the ebb tidal delta (Pole Hill Sands) directly. Once sediment enters the ebb tidal delta system it becomes subjected to tidal processes which redistribute sediment between the flood and ebb tidal delta.
- The inner estuary is indicated to be weakly accreting. Past dredging records imply a gain of some 15,000m^3/yr in the sub-tidal channels. This is roughly equivalent to the material being lost from the beaches of Exmouth, Dawlish Warren and the ebb delta of Pole Sands. LIDAR data shows that the intertidal area around the estuary accreted at an average rate of 0.5mm/yr from 1998 to 2007. It is noted that this is less than the current rate of relative sea level rise over this period (2-3.5mm/yr) which implies a net loss of habitats. Further monitoring and data is needed to confirm this.
- The future evolution of Dawlish Warren is uncertain. However, it is likely that the main body of the spit will remain over the next 100 years in some form. It appears likely that without maintenance regular breaching would occur by 2030. Repeated breaching may lead to the separation of the tip of Dawlish from the main body of the spit. Previous occurrences of Dawlish Warren breaching have resulted in the distal appearing to flatten as it reattached to the rest of the spit. The exact form of the distal end of the spit is subject to higher levels of uncertainty.

Quantification of the linkages, as supported by the EGA sub-tasks, is summarised in Table 1. The quantified key linkages for the Exe Estuary are shown in Figure 5. This shows agreement with previous studies of within an order of magnitude, and indicates:

- Sediment input to Dawlish Beach is sourced from erosion of Holcombe cliffs, and amounts to 1000m^3/yr, as indicated by SCOPAC (2004) and the baseline understanding. Langstone Rock and groyne, under non-extreme conditions, stop further eastward transport through to Dawlish Warren.
- The proximal and central sections of Dawlish Warren lose 35,000m^3/yr of sediment, defined by the beach profile analysis, which is transported alongshore to the distal end, and offshore to the nearshore banks. The proportion between the two is not directly known, but the changes at the distal end indicate that the transport to the nearshore banks is 12,900m^3/yr.
- The distal end of Dawlish Warren is accreting by 21,000m^3/yr, defined by the beach profile analysis, and it is estimated (Posford Duvivier, 1998) that potential transport from the distal end to the estuary mouth is 1,100m^3/yr. This indicates that 22,100m^3/yr could be passed alongshore to the distal end from the central section of Dawlish Warren (giving the remaining balance of 12,900m^3/yr to the nearshore banks).
- Posford Duvivier (1998) and SCOPAC (2004) suggests that the nearshore banks may have a sediment transport link to Pole Sands. Pole Sands is estimated to be reducing by 700m^3/yr (volumetric analysis), which potentially implies the transport from Pole Sands to the estuary mouth is 13,600m^3/yr.
- Sediment input to Sandy Bay is sourced from erosion of Orcombe Cliffs, and amounts to 10,000m^3/yr, as indicated by SCOPAC (2004) and the baseline understanding. This input to Sandy Bay can potentially be completely transported westward to Exmouth beach (Posford Duvivier, 1998).
- Exmouth beach experiences sediment losses of around 6,000m^3/yr as indicated by the beach profile analysis. Sediment from the upper beach is transported during storms to the lower beach, and subsequently to the tidal channel and presumably to the estuary mouth.
- The total estimated input to the estuary mouth is estimated as 30,700m^3/yr, drawn from Exmouth Beach, Pole Sands and the distal end of Dawlish Warren. SCOPAC (2004) notes that the transport of sediment from the estuary mouth to Bull Hill Banks is 18,000m^3/yr, which has reasonable agreement with the 16,900m^3/yr accretion suggested by the conceptual model. The remaining balance (potential accretion of the estuary mouth) of 13,800m^3/yr corresponds well to the historic rate of dredged removal of 15,000m^3/yr.
- SCOPAC (2004) makes the further judgement that 1000m^3/yr is passed from Bull Hill Banks to the inner estuary. Whilst there is large uncertainty, this has agreement with the volumetric analysis which suggests transfer of the order of 4000m^3/yr from all sources (equivalent to 2,100m^3/yr from Bull Hill Banks). Fluvial sediment inputs (mainly the rivers Exe and Clyst) to the inner estuary amount to 1,900m^3/yr (SCOPAC, 2003).
- Sediment transfers that are still completely unquantified are from the inner estuary (tidal transport) and outer Dawlish Warren (aeolian transport) to the inner Dawlish Warren. The potential for an offshore source of sediment to Pole Sands (with the consensus understanding weighing towards this not being the case) is not quantified.

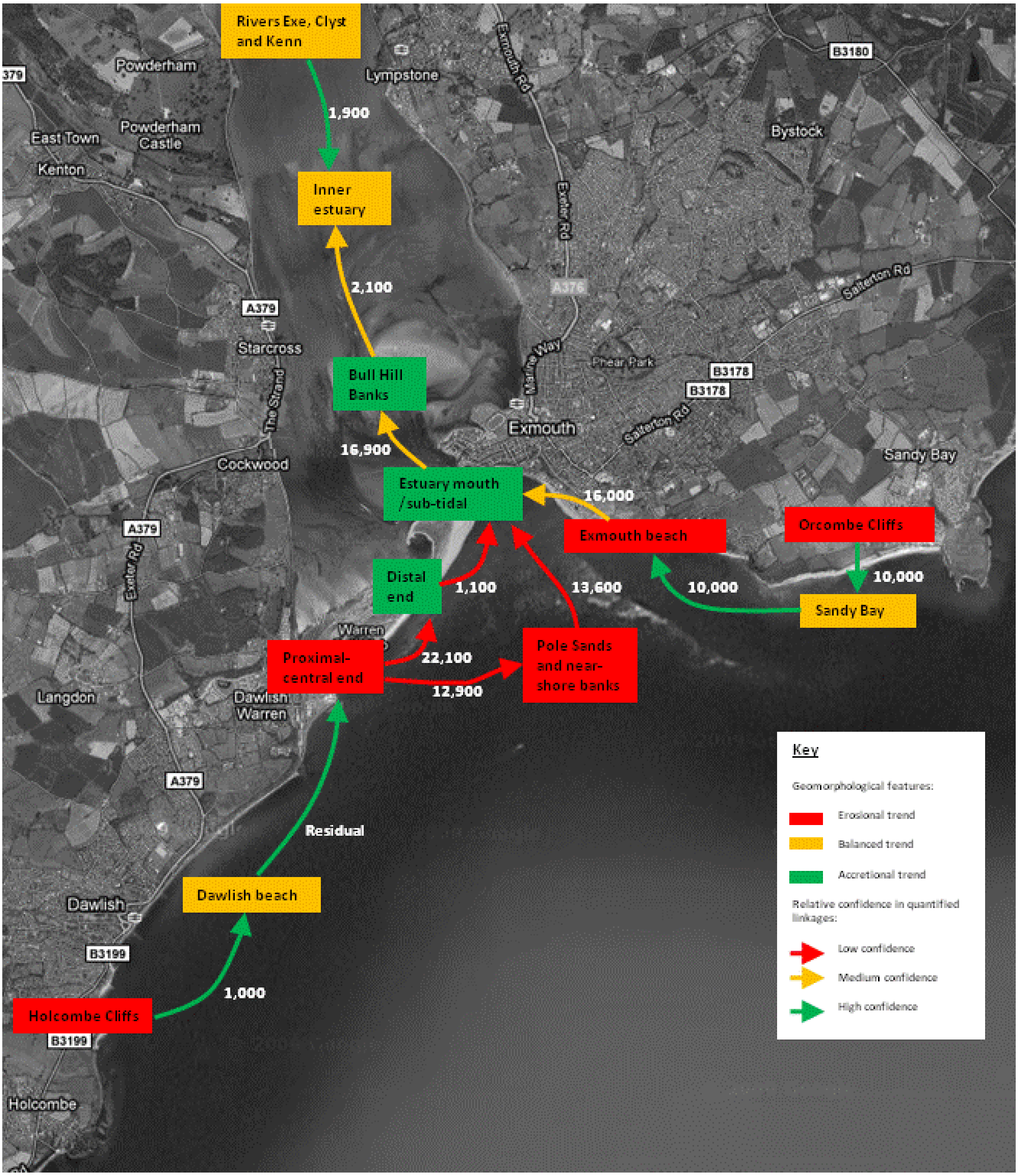


Figure 5. Conceptual model of the Exe Estuary with quantified net sediment exchanges (m^3/yr).

Transfer path	Quantification of transfer (m^3/yr)	
	Previous studies	Conceptual model
Fluvial input to inner estuary	1,900	NA
Bull Hill Banks to inner estuary	1,000	2,100
Estuary mouth to Bull Hill Banks	18,000	15,800
Orcombe cliffs to Sandy Bay	10,000	NA
Sandy Bay to Exmouth Beach	10,000	NA
Exmouth Beach to estuary mouth	NA	16,000
Pole Sands to estuary mouth	18,000	13,600
Estuary mouth to dredge disposal site	15,000	12,300
Nearshore banks to Pole Sands	NA	12,900
Distal end of Dawlish Warren to estuary mouth	1,100	NA
Central Dawlish Warren to nearshore banks	NA	12,900
Central to distal Dawlish Warren	8,400	21,000
Holcombe Cliffs to Dawlish beach	1,000	NA

Table 1. Quantification of sediment transfers.

4 Future Evolution of the Exe Estuary

To provide a comparative analysis of the changes, the sub-task findings have been summarised for a range of historic epochs, ranging from 1830 to 2010. This is given in Table 2. Similarly, the predictive sub-tasks have been considered in light of the historic changes and the conceptual model, to provide a comparative analysis of future change. This is given in Table 3.

The future evolution of Dawlish Warren is described generally in Table 3. For modelling purposes, quantification of the actual change in Dawlish Warren was considered. The evidence base in Table 3 indicates that the distal end of Dawlish Warren is particularly at risk of being detached and flattened in the future. Inspection of the good quality records surrounding the 1941-1946 evolution of Dawlish Warren indicated that a reasonable point for defining the maximum extent of the damaged Dawlish Warren would be where the 1941-1946 separation occurred. This coincides closely with the weak point found in the breach analysis. The co-ordinates of the reduced maximum extent are 299070E, 79690N. The distal end bathymetry north east of this location was flattened to 0mAOD, qualitatively representative of the flattening that occurred after 1946. The location and area of flattening are shown in Figure 6. The future evolution of the wider inner estuary was considered in light of the historic changes and the conceptual model, and particularly focussed on the rate of accretion in the inner estuary. This historic rate of accretion was extrapolated based on the findings of the conceptual model and acceleration in sea level rise through to 2110. This predicts limited siltation in the estuary up to 2060, and siltation of the order of 0.1m by 2110.

Figure 6. Predicted change in intertidal form of Dawlish Warren distal end.

5 Conclusions

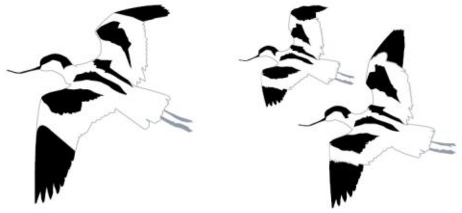
The analyses undertaken have produced a conceptual model for the geomorphological system, including the open coast, the sub-tidal features around the estuary mouth and the inner estuary. The model is consistent with previous investigations. The work advances earlier understanding presented in the EECMS (Halcrow (2008) in a number of areas.

This morphological model will be used to support the development of the wider strategy by allowing impacts of different strategies management options to be assessed. The key implications of the conceptual model for management of FCRM assets around the Exe are:

- It is considered likely that the distal end of Dawlish Warren will become permanently detached from the main body between 2030 and 2060, and potentially be lost in supra-tidal form. The main body of Dawlish Warren is likely to continue rotating anti-clockwise into the estuary, and remain present in some form through to 2110.
- The recent average rate of vertical accretion in the estuary is 15-25% of recent sea level rise. This suggests that habitat losses should be widespread, and further monitoring of intertidal areas is required to establish this. By 2110 the average vertical accretion in the estuary is estimated to be of the order of 0.1m, indicating that the estuary would progressively ‘drown’.

	1810 to 1930	1930 to 1960	1960 to 2010
Human impacts	• Exminster marshes were reclaimed progressively through the 12th-18th centuries. Topsham quay constructed in 1613. • Reclamation occurred at Exmouth around 1790-1810. • Original Dawlish seawall constructed in 1836, superseded by the railway wall in 1846. • Reclamation at the Lower Clyst around the 1840s. • Exmouth seawalls constructed in 1841, with docks formed in 1865-9. • In 1862 an embankment along Dawlish Warren was constructed. • Thousands of tonnes of gravel removed off Starcross in 1870-80. • Railways constructed. • Dawlish Warren becomes more developed with bungalows built, railway platform and defences between 1900-1920. • Between 1912-1932 the Maer was reclaimed, with a seawall and promenade constructed.	• Between 1949-59 Dawlish Warren was further protected and fixed in place with trees, brushwood fences and railway sleepers. • Buildings on the distal end of Dawlish Warren were progressively removed due to storm action.	• Between 1959-80, timber groynes, gabion reinforcement and a revetment were constructed along Dawlish Warren. • Subsequent to this, between 1980-2003 the existing wave return wall and revetment was constructed. • A 40,000m^3 capital dredge occurred in 1986 and similarly in 1996 at the Exmouth Approaches. • In 2006 the Lympstone tidal gates were installed.
Natural events	• Storm event in 1817 removed 5 acres of Dawlish Warren, and in 1823 damaged buildings. • In 1824 a breach occurred in Dawlish Warren, large enough for ship passage. • In 1838 and 1844 storms washed away 25%, and covered 300 acres, of Dawlish Warren respectively. • A storm in 1859 at Dawlish Warren severely damaged the distal end of Dawlish Warren and partially blocked up the estuary mouth with sand. • In 1869 and 1930 further storms damaged Dawlish Warren.	• Series of storm events cause separation of distal end of Dawlish Warren between 1941 and April 1946. • Around 10 flood events reported elsewhere in the estuary.	• 8 and 9 flood events reported at Dawlish Warren and Exmouth respectively. • Two breach events at Dawlish Warren in 1963 and 1969. • Around 30 flood events reported elsewhere in the estuary.
Spatial analysis	• Between 1900-30 the central and distal sections moved in-estuary by 100-200m, representing a rate of 3-7m/yr. Whilst the distal end changed shape, the spatial area remained relatively constant between 1890-1930. • Pole Sands spatial area reduces by 26% between 1890 and 1930 • Bull Hill Banks experiences large changes in shape and location between 1890 and 1930, There is a westward movement of 500m, and the spatial area reduces by 25%. • In 1890 Pole Sands LWMOT was linked to the Dawlish Warren LWMOT, however by 1900 this had separated, and by 1930 a clear LWMOT channel exists between Dawlish Warren and Pole Sands of up to 350m width.	• In 1941 Dawlish Warren has its distal end intact but damaged: by April 1946 it can be seen that the distal end has become partially detached. Within 7 months the island had reattached, and possibly lowered (due to lack of vegetation) and become more active. • By 1950 the distal end had grown significantly, although still un-vegetated, • By 1969 re-vegetation of the distal end is occurring, which expands consistently through to 1999, thickening in estuary by around 100m. • Between 1930 and 2000 the in-estuary movement of Dawlish Warren continued by 100-200m (1-2m/yr), and the distal end reduced in size by around 50%. • Pole Sands reversed its erosionary trend and increased in size by 37%. • Bull Hill banks experiences a similar trend, moving 300m eastwards and increasing in size by 30%. The LWMOT channel between Dawlish Warren and Pole Sands still exists, but is less coherent.	
Volumetric and beach profile analysis	• Between 1890-1930 Pole Sands accretes by around 11,100m^3/yr, • Bull Hill Banks accretes by 19,600m^3/yr. • Westward intertidal accretes between 1890-1930 by 0.03-0.05m/yr.	• Between 1930-2007 Pole Sands marginally erodes by 700m^3/yr. • Bull Hill Banks accretes by around 14,800m^3/yr. • Between 1930-2007 the general inner estuary also marginally accretes.	
Climate change	Indicative 1mm per year sea level rise (UKCP09, 2008).	Indicative 2mm per year sea level rise (UKCP09, 2008), and 3.5 mm/yr (Defra, 2006) after 1990.	
Summary	• **Storms indicate damage SoP of 7% AEP and breach SoP of 3% AEP at Dawlish Warren. Large scale human intervention in the form of reclamation.** • **General trend of in-estuary movement of central and distal sections of Dawlish Warren by 3-7m/yr.** • **Pole Sands and Bull Hill Banks reduce in size but vertically accrete.** • **Evidence that the inner estuary may have accreted by up to 0.05m/yr.**	• **Storms indicate damage SoP of 10% AEP and breach SoP of 4% AEP at Dawlish Warren, even though significant protection measures are constructed.** • **In-estuary movement of central and distal sections of Dawlish Warren slows to 1-2m/yr.** • **The well documented breach event in around 1946 indicates that Dawlish Warren distal end regenerated within 10 years.** • **Bull Hill Banks and Pole Sands increase spatially towards their historic size, although accretion slows and Pole Sands experiences marginal erosion.** • **Complementary evidence that the inner estuary was accreting more slowly than previously.**	

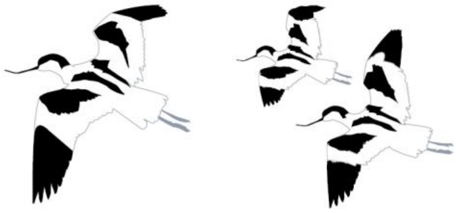
Table 2. Timeline of historic changes.



	Present Day	2010 to 2030	2030 to 2060	2060 to 2110
Conceptual Model	• Central Dawlish Warren is eroding, with corresponding accretion at the distal end. • Bull Hill Banks is currently accreting, with Pole Sands having a marginal erosionary trend. • Siltation within the general inner estuary is marginal.	• The volume of central Dawlish Warren will reduce significantly, with the distal end accreting by a larger amount. • Bull Hill Banks will continue to accrete. Pole Sands may continue eroding dependent on whether an offshore sediment source exists. • Siltation within the wider inner estuary will be marginal.	• The volume of central Dawlish Warren could reduce massively, with the distal end accreting. • Bull Hill Banks and Pole Sands evolution will be highly variable. • Siltation within the wider inner estuary will still be marginal.	• The volume of central Dawlish Warren could reduce critically and no longer be sustainable. • The distal end of Dawlish Warren, along with Bull Hill Banks and Pole Sands will significantly change form. • Siltation within the wider inner estuary will be of the order of 0.1m.
Breach analysis	• The thin neck between the central and distal section of Dawlish Warren has a breach SoP of 4%, whilst over-washing risk is limited. • More generally the breach SoP is 1% AEP.	• The thin neck between the central and distal section of Dawlish Warren has a breach SoP of 10%, indicating it is likely to temporarily breach in this epoch. • Over-washing risk remains low. More generally the breach SoP is 2% AEP. • The intertidal volume of Dawlish Warren marginally reduces.	• The thin neck between the central and distal section of Dawlish Warren has a breach SoP of 100%, indicating it is likely to breach regularly and not have time to regenerate. • Over-washing risk increases to 2% AEP, indicating this would also be likely to happen in this epoch. More generally the breach SoP is 10% AEP, indicating that Dawlish Warren will begin to lose its coherency as a sand spit. • The intertidal volume of Dawlish Warren reduces by 5%, whilst the supratidal volume reduces by 25%.	• Overwashing and breach risk along the central and distal ends of Dawlish Warren will occur on a regular basis, indicating a wider loss of coherency as a sand spit. • The intertidal volume of Dawlish Warren reduces by 15%, however the supratidal volume reduces by 55%. • At this point, whilst continuing to rotate anti-clockwise into the estuary, it is possible that Dawlish Warren would change form to a field of sandbanks and shoals.
Climate change	• Average 6mm per year sea level rise under medium emissions 95%ile scenario (EA, 2011). Potential 5% increase in storminess (defra, 2006).		• Average 7-9mm per year sea level rise under medium emissions 95%ile scenario (EA, 2011). Potential 10% increase in storminess (defra, 2006).	

Do Nothing Scenario	**• Dawlish Warren coast facing length has breach SoP of 4% AEP (the neck), more generally 1% AEP. Estuary facing length has breach SoP of 10% AEP.**	**• Dunes, beach, groynes and gabions deteriorating rapidly. • Central Dawlish Warren would be seriously damaged. • The distal end would be separated on a temporary basis. • Dawlish Warren would continue to provide shelter from offshore waves.**	**• Dunes, beach, groynes and gabions would fail. • Central Dawlish Warren permanently damaged and open to in-estuary movement of up to 60m (2m/yr). • The distal end would be regularly separated from the main body and lost in supratidal form. • This would allow some penetration of offshore waves into the inner estuary.**	**• Dawlish Warren would likely move in-estuary and become an intermittent intertidal sandbank feature, but would continue to provide some shelter from offshore waves. • Some siltation of the wider inner estuary would occur of the order of 0.1m.**
Do Minimum Scenario		**• Dunes, beach, groynes and gabions would require regular maintenance. • Central Dawlish Warren would intermittently be damaged. • The distal end would be separated on a temporary basis. • Dawlish Warren would continue to provide shelter from offshore waves.**	**• Dunes, beach, groynes and gabions would require extensive regular maintenance. • Central Dawlish Warren protection would require extensive regular maintenance to remain fixed in place. • The distal end would be regularly separated but still exist as an island feature. • This would provide shelter from offshore waves for parts of the inner estuary.**	

Table 3. Timeline of future changes.



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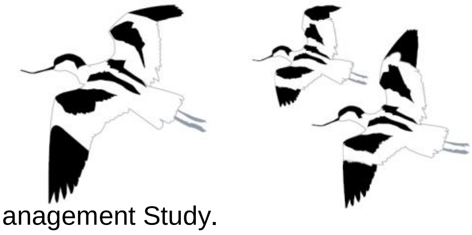

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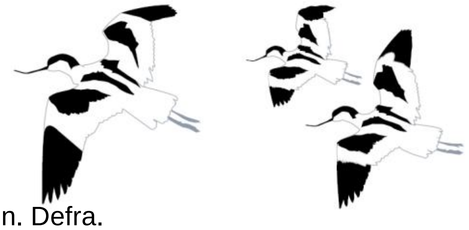

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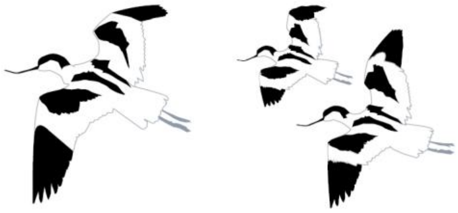
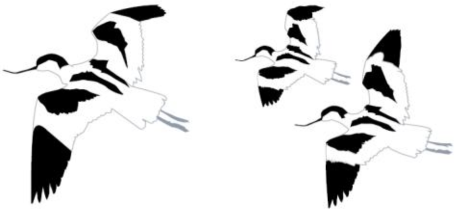


Appendix B : Joint Probability Analysis Tables

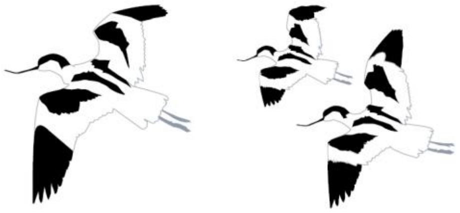


FCRMU01: Sandy Bay

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.84	2.58	2.62	2.67	2.69	2.72	2.74	2.75	2.76	2.79
1.99	2.58	2.62	2.67	2.69	2.72	2.74	2.75	2.76	2.79
2.14	2.53	2.59	2.65	2.69	2.72	2.74	2.75	2.76	2.79
2.29	2.50	2.55	2.62	2.66	2.70	2.73	2.75	2.76	2.79
2.44	2.46	2.51	2.58	2.63	2.67	2.72	2.74	2.76	2.79
2.59	2.41	2.47	2.53	2.58	2.63	2.69	2.72	2.74	2.78
2.74	2.37	2.43	2.50	2.54	2.59	2.66	2.69	2.72	2.77
2.82		2.39	2.46	2.51	2.55	2.63	2.67	2.70	2.75
2.90			2.40	2.46	2.51	2.57	2.63	2.67	2.73
2.97				2.42	2.47	2.53	2.58	2.64	2.72
3.06					2.43	2.50	2.54	2.60	2.70
3.13						2.45	2.50	2.55	2.66
3.20							2.46	2.51	2.63
3.27								2.48	2.59
3.46									2.51

FCRMU02: The Maer

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.84	2.20	2.24	2.28	2.30	2.32	2.34	2.35	2.36	2.39
1.99	2.20	2.24	2.28	2.30	2.32	2.34	2.35	2.36	2.39
2.14	2.15	2.20	2.27	2.30	2.32	2.34	2.35	2.36	2.39
2.29	2.12	2.16	2.23	2.28	2.31	2.33	2.35	2.36	2.39
2.44	2.08	2.13	2.19	2.25	2.28	2.32	2.34	2.35	2.39
2.59	2.03	2.08	2.14	2.19	2.25	2.29	2.32	2.34	2.37
2.74	1.98	2.04	2.11	2.15	2.21	2.27	2.30	2.33	2.36
2.82		2.00	2.07	2.12	2.17	2.24	2.28	2.31	2.35
2.90			2.02	2.07	2.12	2.19	2.24	2.28	2.34
2.97				2.03	2.09	2.15	2.20	2.25	2.33
3.06					2.05	2.12	2.16	2.22	2.31
3.13						2.06	2.12	2.16	2.28
3.20							2.08	2.13	2.25
3.27								2.09	2.21
3.46									2.12

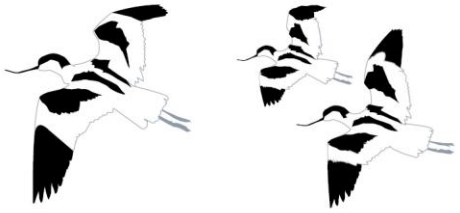


FCRMU03: Exmouth

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.84	0.44	0.50	0.57	0.62	0.67	0.73	0.78	0.82	0.92
1.99	0.44	0.50	0.57	0.62	0.67	0.73	0.78	0.82	0.92
2.14	0.37	0.45	0.55	0.61	0.67	0.73	0.78	0.82	0.92
2.29	0.32	0.39	0.50	0.56	0.63	0.72	0.78	0.82	0.92
2.44	0.26	0.34	0.44	0.52	0.58	0.67	0.74	0.80	0.92
2.59	0.18	0.26	0.36	0.44	0.52	0.61	0.67	0.74	0.88
2.74	0.12	0.20	0.31	0.38	0.46	0.56	0.62	0.69	0.83
2.82		0.14	0.25	0.33	0.40	0.51	0.57	0.64	0.79
2.90			0.17	0.25	0.33	0.43	0.51	0.57	0.73
2.97				0.19	0.27	0.37	0.45	0.53	0.68
3.06					0.21	0.32	0.39	0.47	0.63
3.13						0.24	0.32	0.39	0.57
3.20							0.26	0.34	0.52
3.27								0.28	0.46
3.46									0.33

FCRMU04: Courtlands

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.89	0.66	0.71	0.76	0.81	0.87	0.91	0.96	1.00	1.10
2.04	0.66	0.71	0.76	0.81	0.87	0.91	0.96	1.00	1.10
2.19	0.60	0.67	0.75	0.81	0.87	0.91	0.96	1.00	1.10
2.34	0.57	0.62	0.71	0.76	0.83	0.91	0.96	1.00	1.10
2.49	0.52	0.58	0.66	0.72	0.78	0.87	0.92	0.98	1.10
2.64	0.45	0.52	0.60	0.66	0.72	0.80	0.87	0.92	1.06
2.79	0.40	0.47	0.56	0.61	0.68	0.75	0.82	0.88	1.01
2.85		0.42	0.51	0.57	0.63	0.72	0.77	0.84	0.97
2.94			0.44	0.51	0.57	0.65	0.72	0.77	0.91
3.01				0.46	0.53	0.60	0.67	0.73	0.88
3.08					0.48	0.57	0.62	0.69	0.83
3.17						0.50	0.57	0.62	0.76
3.24							0.52	0.58	0.72
3.32								0.54	0.68
3.50									0.57

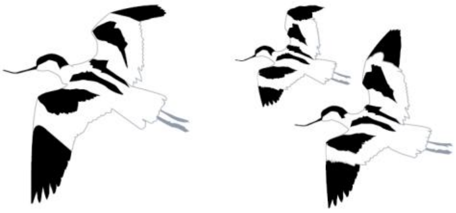


FCRMU05: Lympstone

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.94	0.60	0.65	0.69	0.73	0.79	0.83	0.87	0.91	1.01
2.09	0.60	0.65	0.69	0.73	0.79	0.83	0.87	0.91	1.01
2.24	0.55	0.61	0.68	0.73	0.79	0.83	0.87	0.91	1.01
2.39	0.51	0.56	0.64	0.69	0.75	0.82	0.87	0.91	1.01
2.54	0.47	0.52	0.60	0.66	0.71	0.79	0.84	0.89	1.01
2.69	0.41	0.47	0.54	0.60	0.66	0.73	0.79	0.84	0.97
2.84	0.36	0.42	0.51	0.55	0.61	0.68	0.74	0.80	0.93
2.90		0.38	0.46	0.52	0.57	0.65	0.70	0.76	0.89
2.99			0.40	0.46	0.52	0.59	0.65	0.70	0.83
3.06				0.41	0.48	0.55	0.61	0.66	0.80
3.13					0.43	0.51	0.56	0.62	0.75
3.22						0.45	0.51	0.56	0.69
3.29							0.47	0.52	0.66
3.37								0.48	0.61
3.55									0.52

FCRMU06: Lympstone Commando

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.96	0.61	0.66	0.70	0.74	0.80	0.84	0.88	0.92	1.02
2.11	0.61	0.66	0.70	0.74	0.80	0.84	0.88	0.92	1.02
2.26	0.56	0.62	0.69	0.74	0.80	0.84	0.88	0.92	1.02
2.41	0.52	0.57	0.65	0.70	0.76	0.83	0.88	0.92	1.02
2.56	0.48	0.53	0.61	0.67	0.72	0.80	0.85	0.90	1.02
2.71	0.42	0.48	0.55	0.61	0.67	0.73	0.80	0.85	0.97
2.86	0.37	0.43	0.52	0.56	0.62	0.69	0.75	0.81	0.93
2.92		0.39	0.47	0.53	0.58	0.66	0.71	0.77	0.89
3.01			0.41	0.47	0.53	0.60	0.66	0.71	0.84
3.08				0.42	0.49	0.56	0.62	0.67	0.81
3.15					0.44	0.52	0.57	0.63	0.76
3.24						0.46	0.52	0.57	0.70
3.31							0.48	0.53	0.67
3.39								0.49	0.62
3.57									0.53

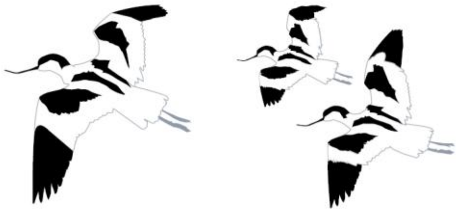


FCRMU07: Exton

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	**50% AEP**	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.1% AEP**
1.98	0.57	0.61	0.66	0.69	0.74	0.78	0.82	0.85	0.93
2.13	0.57	0.61	0.66	0.69	0.74	0.78	0.82	0.85	0.93
2.28	0.52	0.58	0.64	0.69	0.74	0.78	0.82	0.85	0.93
2.43	0.49	0.54	0.61	0.66	0.71	0.77	0.82	0.85	0.93
2.58	0.45	0.50	0.57	0.62	0.67	0.75	0.79	0.83	0.93
2.73	0.39	0.45	0.52	0.57	0.62	0.69	0.75	0.79	0.90
2.88	0.35	0.41	0.49	0.53	0.59	0.65	0.70	0.76	0.86
2.94		0.37	0.44	0.50	0.54	0.62	0.66	0.72	0.83
3.03			0.39	0.44	0.50	0.56	0.62	0.66	0.78
3.10				0.40	0.46	0.52	0.58	0.63	0.75
3.17					0.42	0.49	0.54	0.59	0.71
3.26						0.44	0.49	0.54	0.66
3.33							0.45	0.50	0.62
3.41								0.47	0.58
3.59									0.50

FCRMU12: Topsham

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	**50% AEP**	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.1% AEP**
1.99	0.55	0.59	0.63	0.66	0.70	0.73	0.76	0.78	0.84
2.14	0.55	0.59	0.63	0.66	0.70	0.73	0.76	0.78	0.84
2.29	0.51	0.56	0.62	0.66	0.70	0.73	0.76	0.78	0.84
2.44	0.48	0.52	0.59	0.63	0.67	0.72	0.76	0.78	0.84
2.59	0.44	0.49	0.55	0.60	0.64	0.70	0.73	0.77	0.84
2.74	0.39	0.44	0.50	0.55	0.60	0.66	0.70	0.73	0.81
2.89	0.35	0.40	0.47	0.51	0.57	0.62	0.67	0.71	0.79
2.95		0.36	0.43	0.48	0.53	0.59	0.64	0.68	0.76
3.04			0.38	0.43	0.48	0.54	0.60	0.64	0.73
3.11				0.39	0.45	0.51	0.56	0.61	0.71
3.18					0.41	0.48	0.52	0.57	0.67
3.27						0.43	0.48	0.52	0.63
3.34							0.44	0.49	0.60
3.42								0.45	0.56
3.60									0.48

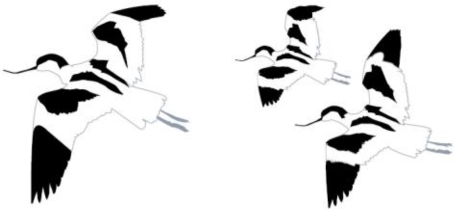


FCRMU14: Exminster Marshes and Powderham Banks

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	**50% AEP**	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.1% AEP**
1.99	0.21	0.23	0.24	0.26	0.27	0.29	0.30	0.31	0.34
2.14	0.21	0.23	0.24	0.26	0.27	0.29	0.30	0.31	0.34
2.29	0.19	0.21	0.24	0.26	0.27	0.29	0.30	0.31	0.34
2.44	0.18	0.19	0.23	0.24	0.26	0.28	0.30	0.31	0.34
2.59	0.16	0.18	0.21	0.23	0.25	0.27	0.29	0.30	0.34
2.74	0.14	0.16	0.19	0.21	0.23	0.25	0.28	0.29	0.32
2.89	0.12	0.14	0.17	0.19	0.22	0.24	0.26	0.28	0.31
2.95		0.13	0.16	0.18	0.20	0.23	0.25	0.27	0.30
3.04			0.13	0.16	0.18	0.21	0.23	0.25	0.29
3.11				0.14	0.16	0.19	0.21	0.23	0.28
3.18					0.15	0.18	0.19	0.22	0.26
3.27						0.15	0.18	0.19	0.24
3.34							0.16	0.18	0.23
3.42								0.17	0.21
3.60									0.18

FCRMU15: Kenn Valley

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	**50% AEP**	**20% AEP**	**10% AEP**	**5% AEP**	**2% AEP**	**1% AEP**	**0.5% AEP**	**0.1% AEP**
1.91	0.32	0.37	0.42	0.46	0.53	0.57	0.62	0.67	0.78
2.06	0.32	0.37	0.42	0.46	0.53	0.57	0.62	0.67	0.78
2.21	0.26	0.32	0.41	0.46	0.53	0.57	0.62	0.67	0.78
2.36	0.21	0.27	0.37	0.42	0.49	0.57	0.62	0.67	0.78
2.51	0.16	0.23	0.31	0.38	0.44	0.53	0.58	0.64	0.78
2.66	0.09	0.16	0.25	0.31	0.38	0.46	0.53	0.58	0.73
2.81	0.04	0.11	0.21	0.26	0.33	0.41	0.47	0.55	0.68
2.87		0.06	0.15	0.22	0.28	0.37	0.43	0.50	0.64
2.96			0.08	0.15	0.22	0.30	0.37	0.43	0.57
3.03				0.10	0.17	0.25	0.32	0.39	0.54
3.10					0.12	0.21	0.27	0.34	0.48
3.19						0.14	0.21	0.27	0.42
3.26							0.16	0.23	0.38
3.34								0.18	0.33
3.52									0.22

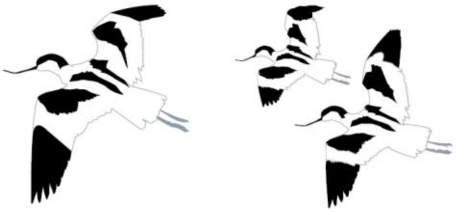


FCRMU16: Starcross

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.88	0.35	0.40	0.45	0.49	0.55	0.60	0.64	0.69	0.79
2.03	0.35	0.40	0.45	0.49	0.55	0.60	0.64	0.69	0.79
2.18	0.28	0.35	0.44	0.49	0.55	0.60	0.64	0.69	0.79
2.33	0.24	0.30	0.40	0.45	0.51	0.59	0.64	0.69	0.79
2.48	0.19	0.26	0.34	0.41	0.47	0.56	0.60	0.66	0.79
2.63	0.12	0.19	0.28	0.34	0.41	0.48	0.56	0.60	0.74
2.78	0.07	0.14	0.24	0.29	0.36	0.44	0.50	0.57	0.70
2.84		0.09	0.18	0.25	0.31	0.40	0.46	0.52	0.66
2.93			0.11	0.18	0.25	0.33	0.41	0.46	0.60
3.00				0.13	0.20	0.28	0.35	0.42	0.56
3.07					0.15	0.24	0.30	0.37	0.51
3.16						0.17	0.24	0.30	0.45
3.23							0.19	0.26	0.41
3.31								0.21	0.36
3.49									0.25

FCRMU17: Dawlish Warren

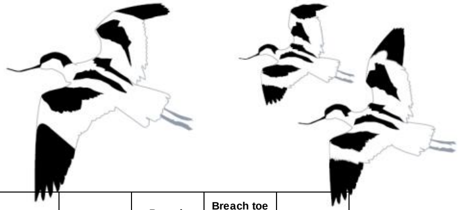
EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.85	0.31	0.36	0.41	0.44	0.48	0.53	0.57	0.61	0.71
2.00	0.31	0.36	0.41	0.44	0.48	0.53	0.57	0.61	0.71
2.15	0.26	0.32	0.39	0.44	0.48	0.53	0.57	0.61	0.71
2.30	0.22	0.27	0.36	0.41	0.45	0.52	0.57	0.61	0.71
2.45	0.18	0.23	0.31	0.37	0.42	0.48	0.54	0.59	0.71
2.60	0.11	0.18	0.25	0.31	0.37	0.43	0.48	0.54	0.66
2.75	0.06	0.13	0.21	0.26	0.33	0.40	0.44	0.50	0.62
2.81		0.08	0.17	0.23	0.28	0.36	0.41	0.46	0.58
2.90			0.10	0.17	0.23	0.30	0.36	0.41	0.53
2.97				0.12	0.18	0.26	0.32	0.38	0.49
3.04					0.14	0.22	0.27	0.33	0.45
3.13						0.16	0.22	0.27	0.41
3.20							0.18	0.23	0.37
3.28								0.19	0.33
3.46									0.23



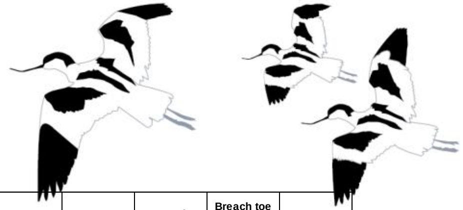
FCRMU18: Dawlish

EWL (mAOD)	Joint Probability wave heights (m)								
	100% AEP	50% AEP	20% AEP	10% AEP	5% AEP	2% AEP	1% AEP	0.5% AEP	0.1% AEP
1.94	2.62	2.81	3.00	3.10	3.20	3.25	3.29	3.31	3.38
2.09	2.62	2.81	3.00	3.10	3.20	3.25	3.29	3.31	3.38
2.24	2.40	2.65	2.95	3.10	3.20	3.25	3.29	3.31	3.38
2.39	2.25	2.46	2.80	3.00	3.13	3.24	3.29	3.31	3.38
2.54	2.07	2.30	2.61	2.85	3.04	3.20	3.25	3.30	3.38
2.69	1.81	2.07	2.37	2.61	2.86	3.08	3.20	3.25	3.35
2.84	1.62	1.88	2.22	2.42	2.68	2.97	3.12	3.22	3.32
2.98		1.69	2.03	2.28	2.49	2.83	3.02	3.15	3.29
3.11			1.78	2.04	2.28	2.58	2.83	3.02	3.25
3.23				1.85	2.11	2.40	2.65	2.88	3.21
3.40					1.91	2.25	2.45	2.71	3.13
3.51						2.00	2.25	2.46	3.00
3.71							2.07	2.31	2.85
3.85								2.14	2.68
4.24									2.28

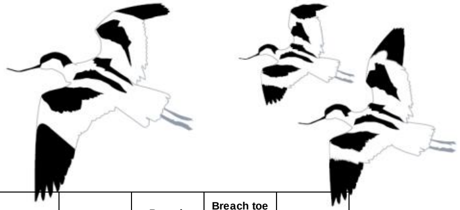
Appendix C : FCRM Asset Characterisation



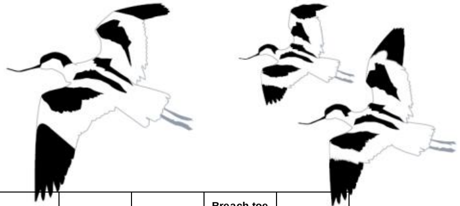
FCRM unit (working from Straight Point anti-clockwise around the estuary and coastline)	Additional sources of data that have been used	NFCDD reference	Asset location	Asset type	Asset description	Analysed Type	Maintainer	Asset condition	Asset length (m)	Crest level used (mAOD)	Toe level (mAOD), from LiDAR	Front face slope (Y:X), generally from LiDAR	Foreshore slope (Y:X), generally from LiDAR	Residual life (years) from SCHO0509B QAT-E-P	Critical damage rate (m3/s/m)	Critical breach rate (m3/s/m)	Breach width (m) based on EA (2004)	Breach toe (mAOD) based on adjacent ground level	HD Processes
FCRMU01		113FAS3350501C01	Straight Point Rifle Range South to West Boundry	coastal protection (natural)	Natural Cliff	Natural or breach resilient	private	3	579.4	100	3.25	100	0.03	100	0.05	100	0	100	Wave, tidal
FCRMU01		113FAS3350501C02	Sandy Bay	coastal protection (natural)	Natural Cliff	Natural or breach resilient	private	3	1055	100	3.25	100	0.03	100	0.05	100	0	100	Wave, tidal
FCRMU01		113FAS3350501C03	Sandy Bay	coastal protection (natural)	Natural Cliff	Natural or breach resilient	private	3	426.7	100	3.25	100	0.03	100	0.05	100	0	100	Wave, tidal
FCRMU01		113FAS3351001C01	Orcombe Point to Beach	coastal protection (natural)	Natural Cliff	Natural or breach resilient	private	3	511.1	100	3.25	100	0.03	100	0.05	100	0	100	Wave, tidal
FCRMU02		113FAS3351001C02	Queen's Drive, Exmouth	coastal protection (man-made)	Wall with Groynes	Natural or breach resilient	local authority	3	951.5	100	2.8	100	0.01	45	0.05	100	0	100	Wave, tidal
FCRMU02		113FAS3351002C01	EXMOUTH - QUEENS DRIVE	sea defence (man-made)	MASONRY SEA WALL	Natural or breach resilient	local authority	3	1688.4	4.53	2.8	100	0.01	45	0.05	100	0	4.8	Wave, tidal
FCRMU02		113FAS3351002C02	EXMOUTH - QUEENS DRIVE	sea defence (man-made)	MASONRY SEA WALL	Natural or breach resilient	local authority	3	61.1	4.65	2.6	100	0.01	45	0.05	100	0	4.6	Wave, tidal
FCRMU02		113FAS3351002C03	EXMOUTH - QUEENS DRIVE	sea defence (man-made)	MASONRY SEA WALL	Natural or breach resilient	local authority	3	136.5	5.24	2.4	100	0.01	45	0.05	100	0	5	Wave, tidal
FCRMU03	Scheme dwgs indicate 5.75mAOD crest (dwg 9R2302/032)	113FAS3351002C04	EXMOUTH - QUEENS DRIVE	sea defence (man-made)	MASONRY SEA WALL	Natural or breach resilient	local authority	3	171.2	5.25	3.5	100	0.08	45	0.05	100	0	5.1	Wave, tidal
FCRMU03	Scheme dwgs indicate 5.75mAOD crest (dwg 9R2302/021)	113FAS3351002C05	EXMOUTH - Sea Front	sea defence (man-made)	MASONRY SEA WALL	Natural or breach resilient	local authority	3	695.1	5.75	2	100	0.08	45	0.05	100	0	4.5	Wave, tidal
FCRMU03		113FAS3351003C01	EXMOUTH - HARBOUR	sea defence (man-made)	Sheet Piled Wall	Natural or breach resilient	private	3	93	4.2	0	100	0.1	20	0.05	100	0	4.2	Wave, tidal
FCRMU03		113FAS3351003C02	Exmouth Point	sea defence (man-made)	Complex Wall	Natural or breach resilient	private	3	1009.4	3.7	0	100	0.1	20	0.05	100	0	3.7	Wave, tidal
FCRMU03		113FAS3351003C03	EXMOUTH POINT	sea defence (man-made)	Concrete Wall	Natural or breach resilient	private	3	116.6	4.1	1	100	0.1	45	0.05	100	0	4.1	Wave, tidal
FCRMU03		113FAS3351003C04	EXMOUTH - Exe Sailing Club	coastal protection (man-made)	Timber Revetment	Natural or breach resilient	private	2	75.7	4	1	100	0.01	30	0.05	100	0	4	Wave, tidal
FCRMU03		113FAS3351003C05	EXMOUTH - Exe Sailing Club.	coastal protection (man-made)	Concrete and Masonry Wall	Natural or breach resilient	private	2	55.7	2.59	1	100	0.01	65	0.05	100	0	3.2	Wave, tidal
FCRMU03		113FAS3351003C06	EXMOUTH - Exe Sailing Club	coastal protection (man-made)	Gabion Wall	Natural or breach resilient	private	2	64.5	2.57	1	100	0.01	30	0.05	100	0	3	Wave, tidal
FCRMU03		113FAS3351003C07	EXMOUTH - Camperdown Terrace	coastal protection (man-made)	Pitched Stone Revetment	Natural or breach resilient	private	2	46.1	3.3	1	100	0.01	30	0.05	100	0	3.3	Wave, tidal
FCRMU03		113FAS3351003C08	EXMOUTH - Camperdown Terrace	sea defence (man-made)	Complex Wall	Natural or breach resilient	private	3	75.9	3.5	1	100	0.01	45	0.05	100	0	3.5	Wave, tidal
FCRMU03		113FAS3351003C09	EXMOUTH - Camperdown Terrace	sea defence (man-made)	Masonry Wall	Natural or breach resilient	private	3	66.7	2.8	1	100	0.01	45	0.05	100	0	2.8	Wave, tidal
FCRMU03		113FAS3351003C10	EXMOUTH - Camperdown Terrace	sea defence (man-made)	Masonary Wall	Natural or breach resilient	private	3	61.9	2.87	1	100	0.01	45	0.05	100	0	2.8	Wave, tidal
FCRMU03		113FAS3351004C01	EXMOUTH, Lavis Boat Yard	sea defence (man-made)	Complex wall	Natural or breach resilient	private	3	92	3	2	100	0.01	45	0.05	100	0	3	Wave, tidal
FCRMU03		113FAS3351004C02	EXMOUTH, Playing Field	sea defence (man-made)	Gabion toe revetment	Natural or breach resilient	local authority	3	110.3	3.31	2.5	0.4	0.01	20	0.05	100	0	3	Wave, tidal
FCRMU03		113FAS3351004C03	EXMOUTH	sea defence (man-made)	Block Revetment	Natural or breach resilient	local authority	3	549.7	4.5	1.5	0.25	0.01	20	0.05	100	0	4.5	Wave, tidal
FCRMU03		113FAS3351004C04	EXMOUTH,Station Car park	sea defence (natural)	Raised Ground	Natural or breach resilient	local authority	3	393.5	3.55	1	100	0.01	34	0.05	100	0	3.5	Wave, tidal
FCRMU03		113FAS3351004C05	EXMOUTH, Withycombe Brook to Bus Station	sea defence (man-made)	Embankment	Natural or breach resilient	local authority	3	562.5	4	1	0.333333333	0.01	34	0.05	100	0	4	Wave, tidal



FCRM unit (working from Straight Point anti-clockwise around the estuary and coastline)	Additional sources of data that have been used	NFCDD reference	Asset location	Asset type	Asset description	Analysed Type	Maintainer	Asset condition	Asset length (m)	Crest level used (mAOD)	Toe level (mAOD), from LiDAR	Front face slope (Y:X), generally from LiDAR	Foreshore slope (Y:X), generally from LiDAR	Residual life (years) from SCHO0509BQAT-E-P	Critical damage rate (m3/s/m)	Critical breach rate (m3/s/m)	Breach width (m) based on EA (2004)	Breach toe (mAOD) based on adjacent ground level	HD Processes
FCRMU04	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351005C01	Cockle Sand Exmouth	coastal protection (man-made)	Railway Embankment with Revetment	Natural or breach resilient	private	3	593.8	4.5	1.7	0.544502618	0.01	35	0.05	100	0	100	Wave, tidal
FCRMU04	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351005C02	Exmouth North	coastal protection (man-made)	Wall	Natural or breach resilient	private	3	367.3	4	1.7	0.544502618	0.01	45	0.05	100	0	4	Wave, tidal
FCRMU04	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351005C03	Exmouth to Lympstone	coastal protection (man-made)	Railway Embankment with Revetment	Hard	private	3	598.2	4.2	1.7	0.544502618	0.01	35	0.05	0.2	20	2.5	Wave, tidal
FCRMU04	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351005C04	South Lympstone	coastal protection (man-made)	Timber Wall	Natural or breach resilient	private	3	82.8	7.5	1.7	0.544502618	0.01	20	0.05	100	0	100	Wave, tidal
FCRMU04	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351005C05	South Lympstone	coastal protection (man-made)	Concrete Revetment	Natural or breach resilient	private	3	220.3	2.9	1.7	0.544502618	0.01	20	0.05	100	0	3	Wave, tidal
FCRMU04	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351005C06	Lympstone	coastal protection (man-made)	Masonry Wall	Natural or breach resilient	local authority	3	168.4	3.5	1.7	0.544502618	0.01	45	0.05	100	0	100	Wave, tidal
FCRMU04		113FAS3351005C07	Lympstone	coastal protection (natural)	Natural Cliff (check elements)	Natural or breach resilient	private	3	268.2	100	0	100	0.01	100	0.05	100	0	100	Wave, tidal
FCRMU05		113FAS3351006C02	LYMPSTONE - THE STRAND	sea defence (man-made)	MASONRY WALL	Hard	private	3	44.7	3.87	3.2	100	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351006C03	LYMPSTONE - CURLEWS SLIPWAY	sea defence (man-made)	Masonry Wall	Hard	private	3	39.5	3.67	2.7	0.066666667	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351006C04	LYMPSTONE	sea defence (man-made)	Masonry Wall	Hard	private	3	37.9	3.76	3	0.07	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351006C05	0	sea defence (man-made)	MASONRY WALL	Hard	private	3	50.3	3.44	1	0.1	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351006C06	S of The Green	sea defence (man-made)	MASONRY WALL	Hard	private	3	27.2	3.83	1	0.1	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351006C07	Arround 'The Green'.	sea defence (man-made)	MASONRY WALL	Hard	private	3	48.4	3.8	1	100	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351006C08	0	sea defence (man-made)	Masonry Wall, Limekiln.	Hard	private	3	17.8	3.81	1.8	0.25	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351006C09	Memorial Tower to Cottage Wall	sea defence (man-made)	Masonry Wall	Hard	Environment Agency	3	33.9	3.81	1.8	0.666666667	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351006C10	0	sea defence (man-made)	Building Walls	Hard	private	3	15.2	3.8	1.8	100	0.01	45	0.05	0.2	20	3	Wave, tidal
FCRMU05		113FAS3351007C01	Darling's Rock, Lympstone	coastal protection (natural)	Natural Cliff	Natural or breach resilient	private	3	386.4	100	1	100	0.01	100	0.05	100	0	100	Wave, tidal
FCRMU05	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351007C07	Lympstone	coastal protection (man-made)	Railway Embankment with Revetment and Wall	Natural or breach resilient	private	3	396	100	1.7	0.544502618	0.01	20	0.05	100	0	100	Wave, tidal
FCRMU06	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351007C07	Lympstone	coastal protection (man-made)	Railway Embankment with Revetment and Wall	Hard	private	3	896.9	4.2	1.7	0.544502618	0.01	20	0.05	0.2	20	3	Wave, tidal
FCRMU06	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	1131801070101L01	Exton	raised defence (man-made)	Railway Embankment (check elements)	Hard	private	3	399	4.2	1.7	0.544502618	0.01	20	0.05	0.2	20	3	Wave, tidal
FCRMU06	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	1131801070101L01	Exton	raised defence (man-made)	Railway Embankment (check elements)	Hard	private	3	707.1	4.2	1.7	0.544502618	0.01	20	0.05	0.2	20	3	Wave, tidal
FCRMU07	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	1131801070101L02	0	raised defence (man-made)	Railway Embankment (check elements)	Hard	private	3	709.3	4.2	1.7	0.544502618	0.1	20	0.05	0.2	20	3	Wave, tidal
FCRMU07	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	1131801070102L01	0	raised defence (man-made)	Railway Embankment (check elements)	Hard	private	3	368.5	5.2	1.7	0.544502618	0.01	20	0.05	0.2	20	2.5	Wave, tidal
FCRMU07		1131801070201L01	0	raised defence (man-made)	Earth Embankment (check elements)	Natural or breach resilient	private	3	292.5	6.75	1.7	0.544502618	0.01	34	0.05	100	0	100	Wave, tidal
FCRMU08		1131801070204L01	Bridge Mill to Boatyard.	raised defence (man-made)	Earth Embankment	Soft	Environment Agency	3	777.6	3.4	0	0.333333333	0.01	34	0.002	0.03	50	2	Tidal



FCRM unit (working from Straight Point anti-clockwise around the estuary and coastline)	Additional sources of data that have been used	NFCDD reference	Asset location	Asset type	Asset description	Analysed Type	Maintainer	Asset condition	Asset length (m)	Crest level used (mAOD)	Toe level (mAOD), from LiDAR	Front face slope (Y:X), generally from LiDAR	Foreshore slope (Y:X), generally from LiDAR	Residual life (years) from SCHO0509BQAT-E-P	Critical damage rate (m3/s/m)	Critical breach rate (m3/s/m)	Breach width (m) based on EA (2004)	Breach toe (mAOD) based on adjacent ground level	HD Processes
FCRMU08		1131801070202L05	TREMLETT POWER BOATS WORK SHOPS	raised defence (man-made)	Wall	Hard	private	3	42.2	4.4	0	0.333333333	0.01	45	0.05	0.2	20	2	Tidal
FCRMU08		1131801070202L06	UPSTREAM WORK SHOP	raised defence (man-made)	Timber Pile Wall With Concrete Cap	Hard	private	3	15.6	4.37	0	0.333333333	0.01	20	0.05	0.2	20	2	Tidal
FCRMU08		1131801070202L03	EMBANKMENT TO WALL AT TREMLETT MAIN RAMP	raised defence (man-made)	Ramp block wall.	Hard	private	3	17.5	3.79	0	0.333333333	0.01	45	0.05	0.2	20	2	Tidal
FCRMU08		1131801070202L02	CONCRETE RAMP TO RAMP WITH DROP BD FACIL	raised defence (man-made)	Earth Embankment	Soft	private	3	55	3.73	0	0.333333333	0.01	34	0.002	0.03	50	2	Tidal
FCRMU08		1131801070202L01	TRK FROM HG APPROX 200M US RLY-TREMLETT	raised defence (man-made)	Earth Embankment	Soft	private	3	86.5	4.04	0	0.333333333	0.01	34	0.002	0.03	50	2	Tidal
FCRMU08	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	2261	3	0	0.333333333	0.01	15	0.002	0.03	50	2	Tidal
FCRMU09	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	1734	3	0	0.333333333	0.01	15	0.002	0.03	50	2	Fluvial, tidal
FCRMU09	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	574	3.6	0	0.333333333	0.01	15	0.002	0.03	50	2	Fluvial, tidal
FCRMU09	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	726	4	0	0.333333333	0.01	15	0.002	0.03	50	2	Fluvial, tidal
FCRMU09	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	946	4.8	0	0.333333333	0.01	15	0.002	0.03	50	2.5	Fluvial, tidal
FCRMU09	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	693	5.3	0	0.333333333	0.01	15	0.002	0.03	50	4.6	Fluvial, tidal
FCRMU10	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	1047	5.25	0	0.333333333	0.01	15	0.002	0.03	50	5.2	Fluvial, tidal
FCRMU10	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	1089	4	0	0.333333333	0.01	15	0.002	0.03	50	3.1	Fluvial, tidal
FCRMU11	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	1168	3.3	0	0.333333333	0.01	15	0.002	0.03	50	2	Fluvial, tidal
FCRMU11	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	368	4.3	0	0.333333333	0.01	15	0.002	0.03	50	2	Fluvial, tidal
FCRMU11	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	2404	2.9	0	0.333333333	0.01	15	0.002	0.03	50	2	Fluvial, tidal
FCRMU11	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	500	3.3	0	0.333333333	0.01	15	0.002	0.03	50	2	Fluvial, tidal
FCRMU11	No NFCDD data: taken from LiDAR and photography	Dummy	0	0	Earth Embankment	Soft	0	4	174	100	0	0.333333333	0.01	15	0.002	0.03	50	2	Fluvial, tidal
FCRMU11		1131801070203R01	In front of carpark	maintained channel	Naturalised bank	Soft	private	3	370	3	0	0.333333333	0.01	34	0.002	0.03	50	1.5	Fluvial, tidal
FCRMU11		1131801070202R01	0	natural channel	0	Soft	private	3	175	100	0	0.333333333	0.01	34	0.002	0.03	50	1.5	Fluvial, tidal
FCRMU12		1131801070202R01	0	natural channel	0	Soft	private	3	177.3	100	0.5	0.333333333	0.01	34	0.002	0.03	50	1.5	Tidal
FCRMU12		1131801070201R03	Goosemoor	raised defence (man-made)	Embankment	Soft	Environment Agency	3	571.2	3.37	0.5	0.333333333	0.01	34	0.002	0.03	50	1.5	Tidal
FCRMU12		1131801070201R02	Goosemoor	raised defence (man-made)	Embankment	Soft	Environment Agency	3	227	3.13	0.5	0.333333333	0.01	34	0.002	0.03	50	1.5	Tidal
FCRMU12		1131801070201R01	UPSTREAM RSPB RESERVE	raised defence (man-made)	Railway Bridge Abutment	Hard	private	3	34.7	3.7	0.5	100	0.01	45	0.05	0.2	20	1.5	Tidal
FCRMU12		1131801070102R02	RSPB RESERVE DOWNSTREAM RAILWAY	raised defence (man-made)	Embankment	Soft	Environment Agency	3	506.6	3.52	0.5	0.333333333	0.01	34	0.002	0.03	50	1.5	Wave, tidal
FCRMU12		1131801070102R01	RIVERSMEET HOUSE TO RSPB RESERVE BANK	maintained channel	Flood Wall	Hard	private	3	415	4.87	0.5	100	0.01	45	0.05	0.2	20	1.5	Wave, tidal
FCRMU12		1131801000302L02	0	raised defence (man-made)	Hump In Road	Natural or breach resilient	local authority	3	86.1	3.5	0.5	100	0.01	45	0.05	100	0	3.5	Wave, tidal
FCRMU12		1131801000302L01	0	maintained channel	0	Natural or breach resilient	local authority	3	245.1	3.2	0.5	0.2	0.01	34	0.05	100	0	3.2	Wave, tidal
FCRMU12		1131801000302L40	0	natural channel	Natural Bank	Natural or breach resilient	local authority	3	210.5	2.9	0.5	100	0.01	34	0.05	100	0	3	Tidal
FCRMU12		1131801000302L39	0	maintained channel	Private Slipway and Storage Yard	Natural or breach resilient	private	3	45.9	3	0.5	100	0.01	20	0.05	100	0	3	Tidal
FCRMU12		1131801000302L29	0	raised defence (man-made)	Wall	Hard	private	3	91.2	4.37	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal



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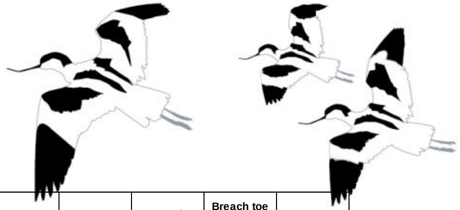
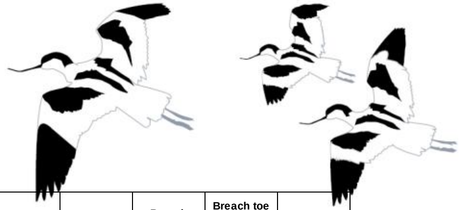
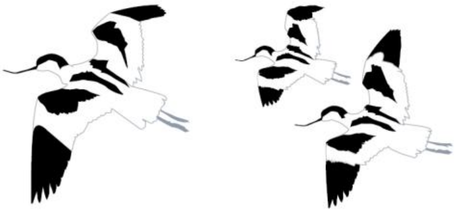
FCRMU12		1131801000302L31	0	maintained channel	Wall	Hard	local authority	3	68.2	3.86	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L32	0	maintained channel	Wall	Hard	private	3	38.9	3.84	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L34	0	raised defence (man-made)	Wall	Natural or breach resilient	private	3	111.6	3.53	0.5	100	0.01	45	0.05	100	0	3.5	Tidal
FCRMU12		1131801000302L35	0	maintained channel	Slipway	Natural or breach resilient	private	3	36.9	3.61	0.5	100	0.01	20	0.05	100	0	3.5	Tidal
FCRMU12		1131801000302L36	0	raised defence (man-made)	Wall	Hard	private	3	95.1	4.02	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L37	0	maintained channel	Wall	Natural or breach resilient	local authority	3	122.8	2.79	0.5	100	0.01	45	0.05	100	0	2.8	Tidal
FCRMU12		1131801000302L38	0	natural channel	Natural Bank	Natural or breach resilient	local authority	3	93.9	3.1	0.5	100	0.01	34	0.05	100	0	3.5	Tidal
FCRMU12		1131801000302L11	0	raised defence (man-made)	Wall Fronting Gardens	Hard	private	3	53.8	4.47	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L15	0	raised defence (man-made)	Wall Fronting Flats	Hard	private	3	27.4	4.22	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L16	0	maintained channel	Wall	Natural or breach resilient	private	3	64.2	3.4	0.5	100	0.01	45	0.05	100	0	3.4	Tidal
FCRMU12		1131801000302L07	0	raised defence (man-made)	Surrounding Wall, With Gate in South West Facing Wall	Natural or breach resilient	local authority	3	145.2	3.32	0.5	100	0.01	45	0.05	100	0	3.5	Tidal
FCRMU12		1131801000302L09	0	raised defence (man-made)	Wall	Hard	private	3	23.1	4.28	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L08	0	maintained channel	Wall	Hard	private	3	28.4	3.83	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L06	0	raised defence (man-made)	Wall With Toe Protection	Hard	local authority	3	37.5	4.54	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L05	0	raised defence (man-made)	Wall With Promenade	Hard	local authority	3	13.6	4.3	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L04	0	raised defence (man-made)	Ramp / Slipway	Natural or breach resilient	local authority	3	31.2	3.5	0.5	100	0.01	20	0.05	100	0	3.5	Tidal
FCRMU12		1131801000302L28	0	maintained channel	Wall / Road	Hard	local authority	3	104.8	4.77	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L27	0	maintained channel	Marina Wall	Hard	local authority	3	46.1	5.03	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L26	0	raised defence (man-made)	Building	Hard	private	3	57.2	3.82	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L25	0	maintained channel	Quay Wall	Natural or breach resilient	local authority	3	198.7	3.4	0.5	100	0.01	45	0.05	100	0	3.4	Tidal
FCRMU12		1131801000302L24	0	raised defence (man-made)	Side Of Building	Natural or breach resilient	private	3	23.4	3.3	0.5	100	0.01	45	0.05	100	0	3.3	Tidal
FCRMU12		1131801000302L23	0	raised defence (man-made)	House / Wall	Natural or breach resilient	private	3	29.4	3.3	0.5	100	0.01	45	0.05	100	0	3.3	Tidal
FCRMU12		1131801000302L22	0	maintained channel	Wall / Road	Natural or breach resilient	local authority	3	43.6	3.3	0.5	100	0.01	45	0.05	100	0	3.3	Tidal
FCRMU12		1131801000302L21	0	raised defence (man-made)	Wall	Hard	private	3	60.8	4.76	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L19	0	raised defence (man-made)	Wall	Hard	private	3	73.9	4.85	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L14	0	maintained channel	Wall	Hard	private	3	40	4.1	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L13	0	raised defence (man-made)	Wall	Hard	private	3	24.7	4.36	0.5	100	0.01	45	0.05	0.2	20	3.5	Tidal
FCRMU12		1131801000302L12	0	maintained channel	Slipway	Natural or breach resilient	private	3	21.5	3.5	0.5	100	0.01	20	0.05	100	0	3.5	Tidal



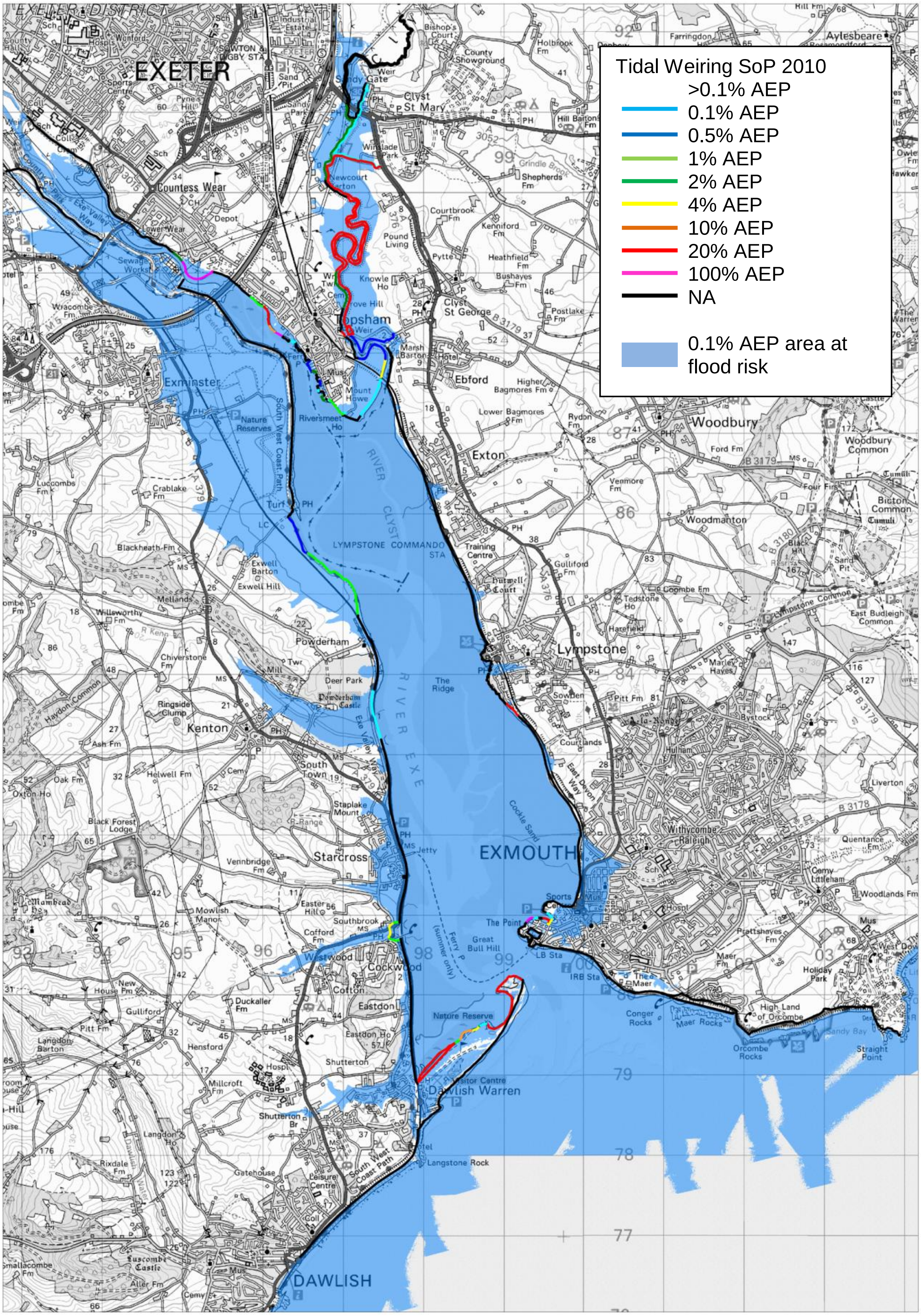
FCRM unit (working from Straight Point anti-clockwise around the estuary and coastline)	Additional sources of data that have been used	NFCDD reference	Asset location	Asset type	Asset description	Analysed Type	Maintainer	Asset condition	Asset length (m)	Crest level used (mAOD)	Toe level (mAOD), from LiDAR	Front face slope (Y:X), generally from LiDAR	Foreshore slope (Y:X), generally from LiDAR	Residual life (years) from SCHO0509BQAT-E-P	Critical damage rate (m3/s/m)	Critical breach rate (m3/s/m)	Breach width (m) based on EA (2004)	Breach toe (mAOD) based on adjacent ground level	HD Processes
FCRMU13		1131801000315L01	From ST James Weir D/S	natural channel	Natural Bank	Natural or breach resilient	private	3	2238.6	4.5	0.5	100	0.01	34	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000309L01	0	natural channel	Natural Bank	Natural or breach resilient	private	3	352.3	4.5	0.5	100	0.01	34	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000305L01	0	natural channel	Natural Bank	Natural or breach resilient	private	3	183	3.3	0.5	100	0.01	34	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000304L01	REED BEDS UPSTREAM M5	natural channel	NATURAL BANK	Natural or breach resilient	Environment Agency	3	435.6	2.2	0.5	100	0.01	34	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000303L03	0	natural channel	0	Natural or breach resilient	private	2	83.8	2.2	0.5	100	0.01	34	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000303L01	D/S END CARAVAN PARK TO BLOCKWORK WALL	raised defence (man-made)	Flood Wall	Natural or breach resilient	private	3	193.8	4.06	0.5	100	0.01	45	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000302L45	0	maintained channel	Walkway	Natural or breach resilient	local authority	3	160.3	5.68	0.5	100	0.01	45	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000302L44	0	maintained channel	Slipway / Platform for Boat Yard	Natural or breach resilient	private	3	47	4	0.5	100	0.01	20	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000302L43	0	maintained channel	Wall With Toe Walkway	Natural or breach resilient	local authority	3	51.4	4.82	0.5	100	0.01	45	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000302L42	0	raised defence (man-made)	Wall / Pathway fronting Gardens	Natural or breach resilient	local authority	3	154.5	4	0.5	100	0.01	45	0.05	100	0	100	Fluvial, tidal
FCRMU13		1131801000302L41	0	raised defence (man-made)	Wall / Pathway fronting Gardens	Natural or breach resilient	local authority	3	212.6	3.25	0.5	100	0.01	45	0.05	100	0	100	Fluvial, tidal
FCRMU14		1131801130118R02	U/S OF B3123 ROAD	raised defence (man-made)	Earth Embankment	Soft	Environment Agency	3	408	7.91	0.5	100	0.01	34	0.002	0.03	50	3.5	Fluvial, tidal
FCRMU14		1131801130117R01	U/S OF RAILWAY LINE	raised defence (man-made)	Earth Embankment	Soft	Environment Agency	3	358.2	7.56	0.5	100	0.01	34	0.002	0.03	50	3.5	Fluvial, tidal
FCRMU14		1131801130104L01	Spillway to Double Locks.	raised defence (man-made)	Canal embankment	Soft	local authority	3	832.4	5.86	0.5	100	0.01	34	0.002	0.03	50	3.5	Tidal
FCRMU14		1131801130106L01	ADJACENT CONC CHANNEL TO FLOOD STORAGE	raised defence (man-made)	Earth Bank	Soft	Environment Agency	3	180.8	5.39	0.5	100	0.01	34	0.002	0.03	50	3.5	Tidal
FCRMU14		1131801130105L01	U/S DOUBLE LOCKS P.H.	raised defence (man-made)	Canal embankment	Soft	Environment Agency	3	364	5.93	0.5	100	0.01	34	0.002	0.03	50	3.5	Tidal
FCRMU14		1131801130102L01	OPPOSITE SPILLWAY	raised defence (man-made)	Earth Embankment With Screeded Stone Rev	Hard	Environment Agency	3	39.9	4.48	0.5	100	0.01	34	0.05	0.2	20	3.5	Tidal
FCRMU14		1131801130103L01	U/S SPILLWAY (RIGHT BANK)	raised defence (man-made)	Canal embankment	Soft	local authority	3	145.4	4.55	0.5	100	0.01	34	0.002	0.03	50	3.5	Tidal
FCRMU14		1131801160106L01	D/S A379	maintained channel	Maintained Channel	Soft	private	3	782	4.5	0.5	100	0.01	34	0.002	0.03	50	3.5	Tidal
FCRMU14		1131801130102R01	U/S OF OUTLET WORKS STR	raised defence (man-made)	Earth Embankment	Natural or breach resilient	Environment Agency	3	343	3.53	0.5	100	0.01	34	0.05	100	0	3.5	Tidal
FCRMU14		1131801000303R01	M5 MOTORWAY TO C'WEAR SEW WKS PERIM FNCE	raised defence (man-made)	Earth Embankment	Soft	local authority	3	588.8	4.3	0.5	100	0.01	34	0.002	0.03	50	3.5	Tidal
FCRMU14	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	1131801000302R01	U/S TURF LOCKS	raised defence (man-made)	Canal Embankment	Soft	local authority	3	3218.8	4.14	1	100	0.01	34	0.002	0.03	50	3.5	Wave, tidal
FCRMU14	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351009C01	0	coastal protection (natural)	Natural Cliff (check elements)	Hard	private	3	528.7	3.4	1	100	0.01	NA	0.05	0.2	20	1	Wave, tidal
FCRMU14	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351009C02	0	coastal protection (natural)	Natural Cliff (check elements)	Hard	private	3	1098.9	3.2	1	100	0.01	NA	0.05	0.2	20	1	Wave, tidal
FCRMU14	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351009C03	Powderham	coastal protection (man-made)	Wall + Revetment	Hard	private	3	350.2	3.8	1	100	0.01	45	0.05	0.2	20	1	Wave, tidal



FCRM unit (working from Straight Point anti-clockwise around the estuary and coastline)	Additional sources of data that have been used	NFCDD reference	Asset location	Asset type	Asset description	Analysed Type	Maintainer	Asset condition	Asset length (m)	Crest level used (mAOD)	Toe level (mAOD), from LiDAR	Front face slope (Y:X), generally from LiDAR	Foreshore slope (Y:X), generally from LiDAR	Residual life (years) from SCHO0509B QAT-E-P	Critical damage rate (m3/s/m)	Critical breach rate (m3/s/m)	Breach width (m) based on EA (2004)	Breach toe (mAOD) based on adjacent ground level	HD Processes
FCRMU15	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	690/1902/01	SX97368442, SX97438419	coastal protection (man-made)	Wall	Hard	private	0	300	4.4	1	100	0.01	45	0.05	0.2	20	1.5	Wave, tidal
FCRMU15	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351009C05	Starcross Yacht Club	coastal protection (man-made)	Wall	Hard	private	3	395.3	4.3	1	100	0.01	45	0.05	0.2	20	1.5	Wave, tidal
FCRMU15	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351009C06	Powderham Castle	coastal protection (man-made)	Wall	Hard	private	3	627.7	3.5	1	100	0.01	45	0.05	0.2	20	1.5	Wave, tidal
FCRMU15	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351009C07	Powderham Castle	coastal protection (man-made)	Wall	Hard	private	3	630.1	3.8	1	100	0.01	45	0.05	0.2	20	1.5	Wave, tidal
FCRMU15	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351010C01	STARCROSS	sea defence (man-made)	Railway embankment	Hard	private	3	219	3.7	1	100	0.01	20	0.05	0.2	20	1.5	Wave, tidal
FCRMU16	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351010C01	STARCROSS	sea defence (man-made)	Railway embankment	Hard	private	3	943.3	3.5	1	100	0.01	20	0.05	0.2	20	2	Wave, tidal
FCRMU16	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.9 indicate no level	113FAS3351011C01	STARCROSS	sea defence (man-made)	Railway embankment	Hard	private	3	613.7	3.8	1	100	0.01	20	0.05	0.2	20	2	Wave, tidal
FCRMU16		113FAS3351011C04	COOKWOOD	sea defence (man-made)	masonry wall	Hard	local authority	3	132.8	3.06	0.5	100	0.01	20	0.05	0.2	20	2	Tidal
FCRMU16		113FAS3351011C05	COCKWOOD	sea defence (man-made)	masonry wall	Hard	local authority	3	105.9	3.1	0.5	100	0.01	20	0.05	0.2	20	2	Tidal
FCRMU16		113FAS3351011C03	0	coastal protection (man-made)	0	Hard	private	3	83.9	3.04	0.5	100	0.01	20	0.05	0.2	20	2	Tidal
FCRMU16		113FAS3351011C02	COOKWOOD HARBOUR	sea defence (man-made)	embankment	Soft	local authority	3	66.1	3.11	0.5	0.544502618	0.01	34	0.002	0.03	50	2	Wave, tidal
FCRMU16		113FAS3351011C06	COOKWOOD	sea defence (man-made)	embankment	Soft	private	3	67.5	3.07	0.5	0.544502618	0.01	34	0.002	0.03	50	2	Wave, tidal
FCRMU16	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351012C01	COOKWOOD - DAWLISH	sea defence (man-made)	Railway embankment	Hard	private	3	218	4.41	0.5	0.544502618	0.01	20	0.05	0.2	20	2	Wave, tidal
FCRMU17	Management of sea wall and estuary defences, Network Rail. Section 3.1 and 10.10 indicate track level of 4.41	113FAS3351012C01	COOKWOOD - DAWLISH	sea defence (man-made)	Railway embankment	Hard	private	3	1613.3	4.41	0.5	0.544502618	0.01	20	0.05	0.2	20	2.3	Wave, tidal
FCRMU17		113FAS3351013C01	DAWLISH WARREN	sea defence (natural)	Embankment	Soft	private	3	700.1	2.84	1.5	0.15	0.02	34	0.002	0.03	50	2.3	Wave, tidal
FCRMU17		113FAS3351013C02	DAWLISH WARREN	sea defence (man-made)	gabions	Hard	private	3	91.1	3.07	1.5	0.15	0.02	18	0.05	0.2	20	3	Wave, tidal
FCRMU17		113FAS3351013C03	DAWLISH WARREN	sea defence (man-made)	wall	Natural or breach resilient	private	3	25.6	2.96	1.5	0.15	0.02	18	0.05	100	0	3	Wave, tidal
FCRMU17		113FAS3351013C04	DAWLISH WARREN	sea defence (man-made)	gabion wall	Natural or breach resilient	private	3	175.7	2.95	1.5	0.15	0.02	18	0.05	100	0	3	Wave, tidal
FCRMU17		113FAS3351013C05	DAWLISH WARREN	sea defence (man-made)	wall	Natural or breach resilient	private	3	122.5	3	1.5	0.15	0.02	18	0.05	100	0	3	Wave, tidal
FCRMU17		113FAS3351013C06	DAWLISH WARREN	sea defence (man-made)	wall	Hard	private	3	18	3.2	1.5	0.15	0.02	18	0.05	0.2	20	3	Wave, tidal
FCRMU17		113FAS3351013C07	DAWLISH WARREN	sea defence (man-made)	gabion revetment	Hard	private	3	79.9	3.36	1.5	0.15	0.02	18	0.05	0.2	20	3	Wave, tidal
FCRMU17		113FAS3351013C09	DAWLISH WARREN	sea defence (man-made)	Bank	Natural or breach resilient	private	3	1265.3	2.82	1.5	0.15	0.02	34	0.05	100	0	3	Wave, tidal
FCRMU17		113FAS3351014C01	DAWLISH WARREN	sea defence (natural)	Dunes	Soft	Environment Agency	3	1634.8	4.5	2.5	0.2	0.05	15	0.002	0.03	50	3	Wave, tidal
FCRMU17		113FBS3351501C01	0	coastal protection (natural)	Natural Cliff	Natural	private	3	103.1	100	0.5	100	0.05	100	0.05	0.2	50	3	Wave, tidal
FCRMU17		113FAS3351015C02	DAWLISH WARREN	sea defence (man-made)	Rock Armour	Hard	Environment Agency	3	281.5	5.72	0	0.2	0.05	34	0.05	0.2	20	3	Wave, tidal
FCRMU17		113FAS3351015C01	DAWLISH WARREN	sea defence (man-made)	concrete wall	Hard	Environment Agency	3	413.8	5.79	0	0.2	0.05	45	0.05	0.2	20	3	Wave, tidal
FCRMU17		113FAS3351014C02	DAWLISH WARREN	sea defence (natural)	Embankment	Soft	Environment Agency	3	315.6	5.74	0	0.2	0.01	34	0.002	0.03	50	3	Wave, tidal
FCRMU18	Management of sea wall and estuary defences, Network Rail. Section 3.2 and 10.1 indicate walkway level of 5.82	113FBS3351501C03	Dawlish	coastal protection (man-made)	Recurved Wall + Splash Wall + Revetment + Groynes	Natural or breach resilient	local authority	2	578.8	5.82	2	0.5	0.1	20	0.05	100	0	100	Wave, tidal
FCRMU18	Management of sea wall and estuary defences, Network Rail. Section 3.2 and 10.1 indicate track level of 6.08	113FBS3351501C02	North Dawlish	coastal protection (man-made)	Recurved Wall + Groynes + Revetment + Splash Wall	Natural or breach resilient	local authority	2	1266.1	6.08	1.5	0.5	0.1	20	0.05	100	0	100	Wave, tidal



Appendix D : Performance Assessment Results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0.1% AEP
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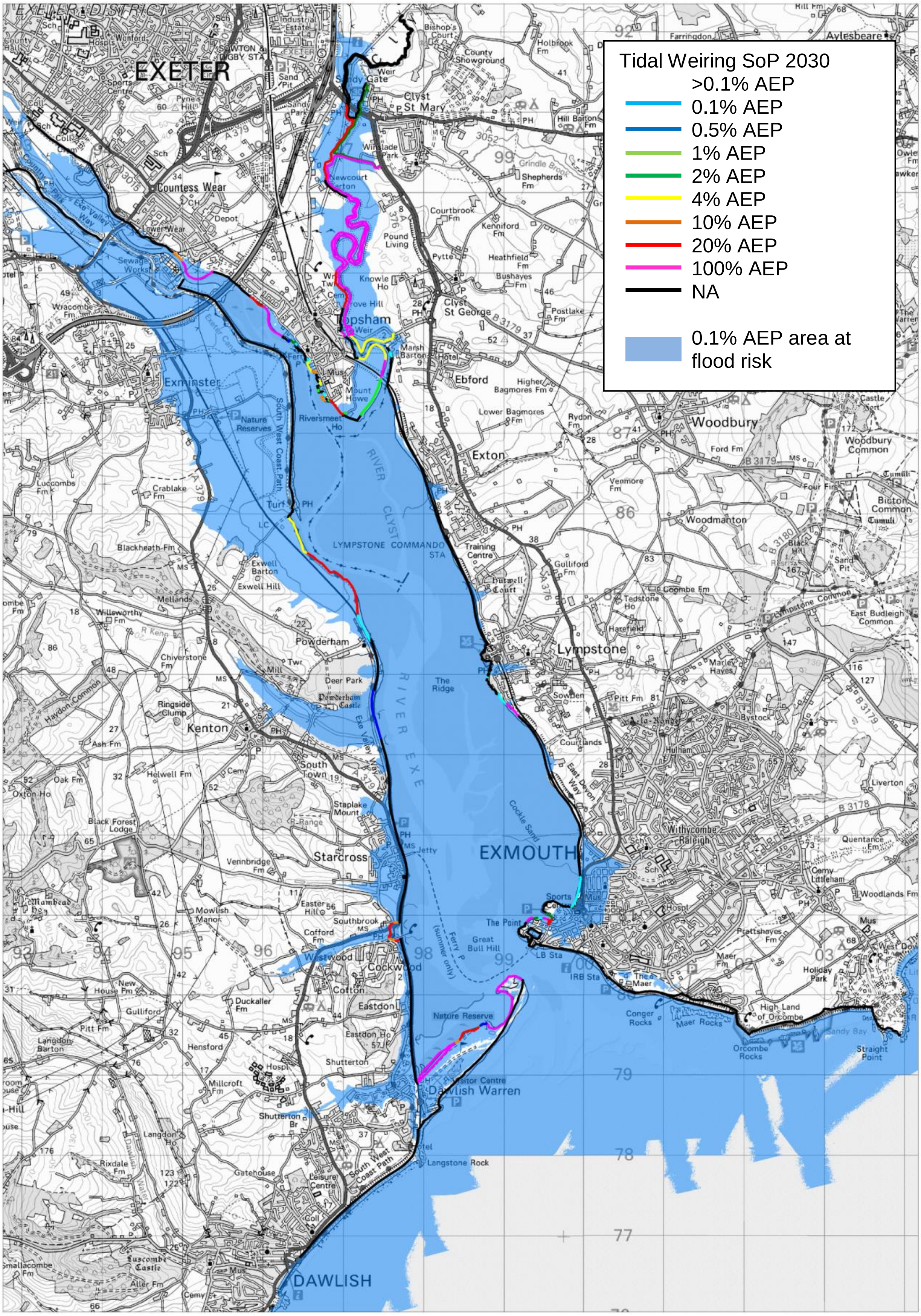
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Lympstone
EXMOUTH
Starcross
Cockwood
Dawlish Warren
DAWLISH
RIVER EXE
RIVER CLYST
Woodbury
Exton
Kenton
Powderham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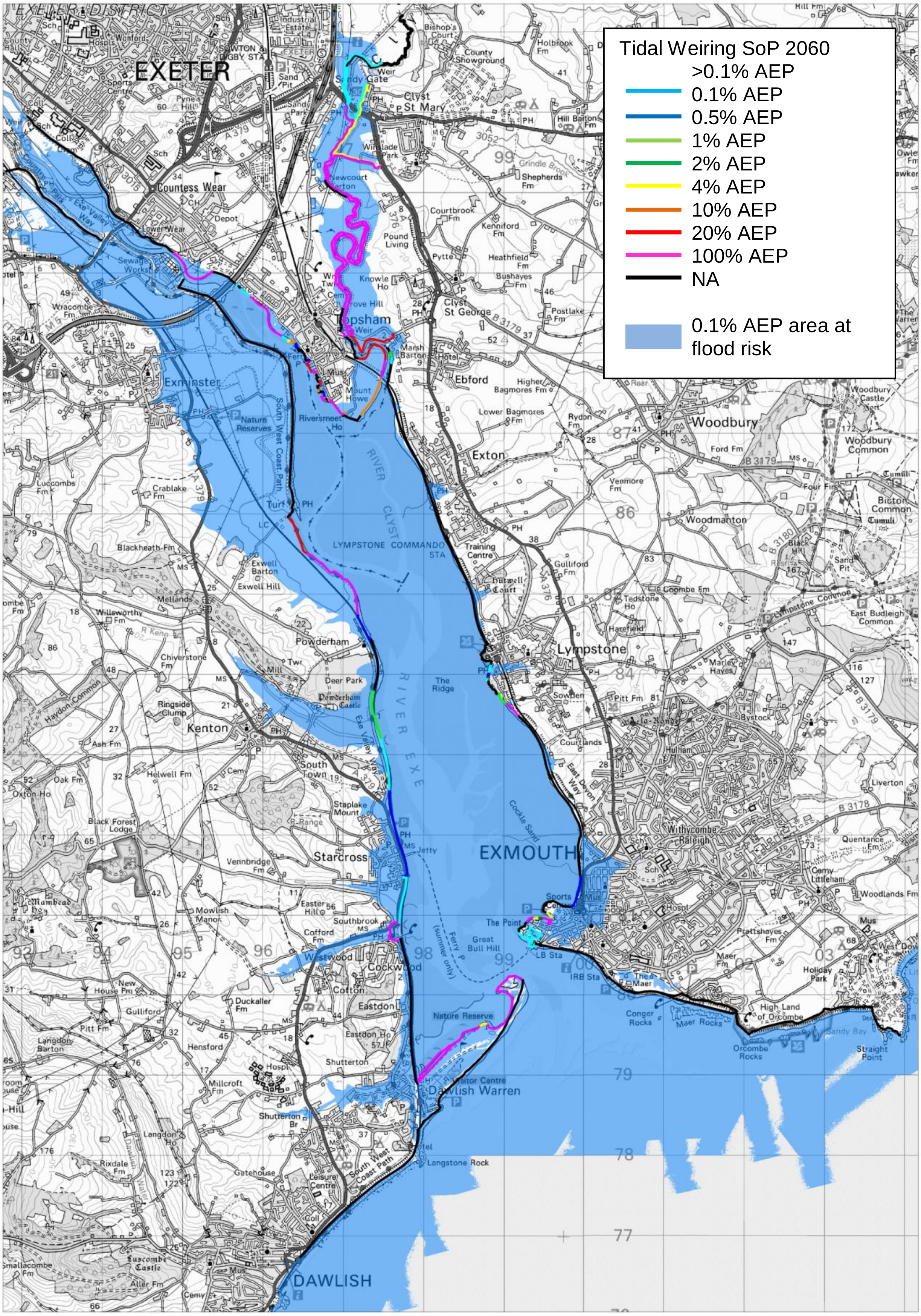
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Powderham
Kenton
Starcross
Cockwood
Dawlish Warren
DAWLISH
Exton
Lympstone
EXMOUTH
RIVER EXE
RIVER CLYST
Woodbury
Ebford
Clyst St Mary
Clyst St George



Tidal Weiring SoP 2060
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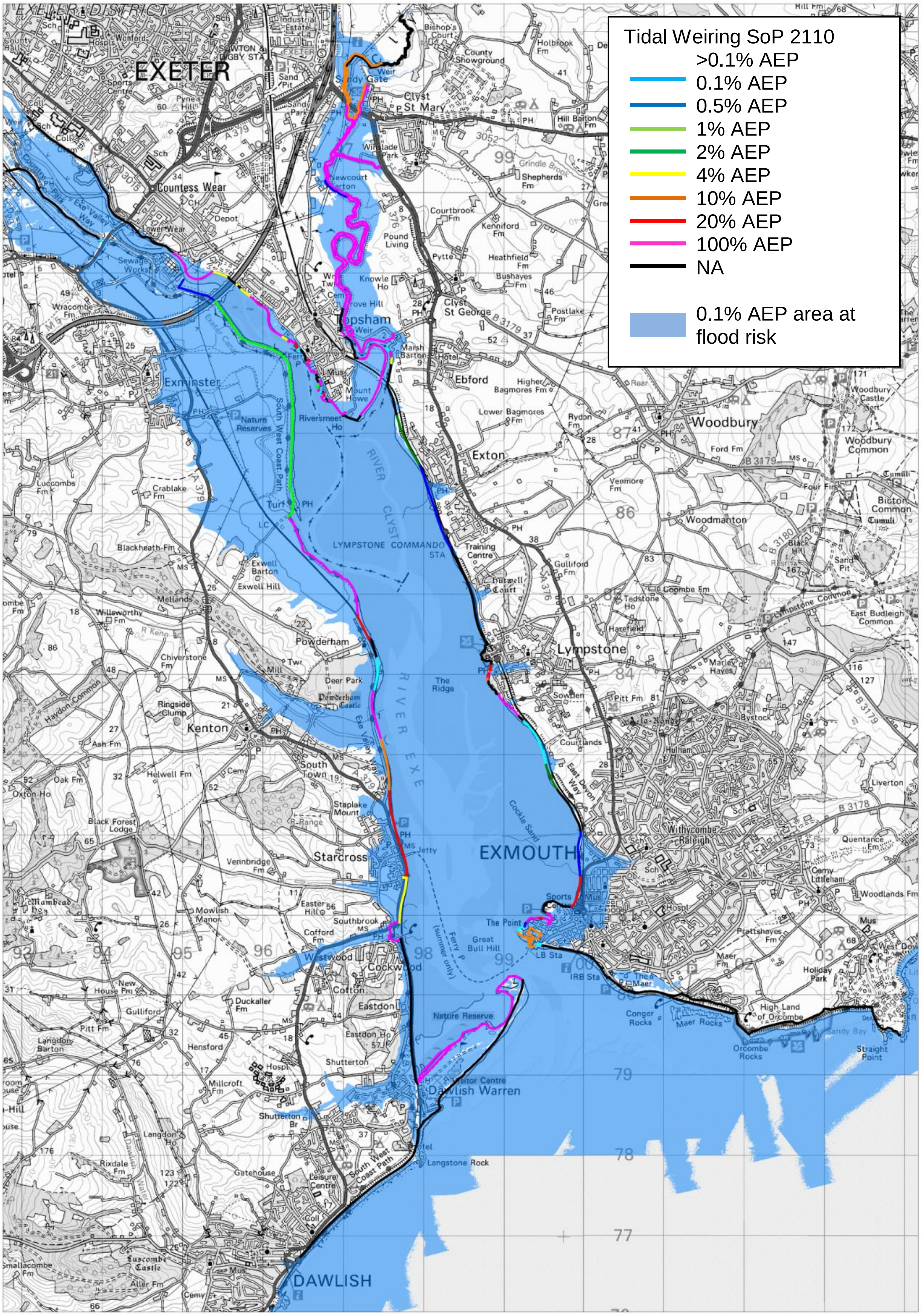
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Exton
Lympstone
Powderham
Kenton
Starcross
EXMOUTH
Cockwood
Dawlish Warren
DAWLISH
RIVER EXE
RIVER CLYST


Tidal Weiring SoP 2110
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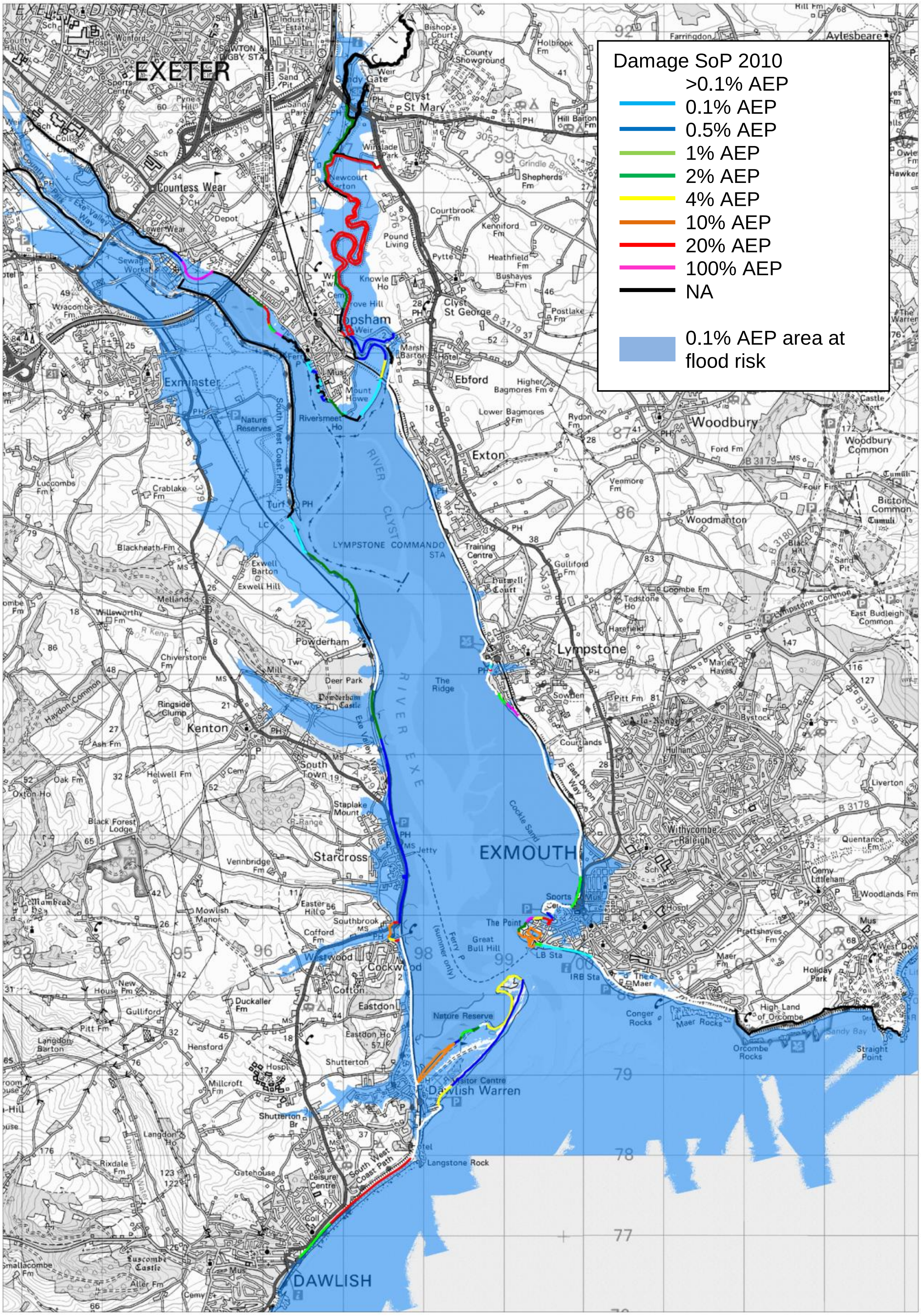
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Exton
Lympstone
Powderham
Kenton
Starcross
EXMOUTH
Dawlish Warren
DAWLISH
RIVER EXE
RIVER CLYST
Woodbury
Clyst St Mary
Ebford
Cockwood
Langstone Rock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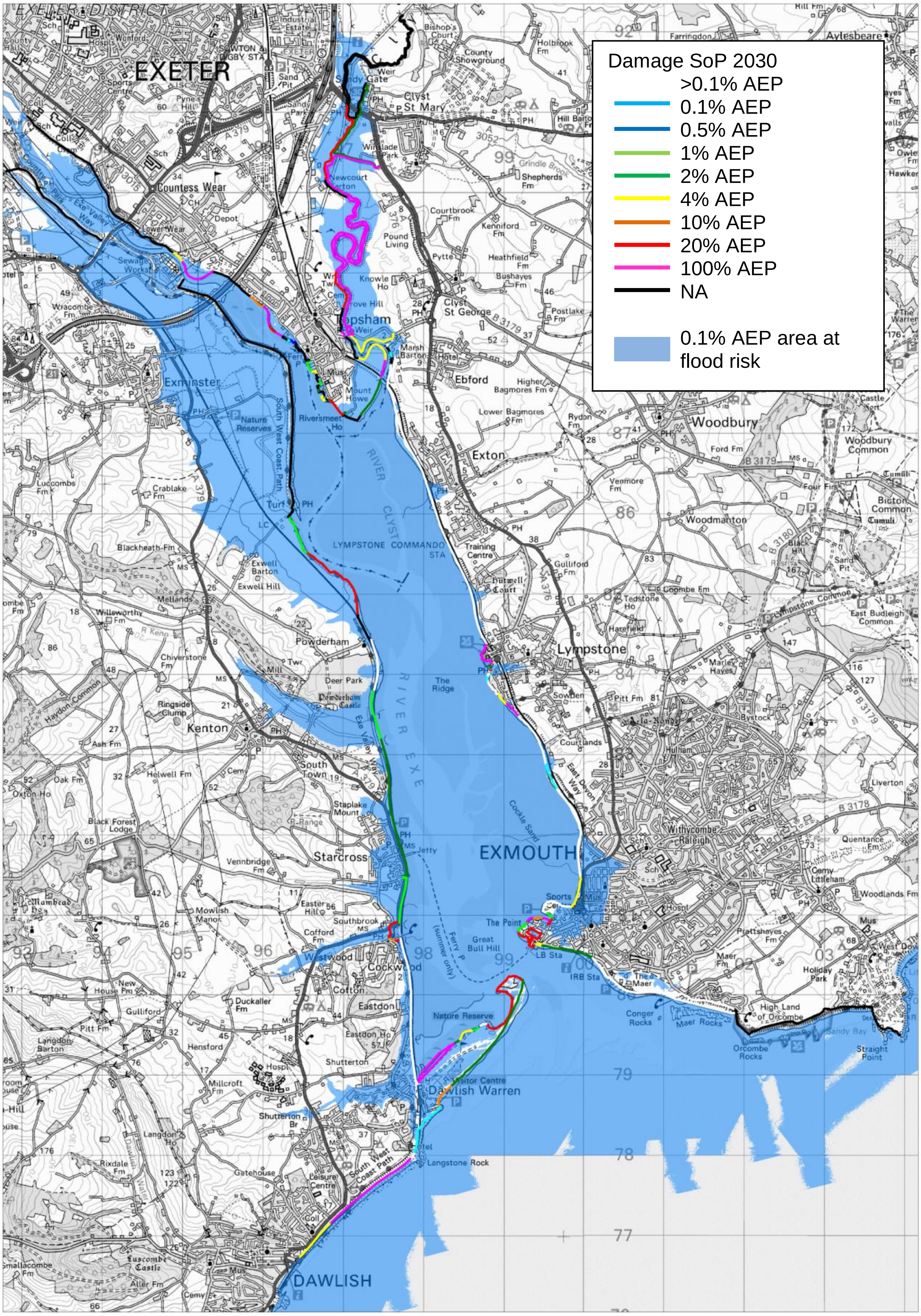
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Woodbury
Exton
Lympstone
Powderham
Kenton
Starcross
EXMOUTH
Dawlish Warren
DAWLISH
RIVER EXE


Damage SoP 2030
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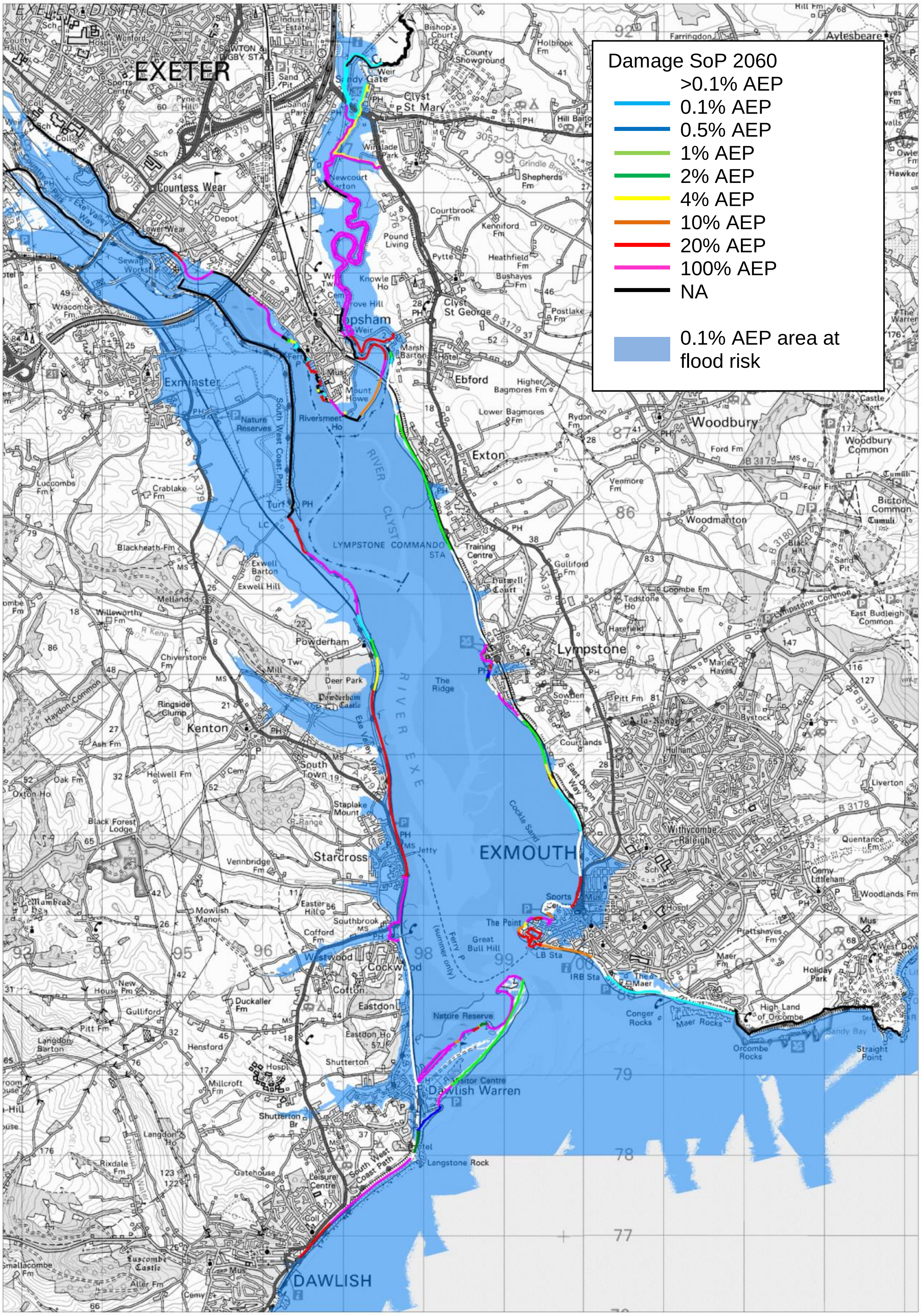
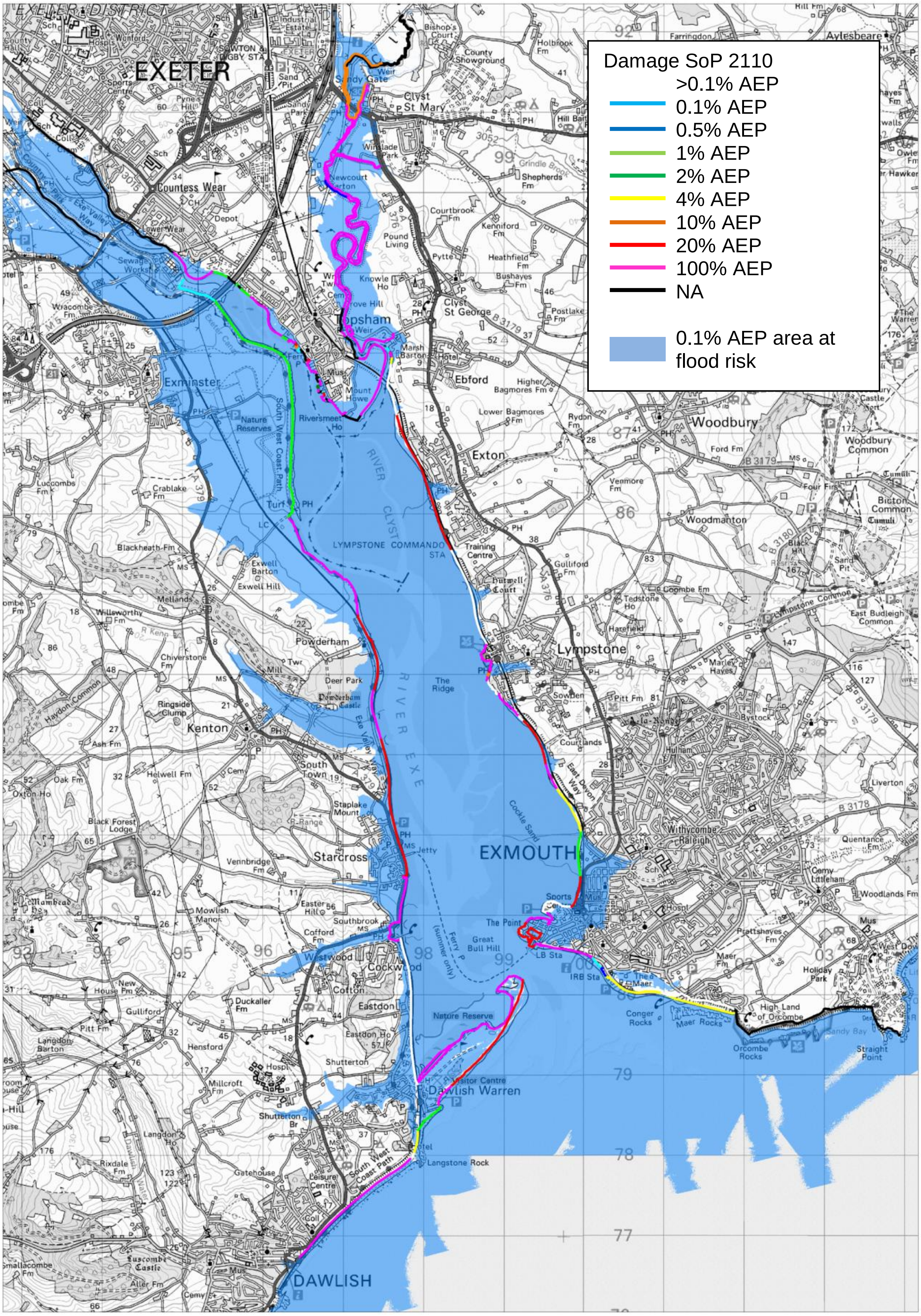
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Exton
Lympstone
RIVER EXE
Powderham
Kenton
Starcross
EXMOUTH
Cockwood
Dawlish Warren
DAWLISH
Woodbury


Damage SoP 2060
>0.1% AEP
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Topsham
Exminster
Exton
Lympstone
EXMOUTH
Starcross
Dawlish Warren
DAWLISH
RIVER EXE


Damage SoP 2110
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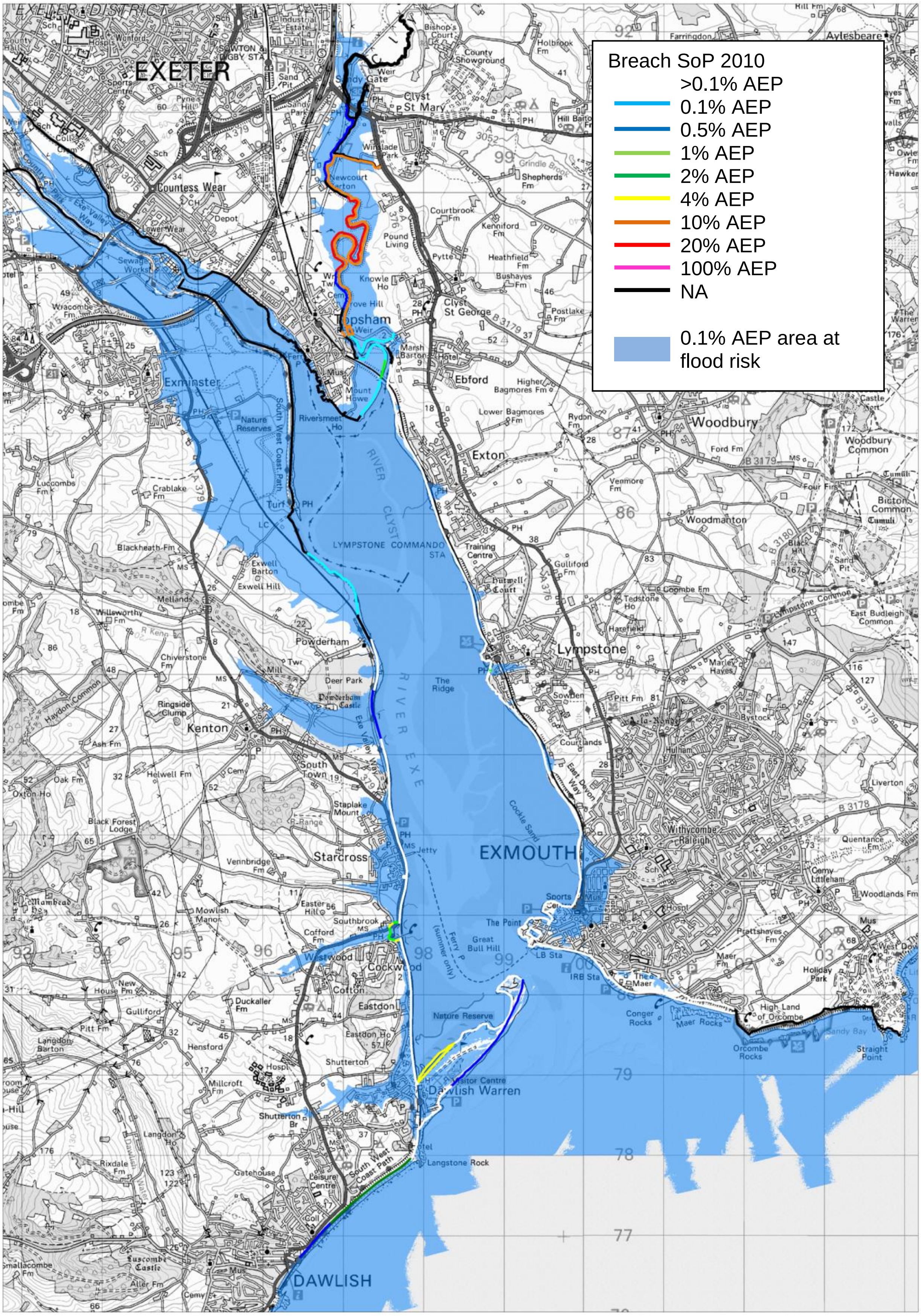
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Ebford
Exton
Lympstone
Powderham
Kenton
Starcross
EXMOUTH
Cockwood
Dawlish Warren
DAWLISH
RIVER EXE
RIVER CLYST


Breach SoP 2010
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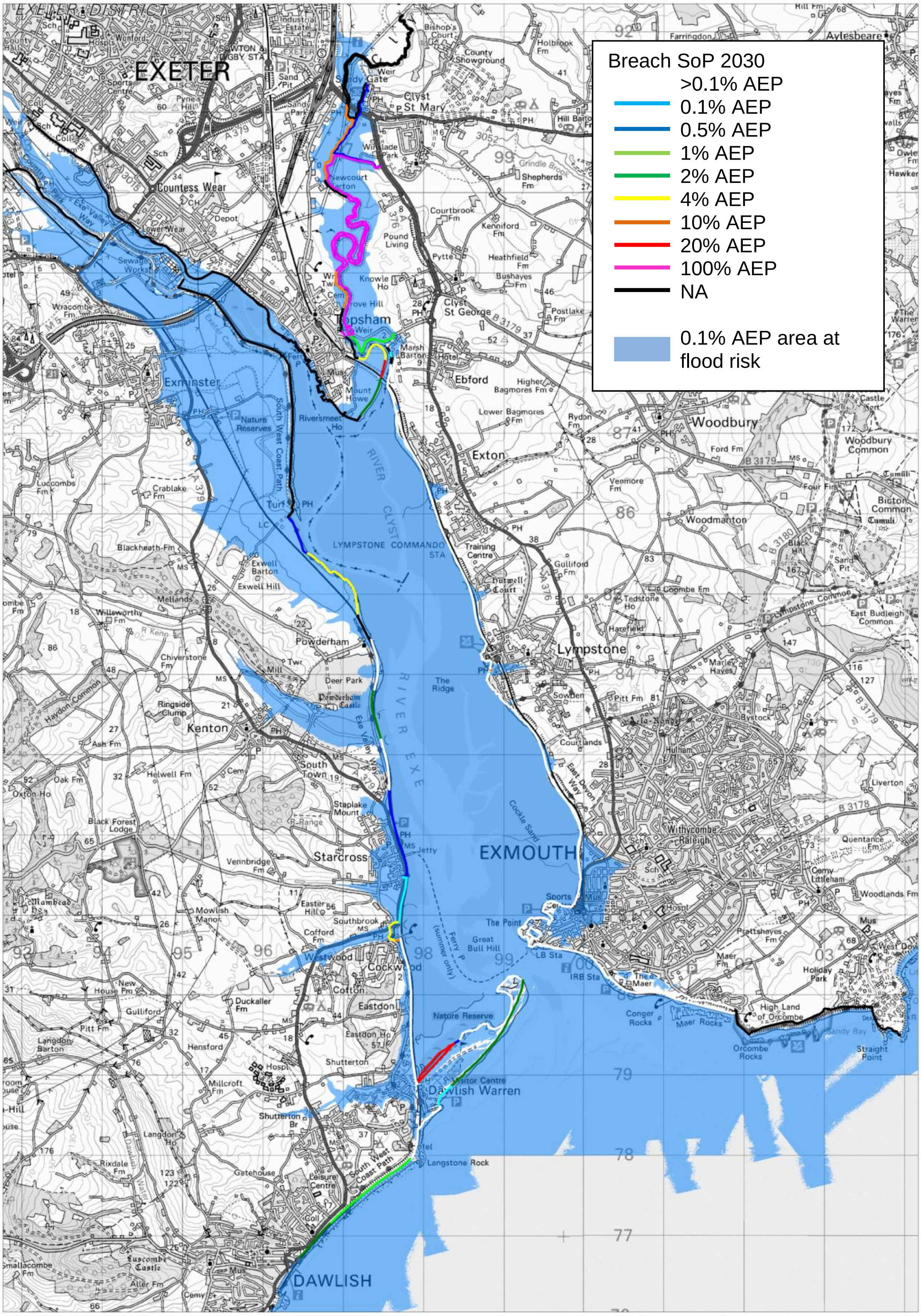
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Ebford
Exton
Lympstone
Powderham
Kenton
Starcross
EXMOUTH
Cockwood
Dawlish Warren
DAWLISH
RIVER EXE
RIVER CLYST
Woodbury
Withycombe Raleigh
LYMPSTONE COMMANDO STA
Cockle Sand
Langstone Rock
Orcombe Rocks


Breach SoP 2030
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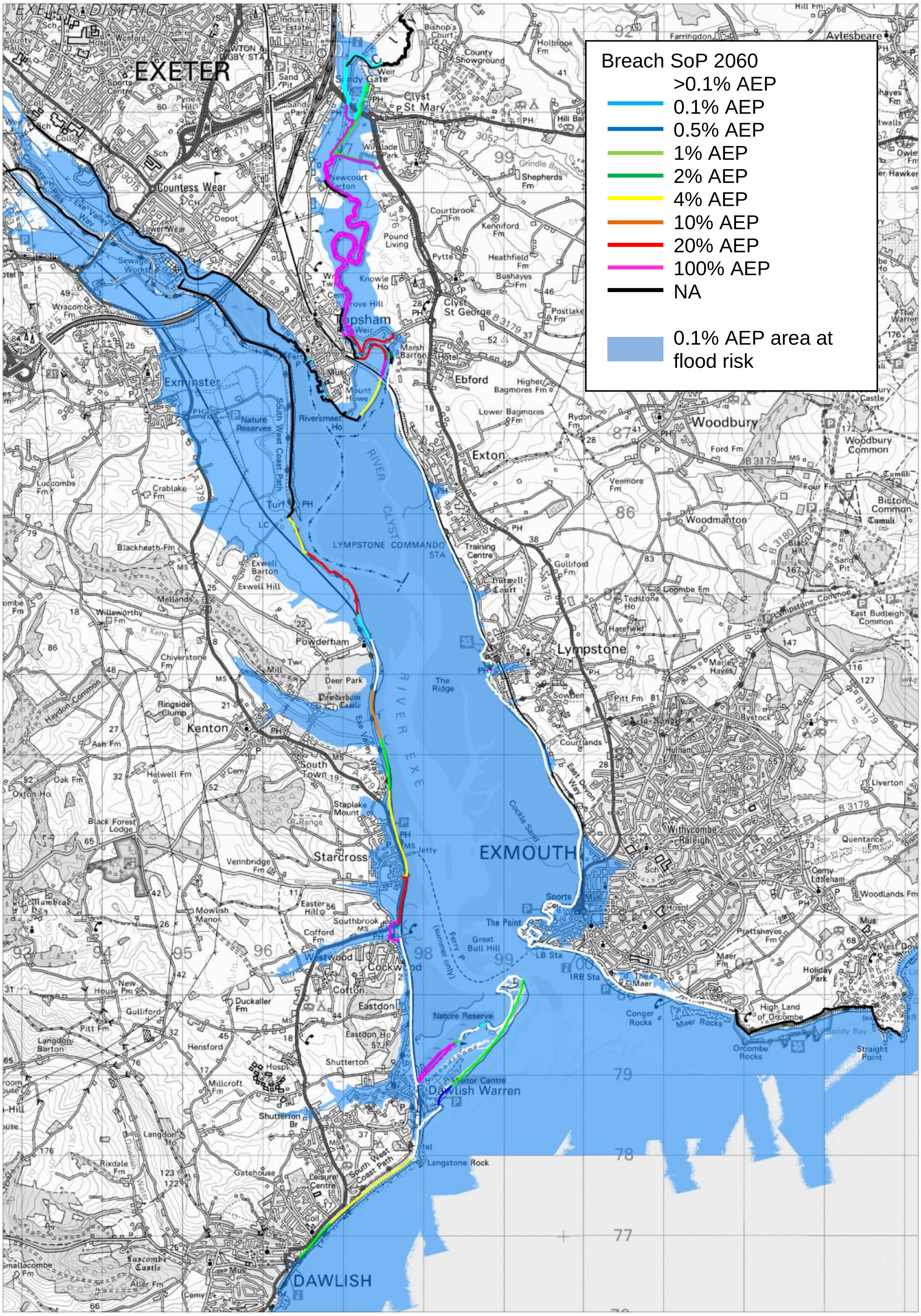
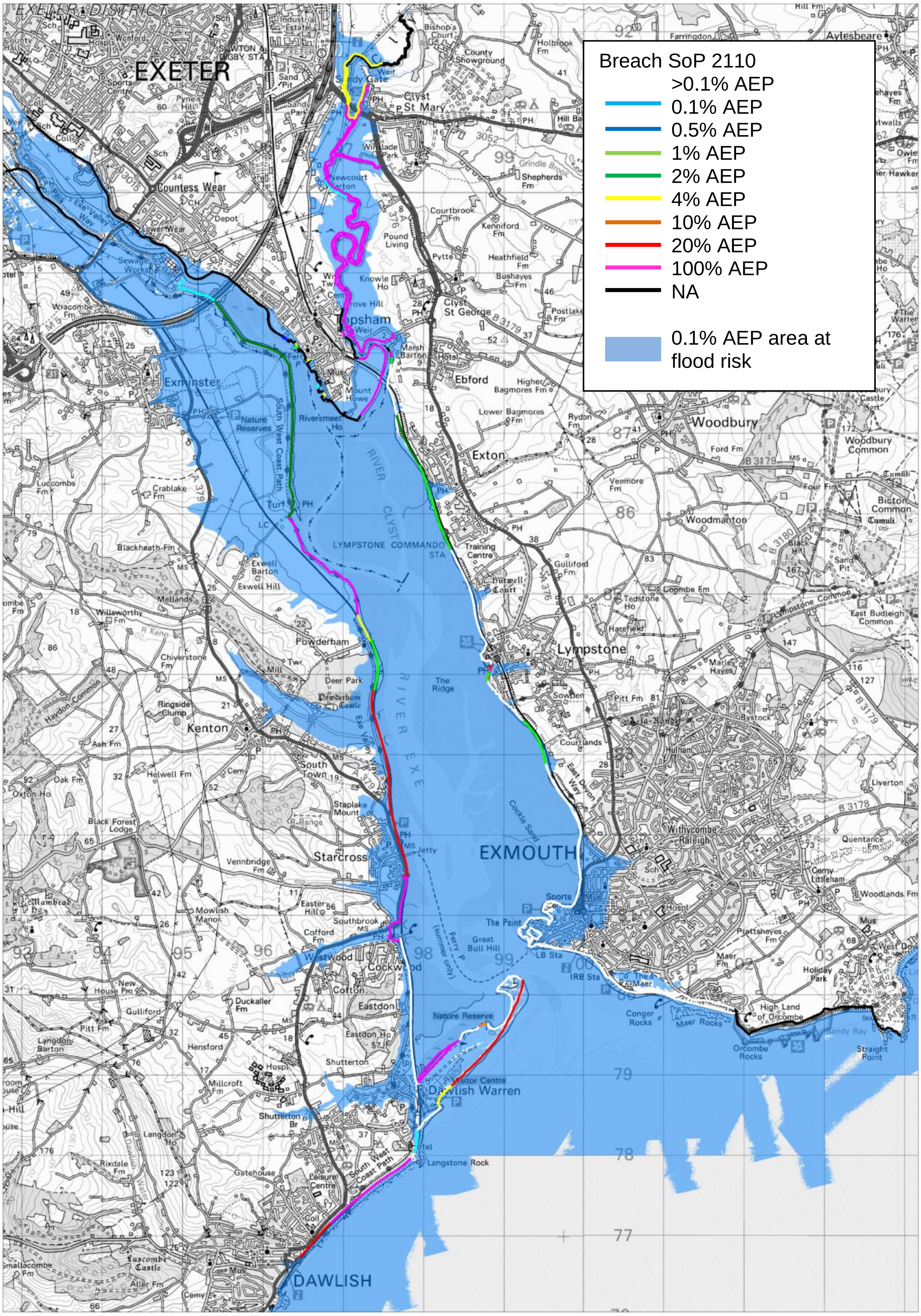
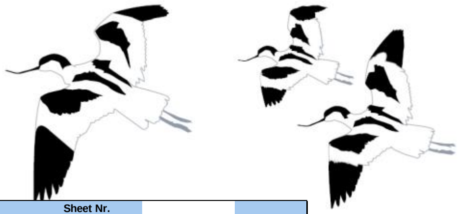
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Topsham
Exminster
Ebford
Exton
Woodbury
Lympstone
Powderham
Kenton
Starcross
EXMOUTH
Cockwood
Dawlish Warren
DAWLISH
RIVER EXE
RIVER CLYST
LYMPSTONE COMMANDO STA


Breach SoP 2060
>0.1% AEP
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Clyst St Mary
Clyst St George
Ebford
Exton
Woodbury
Lympstone
Powderham
Kenton
Starcross
EXMOUTH
Cockwood
Dawlish Warren
DAWLISH
RIVER EXE
RIVER CLYST

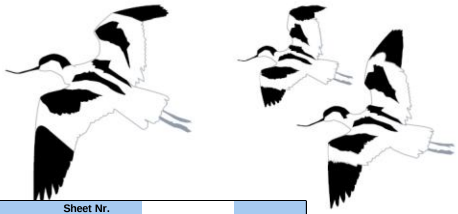

Breach SoP 2110
>0.1% AEP
0.1% AEP
0.5% AEP
1% AEP
2% AEP
4% AEP
10% AEP
20% AEP
100% AEP
NA
0.1% AEP area at flood risk
EXETER
Countess Wear
Topsham
Exminster
Exton
Lympstone
Powderham
Kenton
Starcross
EXMOUTH
Cockwood
Dawlish Warren
DAWLISH
RIVER EXE
RIVER CLYST
Woodbury
Clyst St Mary
Clyst St George
Ebford
Withycombe Raleigh
Langstone Rock
Orcombe Rocks
Straight Point

Appendix E : Socio-Economic Assessment Results



								Sheet Nr.	
Client/Authority									
Environment Agency									
Project name		**Option:**							
Exe Estuary Strategy - FCRMU01		Do nothing							
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**			
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**			
Scaling factor (e.g. £m, £k, £)	£k	Residential property	0	0	0	0	**£k**	Prepared (date)	03/01/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	0	0	**£k**	Printed	18/12/2012
		Temp Acc	0	0	0	0	**£k**	Prepared by	AMC
		Traffic related	0	0	0	0	**£k**	Checked by	PJC
		Emergency services	0	0	0	0	**£k**	Checked date	16/01/2012
		Agricultural	0	0	0	0	**£k**		
			0	0	0	0			
		PV Total Damage	15				**£k**		
		Total Write-off	290				**£k**		

		AAD Post Breach					**£ 290**	**£ -**	**£ 15**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		-	**-**	**-**	**-**	**-**			
0	1.000	-	-	-	-	-			0
1	0.966	-	-	-	-	-			0
2	0.934	-	-	-	-	-			0
3	0.902	-	-	-	-	-			0
4	0.871	-	-	-	-	-			0
5	0.842	-	-	-	-	-			0
6	0.814	-	-	-	-	-			0
7	0.786	-	-	-	-	-			0
8	0.759	-	-	-	-	-			0
9	0.734	-	-	-	-	-			0
10	0.709	-	-	-	-	-			0
11	0.685	-	-	-	-	-			0
12	0.662	-	-	-	-	-			0
13	0.639	-	-	-	-	-			0
14	0.618	-	-	-	-	-			0
15	0.597	-	-	-	-	-			0
16	0.577	-	-	-	-	-			0
17	0.557	-	-	-	-	-			0
18	0.538	-	-	-	-	-			0
19	0.520	-	-	-	-	-			0
20	0.503	-	-	-	-	-			0
21	0.486	-	-	-	-	-			0
22	0.469	-	-	-	-	-			0
23	0.453	-	-	-	-	-			0
24	0.438	-	-	-	-	-			0
25	0.423	-	-	-	-	-			0
26	0.409	-	-	-	-	-			0
27	0.395	-	-	-	-	-			0
28	0.382	-	-	-	-	-			0
29	0.369	-	-	-	-	-			0
30	0.356	-	-	-	-	-			0
31	0.346	-	-	-	-	-			0
32	0.336	-	-	-	-	-			0
33	0.326	-	-	-	-	-			0
34	0.317	-	-	-	-	-			0
35	0.307	-	-	-	-	-			0
36	0.298	-	-	-	-	-			0
37	0.290	-	-	-	-	-			0
38	0.281	-	-	-	-	-			0
39	0.273	-	-	-	-	-			0
40	0.265	-	-	-	-	-			0
41	0.257	-	-	-	-	-			0
42	0.250	-	-	-	-	-			0
43	0.243	-	-	-	-	-			0
44	0.236	-	-	-	-	-			0
45	0.229	-	-	-	-	-			0
46	0.222	-	-	-	-	-			0
47	0.216	-	-	-	-	-			0
48	0.209	-	-	-	-	-			0
49	0.203	-	-	-	-	-			0
50	0.197	-	-	-	-	-			0
51	0.192	-	-	-	-	-			0
52	0.186	-	-	-	-	-			0
53	0.181	-	-	-	-	-			0
54	0.175	-	-	-	-	-			0
55	0.170	-	-	-	-	-			0
56	0.165	-	-	-	-	-			0
57	0.160	-	-	-	-	-			0
58	0.156	-	-	-	-	-			0
59	0.151	-	-	-	-	-			0
60	0.147	-	-	-	-	-			0
61	0.143	-	-	-	-	-			0
62	0.138	-	-	-	-	-			0
63	0.134	-	-	-	-	-			0
64	0.130	-	-	-	-	-			0
65	0.127	-	-	-	-	-			0
66	0.123	-	-	-	-	-			0
67	0.119	-	-	-	-	-			0
68	0.116	-	-	-	-	-			0
69	0.112	-	-	-	-	-			0
70	0.109	-	-	-	-	-			0
71	0.106	-	-	-	-	-			0
72	0.103	-	-	-	-	-			0
73	0.100	-	-	-	-	-			0
74	0.097	-	-	-	-	-			0
75	0.094	-	-	-	-	-			0
76	0.092	-	-	-	-	-			0
77	0.090	-	-	-	-	-			0
78	0.087	-	-	-	-	-			0
79	0.085	-	-	-	-	-			0
80	0.083	-	-	-	-	-			0
81	0.081	-	-	-	-	-			0
82	0.079	-	-	-	-	-			0
83	0.077	-	-	-	-	-			0
84	0.075	-	-	-	-	-			0
85	0.074	-	-	-	-	-			0
86	0.072	-	-	-	-	-			0
87	0.070	-	-	-	-	-			0
88	0.068	-	-	-	-	-			0
89	0.067	-	-	-	-	-			0
90	0.065	-	-	-	-	-			0
91	0.063	-	-	-	-	-			0
92	0.062	-	-	-	-	-			0
93	0.060	-	-	-	-	-			0
94	0.059	-	-	-	-	-			0
95	0.057	-	-	-	-	-			0
96	0.056	-	-	-	-	-			0
97	0.055	-	-	-	-	-			0
98	0.053	-	-	-	-	-			0
99	0.052	-	-	-	-	-	290		15
		0.00	0.00	0.00	0.00	0.00			15.11



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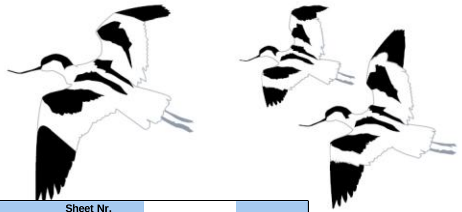
Client/Authority								
Environment Agency								
Project name		**Option:**						
Exe Estuary Strategy - FCRMU02		Do nothing						
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**		
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**		
Scaling factor (e.g. £m, £k, £)	£k	Residential property	0	0	0	0 **£k**	Prepared (date)	20/10/2011
Discount rate	Variable	Ind/commercial (direct)	0	0	0	2 **£k**	Printed	18/12/2012
		Temp Acc	0	0	0	0 **£k**	Prepared by	AMC
		Traffic related	0	0	0	0 **£k**	Checked by	PJC
		Emergency services	0	0	0	0 **£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0 **£k**		
			0	0	0	2		
		PV Total Damage	4			**£k**		
		Total Write-off	-			**£k**		

		AAD Post Breach					**£ -**	**£ -**	**£ 4**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		-	**3**	**-**	**-**	**0**			
0	1.000	-	-	-	-	-	-		0
1	0.966	-	-	-	-	-			0
2	0.934	-	-	-	-	-			0
3	0.902	-	-	-	-	-			0
4	0.871	-	-	-	-	-			0
5	0.842	-	-	-	-	-			0
6	0.814	-	-	-	-	-			0
7	0.786	-	-	-	-	-			0
8	0.759	-	-	-	-	-			0
9	0.734	-	-	-	-	-			0
10	0.709	-	-	-	-	-			0
11	0.685	-	-	-	-	-			0
12	0.662	-	-	-	-	-			0
13	0.639	-	-	-	-	-			0
14	0.618	-	-	-	-	-			0
15	0.597	-	-	-	-	-			0
16	0.577	-	-	-	-	-			0
17	0.557	-	-	-	-	-			0
18	0.538	-	-	-	-	-			0
19	0.520	-	-	-	-	-			0
20	0.503	-	-	-	-	-			0
21	0.486	-	-	-	-	-			0
22	0.469	-	-	-	-	-			0
23	0.453	-	-	-	-	-			0
24	0.438	-	-	-	-	-			0
25	0.423	-	-	-	-	-			0
26	0.409	-	-	-	-	-			0
27	0.395	-	-	-	-	-			0
28	0.382	-	-	-	-	-			0
29	0.369	-	-	-	-	-			0
30	0.356	-	-	-	-	-			0
31	0.346	-	-	-	-	-			0
32	0.336	-	-	-	-	-			0
33	0.326	-	-	-	-	-			0
34	0.317	-	-	-	-	-			0
35	0.307	-	-	-	-	-			0
36	0.298	-	-	-	-	-			0
37	0.290	-	-	-	-	-			0
38	0.281	-	-	-	-	-			0
39	0.273	-	-	-	-	-			0
40	0.265	-	-	-	-	-			0
41	0.257	-	-	-	-	-			0
42	0.250	-	-	-	-	-			0
43	0.243	-	-	-	-	-			0
44	0.236	-	-	-	-	-			0
45	0.229	-	-	-	-	-			0
46	0.222	-	-	-	-	-			0
47	0.216	-	-	-	-	-			0
48	0.209	-	-	-	-	-			0
49	0.203	-	-	-	-	-			0
50	0.197	-	0	-	-	0			0
51	0.192	-	0	-	-	0			0
52	0.186	-	0	-	-	0			0
53	0.181	-	0	-	-	0			0
54	0.175	-	0	-	-	0			0
55	0.170	-	0	-	-	0			0
56	0.165	-	0	-	-	0			0
57	0.160	-	0	-	-	0			0
58	0.156	-	0	-	-	0			0
59	0.151	-	0	-	-	0			0
60	0.147	-	0	-	-	0			0
61	0.143	-	0	-	-	0			0
62	0.138	-	0	-	-	0			0
63	0.134	-	0	-	-	0			0
64	0.130	-	0	-	-	0			0
65	0.127	-	1	-	-	0			0
66	0.123	-	1	-	-	0			0
67	0.119	-	1	-	-	0			0
68	0.116	-	1	-	-	0			0
69	0.112	-	1	-	-	0			0
70	0.109	-	1	-	-	0			0
71	0.106	-	1	-	-	0			0
72	0.103	-	1	-	-	0			0
73	0.100	-	1	-	-	0			0
74	0.097	-	1	-	-	0			0
75	0.094	-	1	-	-	0			0
76	0.092	-	1	-	-	0			0
77	0.090	-	1	-	-	0			0
78	0.087	-	1	-	-	0			0
79	0.085	-	1	-	-	0			0
80	0.083	-	1	-	-	0			0
81	0.081	-	1	-	-	0			0
82	0.079	-	1	-	-	0			0
83	0.077	-	1	-	-	0			0
84	0.075	-	1	-	-	0			0
85	0.074	-	1	-	-	0			0
86	0.072	-	1	-	-	0			0
87	0.070	-	1	-	-	0			0
88	0.068	-	1	-	-	0			0
89	0.067	-	1	-	-	0			0
90	0.065	-	1	-	-	0			0
91	0.063	-	1	-	-	0			0
92	0.062	-	1	-	-	0			0
93	0.060	-	1	-	-	0			0
94	0.059	-	1	-	-	0			0
95	0.057	-	1	-	-	0			0
96	0.056	-	1	-	-	0			0
97	0.055	-	2	-	-	0			0
98	0.053	-	2	-	-	0			0
99	0.052	-	2	-	-	0			0
		0.00	39.93	0.00	0.00	2.24			3.50

								Sheet Nr.	
Client/Authority									
Environment Agency									
Project name		**Option:**							
Exe Estuary Strategy - FCRMU3		Do nothing							
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**			
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**			
Scaling factor (e.g. £m, £k, £)	£k	Residential property	14	32	758	16,419	**£k**	Prepared (date)	12/09/2012
Discount rate	Variable	Ind/commercial (direct)	1	4	59	2,506	**£k**	Printed	18/12/2012
		Temp Acc	698	755	961	1,242	**£k**	Prepared by	AMC
		Traffic related	0	0	0	0	**£k**	Checked by	PJC
		Emergency services	1	2	46	1,060	**£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0	**£k**		
			714	793	1,823	21,227			
		PV Total Damage	354,911				**£k**		
		Total Write-off	280,897				**£k**		

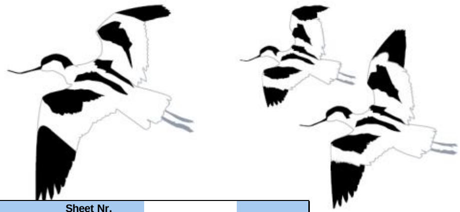
		AAD Post Breach					**£ 280,897**	**£ -**	**£ 354,911**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		40,970	**5,811**	**24,614**	**-**	**2,620**			
0	1.000	14	1	698	-	1	280,897		281611
1	0.966	15	2	701	-	1			694
2	0.934	16	2	704	-	1			675
3	0.902	17	2	707	-	1			655
4	0.871	18	2	710	-	1			637
5	0.842	19	2	713	-	1			619
6	0.814	20	2	716	-	1			601
7	0.786	21	2	719	-	1			584
8	0.759	21	3	722	-	1			568
9	0.734	22	3	725	-	1			551
10	0.709	23	3	728	-	1			536
11	0.685	24	3	731	-	2			520
12	0.662	25	3	734	-	2			506
13	0.639	26	3	737	-	2			491
14	0.618	27	3	740	-	2			477
15	0.597	28	3	743	-	2			463
16	0.577	29	4	746	-	2			450
17	0.557	30	4	749	-	2			437
18	0.538	31	4	752	-	2			425
19	0.520	32	4	755	-	2			412
20	0.503	56	6	762	-	3			416
21	0.486	80	8	769	-	5			418
22	0.469	104	9	776	-	6			420
23	0.453	129	11	782	-	8			422
24	0.438	153	13	789	-	9			422
25	0.423	177	15	796	-	11			423
26	0.409	201	17	803	-	12			422
27	0.395	225	19	810	-	14			422
28	0.382	250	20	817	-	15			421
29	0.369	274	22	824	-	17			419
30	0.356	298	24	830	-	18			417
31	0.346	322	26	837	-	19			417
32	0.336	346	28	844	-	21			416
33	0.326	371	30	851	-	22			415
34	0.317	395	31	858	-	24			414
35	0.307	419	33	865	-	25			412
36	0.298	443	35	872	-	27			411
37	0.290	467	37	878	-	28			409
38	0.281	491	39	885	-	30			406
39	0.273	516	40	892	-	31			404
40	0.265	540	42	899	-	33			401
41	0.257	564	44	906	-	34			398
42	0.250	588	46	913	-	36			395
43	0.243	612	48	920	-	37			392
44	0.236	637	50	926	-	38			389
45	0.229	661	51	933	-	40			385
46	0.222	685	53	940	-	41			382
47	0.216	709	55	947	-	43			378
48	0.209	733	57	954	-	44			374
49	0.203	758	59	961	-	46			370
50	0.197	1,071	108	966	-	66			436
51	0.192	1,384	157	972	-	86			498
52	0.186	1,697	206	978	-	107			555
53	0.181	2,010	254	983	-	127			609
54	0.175	2,324	303	989	-	147			660
55	0.170	2,637	352	994	-	167			706
56	0.165	2,950	401	1,000	-	188			750
57	0.160	3,263	450	1,006	-	208			790
58	0.156	3,577	499	1,011	-	228			828
59	0.151	3,890	548	1,017	-	249			862
60	0.147	4,203	597	1,022	-	269			894
61	0.143	4,516	646	1,028	-	289			923
62	0.138	4,830	695	1,034	-	309			950
63	0.134	5,143	744	1,039	-	330			975
64	0.130	5,456	793	1,045	-	350			997
65	0.127	5,769	842	1,051	-	370			1017
66	0.123	6,082	891	1,056	-	391			1035
67	0.119	6,396	940	1,062	-	411			1051
68	0.116	6,709	989	1,067	-	431			1066
69	0.112	7,022	1,038	1,073	-	451			1078
70	0.109	7,335	1,087	1,079	-	472			1089
71	0.106	7,649	1,136	1,084	-	492			1099
72	0.103	7,962	1,185	1,090	-	512			1107
73	0.100	8,275	1,234	1,095	-	532			1113
74	0.097	8,588	1,282	1,101	-	553			1118
75	0.094	8,901	1,331	1,107	-	573			1122
76	0.092	9,215	1,380	1,112	-	593			1131
77	0.090	9,528	1,429	1,118	-	614			1138
78	0.087	9,841	1,478	1,124	-	634			1144
79	0.085	10,154	1,527	1,129	-	654			1149
80	0.083	10,468	1,576	1,135	-	674			1154
81	0.081	10,781	1,625	1,140	-	695			1157
82	0.079	11,094	1,674	1,146	-	715			1159
83	0.077	11,407	1,723	1,152	-	735			1161
84	0.075	11,721	1,772	1,157	-	756			1162
85	0.074	12,034	1,821	1,163	-	776			1162
86	0.072	12,347	1,870	1,169	-	796			1162
87	0.070	12,660	1,919	1,174	-	816			1161
88	0.068	12,973	1,968	1,180	-	837			1159
89	0.067	13,287	2,017	1,185	-	857			1157
90	0.065	13,600	2,066	1,191	-	877			1154
91	0.063	13,913	2,115	1,197	-	898			1150
92	0.062	14,226	2,164	1,202	-	918			1146
93	0.060	14,540	2,213	1,208	-	938			1142
94	0.059	14,853	2,262	1,213	-	958			1137
95	0.057	15,166	2,310	1,219	-	979			1131
96	0.056	15,479	2,359	1,225	-	999			1125
97	0.055	15,792	2,408	1,230	-	1,019			1119
98	0.053	16,106	2,457	1,236	-	1,040			1113
99	0.052	16,419	2,506	1,242	-	1,060			1106
		449904.87	66370.04	95564.51	0.00	28911.39			354911.43



					Sheet Nr.	
Client/Authority						
Environment Agency						
Project name		**Option:**				
Exe Estuary Strategy - FCRMU4		Do nothing				
Project reference	0					
Base date for estimates (year 0)	Q2 2010					
Scaling factor (e.g. £m, £k, £)	£k				Prepared (date)	12/09/2012
Discount rate	Variable				Printed	18/12/2012
					Prepared by	AMC
					Checked by	PJC
					Checked date	18/12/2012

	AAD Year 0	AAD Year 19	AAD Year 49	AAD Year 99	
	0	**19**	**49**	**99**	
Residential property	0	0	0	1	**£k**
Ind/commercial (direct)	0	0	0	1	**£k**
Temp Acc	0	0	0	1	**£k**
Railway Costs	0	2	4	0	**£k**
Emergency services	0	0	0	0	**£k**
Agricultural	0	0	0	0	**£k**
	0	2	5	3	
PV Total Damage	7,266				**£k**
Total Write-off	7,218				**£k**

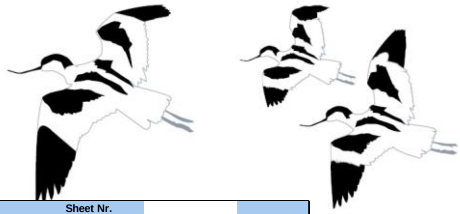
		AAD Post Breach					**£ 7,218**	**£ -**	**£ 7,266**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Railway Costs AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		2	**2**	**2**	**41**	**0**			
0	1.000	-	-	-	-	-	7,218		7218
1	0.966	-	0	0	0	0			0
2	0.934	-	0	0	0	0			0
3	0.902	-	0	0	0	0			0
4	0.871	-	0	0	0	0			0
5	0.842	-	0	0	0	0			0
6	0.814	-	0	0	1	0			0
7	0.786	-	0	0	1	0			1
8	0.759	-	0	0	1	0			1
9	0.734	-	0	0	1	0			1
10	0.709	-	0	0	1	0			1
11	0.685	-	0	0	1	0			1
12	0.662	-	0	0	1	0			1
13	0.639	-	0	0	1	0			1
14	0.618	-	0	0	1	0			1
15	0.597	-	0	0	1	0			1
16	0.577	-	0	0	2	0			1
17	0.557	-	0	0	2	0			1
18	0.538	-	0	0	2	0			1
19	0.520	-	0	0	2	0			1
20	0.503	0	0	0	2	0			1
21	0.486	0	0	0	2	0			1
22	0.469	0	0	0	2	0			1
23	0.453	0	0	0	2	0			1
24	0.438	0	0	0	2	0			1
25	0.423	0	0	0	2	0			1
26	0.409	0	0	0	2	0			1
27	0.395	0	0	0	3	0			1
28	0.382	0	0	0	3	0			1
29	0.369	0	0	0	3	0			1
30	0.356	0	0	0	3	0			1
31	0.346	0	0	0	3	0			1
32	0.336	0	0	0	3	0			1
33	0.326	0	0	0	3	0			1
34	0.317	0	0	0	3	0			1
35	0.307	0	0	0	3	0			1
36	0.298	0	0	0	3	0			1
37	0.290	0	0	0	3	0			1
38	0.281	0	0	0	3	0			1
39	0.273	0	0	0	4	0			1
40	0.265	0	0	0	4	0			1
41	0.257	0	0	0	4	0			1
42	0.250	0	0	0	4	0			1
43	0.243	0	0	0	4	0			1
44	0.236	0	0	0	4	0			1
45	0.229	0	0	0	4	0			1
46	0.222	0	0	0	4	0			1
47	0.216	0	0	0	4	0			1
48	0.209	0	0	0	4	0			1
49	0.203	0	0	0	4	0			1
50	0.197	0	0	0	-	0			0
51	0.192	0	0	0	-	0			0
52	0.186	0	0	0	-	0			0
53	0.181	0	0	0	-	0			0
54	0.175	0	0	0	-	0			0
55	0.170	0	0	0	-	0			0
56	0.165	0	0	0	-	0			0
57	0.160	0	0	0	-	0			0
58	0.156	0	0	0	-	0			0
59	0.151	0	0	0	-	0			0
60	0.147	0	0	0	-	0			0
61	0.143	0	0	0	-	0			0
62	0.138	0	0	0	-	0			0
63	0.134	0	0	0	-	0			0
64	0.130	0	0	0	-	0			0
65	0.127	0	0	0	-	0			0
66	0.123	0	0	0	-	0			0
67	0.119	0	0	0	-	0			0
68	0.116	0	0	0	-	0			0
69	0.112	0	0	0	-	0			0
70	0.109	0	0	0	-	0			0
71	0.106	0	0	0	-	0			0
72	0.103	0	0	0	-	0			0
73	0.100	0	0	0	-	0			0
74	0.097	0	1	0	-	0			0
75	0.094	0	1	0	-	0			0
76	0.092	0	1	0	-	0			0
77	0.090	0	1	0	-	0			0
78	0.087	1	1	0	-	0			0
79	0.085	1	1	0	-	0			0
80	0.083	1	1	0	-	0			0
81	0.081	1	1	0	-	0			0
82	0.079	1	1	1	-	0			0
83	0.077	1	1	1	-	0			0
84	0.075	1	1	1	-	0			0
85	0.074	1	1	1	-	0			0
86	0.072	1	1	1	-	0			0
87	0.070	1	1	1	-	0			0
88	0.068	1	1	1	-	0			0
89	0.067	1	1	1	-	0			0
90	0.065	1	1	1	-	0			0
91	0.063	1	1	1	-	0			0
92	0.062	1	1	1	-	0			0
93	0.060	1	1	1	-	0			0
94	0.059	1	1	1	-	0			0
95	0.057	1	1	1	-	0			0
96	0.056	1	1	1	-	0			0
97	0.055	1	1	1	-	0			0
98	0.053	1	1	1	-	0			0
99	0.052	1	1	1	-	0			0
		22.68	25.94	22.29	113.76	5.20			7265.91



						Sheet Nr.	
Client/Authority							
Environment Agency							
Project name		**Option:**					
Exe Estuary Strategy - FCRMU05		Do nothing					
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**	
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**	

Scaling factor (e.g. £m, £k, £)	£k	Residential property	3	5	134	2,186	**£k**	Prepared (date)	12/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	0	42	**£k**	Printed	18/12/2012
		Temp Acc	26	34	60	81	**£k**	Prepared by	AMC
		Traffic related	0	0	0	0	**£k**	Checked by	PJC
		Emergency services	0	1	14	238	**£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0	**£k**		
			29	39	209	2,548			
		PV Total Damage	22,248				**£k**		
		Total Write-off	14,567				**£k**		

		AAD Post Breach					**£ 14,567**	**£ -**	**£ 22,248**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		5,717	**93**	**1,249**	**-**	**622**			
0	1.000	3	0	26	-	0	14,567		14597
1	0.966	3	0	27	-	0			29
2	0.934	3	0	27	-	0			28
3	0.902	3	0	28	-	0			28
4	0.871	3	0	28	-	0			27
5	0.842	3	0	28	-	0			27
6	0.814	3	0	29	-	0			26
7	0.786	3	0	29	-	0			26
8	0.759	4	0	30	-	0			25
9	0.734	4	0	30	-	0			25
10	0.709	4	0	30	-	0			25
11	0.685	4	0	31	-	0			24
12	0.662	4	0	31	-	0			24
13	0.639	4	0	32	-	0			23
14	0.618	4	0	32	-	0			23
15	0.597	4	0	32	-	0			22
16	0.577	4	0	33	-	0			22
17	0.557	5	0	33	-	0			21
18	0.538	5	0	34	-	1			21
19	0.520	5	0	34	-	1			20
20	0.503	9	0	35	-	1			23
21	0.486	13	0	36	-	1			25
22	0.469	18	0	37	-	2			26
23	0.453	22	0	37	-	2			28
24	0.438	26	0	38	-	3			30
25	0.423	31	0	39	-	3			31
26	0.409	35	0	40	-	4			32
27	0.395	39	0	41	-	4			33
28	0.382	44	0	42	-	5			34
29	0.369	48	0	43	-	5			35
30	0.356	52	0	44	-	6			36
31	0.346	56	0	44	-	6			37
32	0.336	61	0	45	-	7			38
33	0.326	65	0	46	-	7			39
34	0.317	69	0	47	-	7			39
35	0.307	74	0	48	-	8			40
36	0.298	78	0	49	-	8			40
37	0.290	82	0	50	-	9			41
38	0.281	87	0	51	-	9			41
39	0.273	91	0	51	-	10			42
40	0.265	95	0	52	-	10			42
41	0.257	100	0	53	-	11			42
42	0.250	104	0	54	-	11			42
43	0.243	108	0	55	-	12			42
44	0.236	112	0	56	-	12			43
45	0.229	117	0	57	-	13			43
46	0.222	121	0	58	-	13			43
47	0.216	125	0	58	-	13			43
48	0.209	130	0	59	-	14			43
49	0.203	134	0	60	-	14			42
50	0.197	175	1	61	-	19			50
51	0.192	216	2	61	-	23			58
52	0.186	257	3	62	-	28			65
53	0.181	298	4	62	-	32			72
54	0.175	339	5	62	-	37			78
55	0.170	380	5	63	-	41			83
56	0.165	421	6	63	-	46			89
57	0.160	462	7	64	-	50			94
58	0.156	503	8	64	-	55			98
59	0.151	544	9	64	-	59			102
60	0.147	586	10	65	-	64			106
61	0.143	627	10	65	-	68			110
62	0.138	668	11	66	-	73			113
63	0.134	709	12	66	-	77			116
64	0.130	750	13	67	-	82			119
65	0.127	791	14	67	-	86			121
66	0.123	832	15	67	-	91			123
67	0.119	873	15	68	-	95			125
68	0.116	914	16	68	-	100			127
69	0.112	955	17	69	-	104			129
70	0.109	996	18	69	-	108			130
71	0.106	1,037	19	70	-	113			131
72	0.103	1,078	20	70	-	117			132
73	0.100	1,119	20	70	-	122			133
74	0.097	1,160	21	71	-	126			134
75	0.094	1,201	22	71	-	131			134
76	0.092	1,242	23	72	-	135			135
77	0.090	1,283	24	72	-	140			136
78	0.087	1,324	25	73	-	144			137
79	0.085	1,365	25	73	-	149			138
80	0.083	1,406	26	73	-	153			138
81	0.081	1,448	27	74	-	158			139
82	0.079	1,489	28	74	-	162			139
83	0.077	1,530	29	75	-	167			139
84	0.075	1,571	30	75	-	171			139
85	0.074	1,612	30	76	-	176			139
86	0.072	1,653	31	76	-	180			139
87	0.070	1,694	32	76	-	185			139
88	0.068	1,735	33	77	-	189			139
89	0.067	1,776	34	77	-	194			139
90	0.065	1,817	35	78	-	198			138
91	0.063	1,858	35	78	-	203			138
92	0.062	1,899	36	79	-	207			138
93	0.060	1,940	37	79	-	212			137
94	0.059	1,981	38	79	-	216			136
95	0.057	2,022	39	80	-	221			136
96	0.056	2,063	40	80	-	225			135
97	0.055	2,104	40	81	-	229			134
98	0.053	2,145	41	81	-	234			134
99	0.052	2,186	42	81	-	238			133
		61256.35	1091.41	5584.74	0.00	6671.21			22248.12

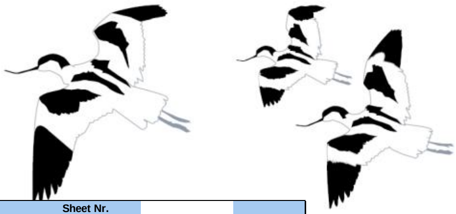


Sheet Nr.

Client/Authority
Environment Agency
Project name | **Option:**
Exe Estuary Strategy - FCRMU06 | Do nothing

			AAD Year 0	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**			
Project reference	0								
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**			
Scaling factor (e.g. £m, £k, £)	£k	Residential property	0	0	0	0	**£k**	Prepared (date)	12/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	0	3	**£k**	Printed	18/12/2012
		Temp Acc	0	0	0	2	**£k**	Prepared by	AMC
		Railway Costs	3	3	3	0	**£k**	Checked by	PJC
		Emergency services	0	0	0	0	**£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0	**£k**		
			3	3	3	5			
		PV Total Damage	7,288				**£k**		
		Total Write-off	7,214				**£k**		

		AAD Post Breach					**£ 7,214**	**£ -**	**£ 7,288**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Railway Costs AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		-	**7**	**4**	**62**	**1**			
0	1.000	-	-	-	3	-	7,214		7216
1	0.966	-	0	0	3	0			2
2	0.934	-	0	0	3	0			2
3	0.902	-	0	0	3	0			2
4	0.871	-	0	0	3	0			2
5	0.842	-	0	0	3	0			2
6	0.814	-	0	0	3	0			2
7	0.786	-	0	0	3	0			2
8	0.759	-	0	0	3	0			2
9	0.734	-	0	0	3	0			2
10	0.709	-	0	0	3	0			2
11	0.685	-	0	0	3	0			2
12	0.662	-	0	0	3	0			2
13	0.639	-	0	0	3	0			2
14	0.618	-	0	0	3	0			2
15	0.597	-	0	0	3	0			2
16	0.577	-	0	0	3	0			1
17	0.557	-	0	0	3	0			1
18	0.538	-	0	0	3	0			1
19	0.520	-	0	0	3	0			1
20	0.503	-	0	0	3	0			1
21	0.486	-	0	0	3	0			1
22	0.469	-	0	0	3	0			1
23	0.453	-	0	0	3	0			1
24	0.438	-	0	0	3	0			1
25	0.423	-	0	0	3	0			1
26	0.409	-	0	0	3	0			1
27	0.395	-	0	0	3	0			1
28	0.382	-	0	0	3	0			1
29	0.369	-	0	0	3	0			1
30	0.356	-	0	0	3	0			1
31	0.346	-	0	0	3	0			1
32	0.336	-	0	0	3	0			1
33	0.326	-	0	0	3	0			1
34	0.317	-	0	0	3	0			1
35	0.307	-	0	0	3	0			1
36	0.298	-	0	0	3	0			1
37	0.290	-	0	0	3	0			1
38	0.281	-	0	0	3	0			1
39	0.273	-	0	0	3	0			1
40	0.265	-	0	0	3	0			1
41	0.257	-	0	0	3	0			1
42	0.250	-	0	0	3	0			1
43	0.243	-	0	0	3	0			1
44	0.236	-	0	0	3	0			1
45	0.229	-	0	0	3	0			1
46	0.222	-	0	0	3	0			1
47	0.216	-	0	0	3	0			1
48	0.209	-	0	0	3	0			1
49	0.203	-	0	0	3	0			1
50	0.197	-	0	0	-	0			0
51	0.192	-	0	0	-	0			0
52	0.186	-	0	0	-	0			0
53	0.181	-	0	0	-	0			0
54	0.175	-	0	0	-	0			0
55	0.170	-	0	0	-	0			0
56	0.165	-	0	0	-	0			0
57	0.160	-	1	0	-	0			0
58	0.156	-	1	0	-	0			0
59	0.151	-	1	0	-	0			0
60	0.147	-	1	0	-	0			0
61	0.143	-	1	0	-	0			0
62	0.138	-	1	0	-	0			0
63	0.134	-	1	1	-	0			0
64	0.130	-	1	1	-	0			0
65	0.127	-	1	1	-	0			0
66	0.123	-	1	1	-	0			0
67	0.119	-	1	1	-	0			0
68	0.116	-	1	1	-	0			0
69	0.112	-	1	1	-	0			0
70	0.109	-	1	1	-	0			0
71	0.106	-	1	1	-	0			0
72	0.103	-	1	1	-	0			0
73	0.100	-	1	1	-	0			0
74	0.097	-	2	1	-	0			0
75	0.094	-	2	1	-	0			0
76	0.092	-	2	1	-	0			0
77	0.090	-	2	1	-	0			0
78	0.087	-	2	1	-	0			0
79	0.085	-	2	1	-	0			0
80	0.083	-	2	1	-	0			0
81	0.081	-	2	1	-	0			0
82	0.079	-	2	1	-	0			0
83	0.077	-	2	1	-	0			0
84	0.075	-	2	1	-	0			0
85	0.074	-	2	1	-	0			0
86	0.072	-	2	1	-	0			0
87	0.070	-	2	1	-	0			0
88	0.068	-	2	1	-	0			0
89	0.067	-	2	1	-	0			0
90	0.065	-	3	1	-	0			0
91	0.063	-	3	1	-	0			0
92	0.062	-	3	1	-	0			0
93	0.060	-	3	1	-	0			0
94	0.059	-	3	1	-	0			0
95	0.057	-	3	1	-	0			0
96	0.056	-	3	1	-	0			0
97	0.055	-	3	2	-	0			0
98	0.053	-	3	2	-	0			0
99	0.052	-	3	2	-	0			0
		0.00	79.72	44.74	125.94	8.53			7287.59



						Sheet Nr.		
Client/Authority								
Environment Agency								
Project name		**Option:**						
Exe Estuary Strategy - FCRMU07		Do nothing						
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**		
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**		
Scaling factor (e.g. £m, £k, £)	£k	Residential property	0	0	1	55 **£k**	Prepared (date)	12/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	0	3 **£k**	Printed	18/12/2012
		Temp Acc	0	0	0	1 **£k**	Prepared by	AMC
		Railway Costs	2	2	2	0 **£k**	Checked by	PJC
		Emergency services	0	0	0	6 **£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0 **£k**		
			2	2	3	66		
		PV Total Damage	7,457			**£k**		
		Total Write-off	7,260			**£k**		

		AAD Post Breach					**£ 7,260**	**£ -**	**£ 7,457**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Railway Costs AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		126	**6**	**4**	**45**	**14**			
0	1.000	0	0	0	2	0	7,260		7262
1	0.966	0	0	0	2	0			2
2	0.934	0	0	0	2	0			2
3	0.902	0	0	0	2	0			2
4	0.871	0	0	0	2	0			2
5	0.842	0	0	0	2	0			2
6	0.814	0	0	0	2	0			2
7	0.786	0	0	0	2	0			1
8	0.759	0	0	0	2	0			1
9	0.734	0	0	0	2	0			1
10	0.709	0	0	0	2	0			1
11	0.685	0	0	0	2	0			1
12	0.662	0	0	0	2	0			1
13	0.639	0	0	0	2	0			1
14	0.618	0	0	0	2	0			1
15	0.597	0	0	0	2	0			1
16	0.577	0	0	0	2	0			1
17	0.557	0	0	0	2	0			1
18	0.538	0	0	0	2	0			1
19	0.520	0	0	0	2	0			1
20	0.503	0	0	0	2	0			1
21	0.486	0	0	0	2	0			1
22	0.469	0	0	0	2	0			1
23	0.453	0	0	0	2	0			1
24	0.438	0	0	0	2	0			1
25	0.423	0	0	0	2	0			1
26	0.409	0	0	0	2	0			1
27	0.395	0	0	0	2	0			1
28	0.382	0	0	0	2	0			1
29	0.369	0	0	0	2	0			1
30	0.356	0	0	0	2	0			1
31	0.346	0	0	0	2	0			1
32	0.336	1	0	0	2	0			1
33	0.326	1	0	0	2	0			1
34	0.317	1	0	0	2	0			1
35	0.307	1	0	0	2	0			1
36	0.298	1	0	0	2	0			1
37	0.290	1	0	0	2	0			1
38	0.281	1	0	0	2	0			1
39	0.273	1	0	0	2	0			1
40	0.265	1	0	0	2	0			1
41	0.257	1	0	0	2	0			1
42	0.250	1	0	0	2	0			1
43	0.243	1	0	0	2	0			1
44	0.236	1	0	0	2	0			1
45	0.229	1	0	0	2	0			1
46	0.222	1	0	0	2	0			1
47	0.216	1	0	0	2	0			1
48	0.209	1	0	0	2	0			1
49	0.203	1	0	0	2	0			1
50	0.197	2	0	0	-	0			1
51	0.192	3	0	0	-	0			1
52	0.186	4	0	0	-	0			1
53	0.181	5	0	0	-	1			1
54	0.175	7	0	0	-	1			1
55	0.170	8	0	0	-	1			2
56	0.165	9	0	0	-	1			2
57	0.160	10	0	0	-	1			2
58	0.156	11	1	0	-	1			2
59	0.151	12	1	0	-	1			2
60	0.147	13	1	0	-	1			2
61	0.143	14	1	0	-	2			2
62	0.138	15	1	0	-	2			3
63	0.134	16	1	0	-	2			3
64	0.130	17	1	0	-	2			3
65	0.127	18	1	0	-	2			3
66	0.123	20	1	0	-	2			3
67	0.119	21	1	1	-	2			3
68	0.116	22	1	1	-	2			3
69	0.112	23	1	1	-	3			3
70	0.109	24	1	1	-	3			3
71	0.106	25	1	1	-	3			3
72	0.103	26	1	1	-	3			3
73	0.100	27	1	1	-	3			3
74	0.097	28	1	1	-	3			3
75	0.094	29	2	1	-	3			3
76	0.092	30	2	1	-	3			3
77	0.090	31	2	1	-	4			3
78	0.087	33	2	1	-	4			3
79	0.085	34	2	1	-	4			3
80	0.083	35	2	1	-	4			3
81	0.081	36	2	1	-	4			3
82	0.079	37	2	1	-	4			3
83	0.077	38	2	1	-	4			3
84	0.075	39	2	1	-	4			4
85	0.074	40	2	1	-	5			4
86	0.072	41	2	1	-	5			4
87	0.070	42	2	1	-	5			4
88	0.068	43	2	1	-	5			4
89	0.067	44	2	1	-	5			4
90	0.065	46	2	1	-	5			4
91	0.063	47	2	1	-	5			4
92	0.062	48	3	1	-	5			4
93	0.060	49	3	1	-	5			4
94	0.059	50	3	1	-	6			3
95	0.057	51	3	1	-	6			3
96	0.056	52	3	1	-	6			3
97	0.055	53	3	1	-	6			3
98	0.053	54	3	1	-	6			3
99	0.052	55	3	1	-	6			3
		1457.50	75.75	36.81	92.19	164.06			7456.54

Sheet Nr.

Client/Authority
Environment Agency
Project name
Exe Estuary Strategy - FCRMU08

Option:
Do nothing

Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**		
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**		
Scaling factor (e.g. £m, £k, £)	£k	Residential property	0	0	0	0	**£k**	Prepared (date) 13/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	2	142	**£k**	Printed 18/12/2012
		Temp Acc	11	13	19	23	**£k**	Prepared by AMC
		Traffic related	0	0	0	0	**£k**	Checked by PJC
		Emergency services	0	0	0	15	**£k**	Checked date 18/12/2012
		Agricultural	0	0	0	0	**£k**	
			11	13	21	179		
		PV Total Damage	4,852				**£k**	
		Total Write-off	4,064				**£k**	

		AAD Post Breach					£ 4,064	£ -	£ 4,852
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		0	**314**	**439**	**-**	**34**			
0	1.000	-	0	11	-	0	4,064		4075
1	0.966	-	0	11	-	0			11
2	0.934	-	0	11	-	0			10
3	0.902	-	0	11	-	0			10
4	0.871	-	0	11	-	0			10
5	0.842	-	0	12	-	0			10
6	0.814	-	0	12	-	0			10
7	0.786	-	0	12	-	0			9
8	0.759	-	0	12	-	0			9
9	0.734	-	0	12	-	0			9
10	0.709	-	0	12	-	0			9
11	0.685	-	0	12	-	0			8
12	0.662	-	0	12	-	0			8
13	0.639	-	0	13	-	0			8
14	0.618	-	0	13	-	0			8
15	0.597	-	0	13	-	0			8
16	0.577	-	0	13	-	0			8
17	0.557	-	0	13	-	0			7
18	0.538	-	0	13	-	0			7
19	0.520	-	0	13	-	0			7
20	0.503	-	0	14	-	0			7
21	0.486	-	0	14	-	0			7
22	0.469	-	0	14	-	0			7
23	0.453	-	0	14	-	0			7
24	0.438	-	0	14	-	0			6
25	0.423	-	0	14	-	0			6
26	0.409	-	0	15	-	0			6
27	0.395	-	1	15	-	0			6
28	0.382	-	1	15	-	0			6
29	0.369	-	1	15	-	0			6
30	0.356	-	1	15	-	0			6
31	0.346	-	1	16	-	0			6
32	0.336	-	1	16	-	0			6
33	0.326	-	1	16	-	0			6
34	0.317	-	1	16	-	0			5
35	0.307	-	1	16	-	0			5
36	0.298	-	1	17	-	0			5
37	0.290	-	1	17	-	0			5
38	0.281	-	1	17	-	0			5
39	0.273	-	1	17	-	0			5
40	0.265	-	1	17	-	0			5
41	0.257	-	1	17	-	0			5
42	0.250	-	1	18	-	0			5
43	0.243	-	1	18	-	0			5
44	0.236	-	1	18	-	0			5
45	0.229	-	1	18	-	0			5
46	0.222	-	2	18	-	0			4
47	0.216	-	2	19	-	0			4
48	0.209	-	2	19	-	0			4
49	0.203	-	2	19	-	0			4
50	0.197	0	5	19	-	0			5
51	0.192	0	7	19	-	1			5
52	0.186	0	10	19	-	1			6
53	0.181	0	13	19	-	1			6
54	0.175	0	16	19	-	2			6
55	0.170	0	18	19	-	2			7
56	0.165	0	21	19	-	2			7
57	0.160	0	24	20	-	3			7
58	0.156	0	27	20	-	3			8
59	0.151	0	30	20	-	3			8
60	0.147	0	32	20	-	3			8
61	0.143	0	35	20	-	4			8
62	0.138	0	38	20	-	4			9
63	0.134	0	41	20	-	4			9
64	0.130	0	44	20	-	5			9
65	0.127	0	46	20	-	5			9
66	0.123	0	49	20	-	5			9
67	0.119	0	52	20	-	6			9
68	0.116	0	55	20	-	6			9
69	0.112	0	58	20	-	6			9
70	0.109	0	60	20	-	6			10
71	0.106	0	63	21	-	7			10
72	0.103	0	66	21	-	7			10
73	0.100	0	69	21	-	7			10
74	0.097	0	72	21	-	8			10
75	0.094	0	74	21	-	8			10
76	0.092	0	77	21	-	8			10
77	0.090	0	80	21	-	9			10
78	0.087	0	83	21	-	9			10
79	0.085	0	86	21	-	9			10
80	0.083	0	88	21	-	9			10
81	0.081	0	91	21	-	10			10
82	0.079	0	94	21	-	10			10
83	0.077	0	97	21	-	10			10
84	0.075	0	100	21	-	11			10
85	0.074	0	102	22	-	11			10
86	0.072	0	105	22	-	11			10
87	0.070	0	108	22	-	12			10
88	0.068	0	111	22	-	12			10
89	0.067	0	114	22	-	12			10
90	0.065	0	116	22	-	12			10
91	0.063	0	119	22	-	13			10
92	0.062	0	122	22	-	13			10
93	0.060	0	125	22	-	13			10
94	0.059	0	128	22	-	14			10
95	0.057	0	130	22	-	14			10
96	0.056	0	133	22	-	14			10
97	0.055	0	136	22	-	15			9
98	0.053	0	139	22	-	15			9
99	0.052	0	142	23	-	15			9
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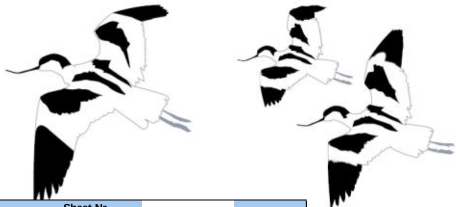


Sheet Nr.

Client/Authority
Environment Agency

Project name
Exe Estuary Strategy - FCRMU09

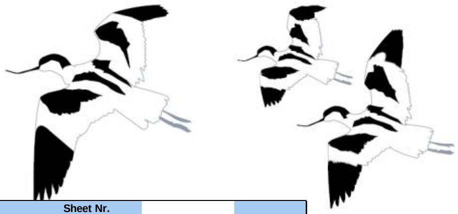
Option:
Do nothing

Project reference	0
Base date for estimates (year 0)	Q2 2010
Scaling factor (e.g. £m, £k, £)	£k
Discount rate	Variable

	AAD Year 0	AAD Year 19	AAD Year 49	AAD Year 99	
	0	**19**	**49**	**99**	
Residential property	1	2	38	938	**£k**
Ind/commercial (direct)	0	0	0	17	**£k**
Temp Acc	1	3	14	42	**£k**
Traffic related	0	0	0	0	**£k**
Emergency services	0	0	4	102	**£k**
Agricultural	0	0	0	0	**£k**
	2	5	57	1,099	
PV Total Damage	4,012				**£k**
Total Write-off	1,184				**£k**

Prepared (date)	13/09/2012
Printed	18/12/2012
Prepared by	AMC
Checked by	PJC
Checked date	18/12/2012

		AAD Post Breach					**£ 1,184**	**£ -**	**£ 4,012**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		2,301	**38**	**238**	**-**	**250**			
0	1.000	1	-	1	-	0	1,184		1187
1	0.966	1	0	1	-	0			2
2	0.934	1	0	2	-	0			2
3	0.902	1	0	2	-	0			2
4	0.871	1	0	2	-	0			3
5	0.842	1	0	2	-	0			3
6	0.814	1	0	2	-	0			3
7	0.786	1	0	2	-	0			3
8	0.759	1	0	2	-	0			3
9	0.734	1	0	2	-	0			3
10	0.709	1	0	2	-	0			3
11	0.685	1	0	2	-	0			3
12	0.662	1	0	2	-	0			3
13	0.639	2	0	2	-	0			2
14	0.618	2	0	2	-	0			2
15	0.597	2	0	2	-	0			2
16	0.577	2	0	2	-	0			2
17	0.557	2	0	2	-	0			2
18	0.538	2	0	3	-	0			2
19	0.520	2	0	3	-	0			2
20	0.503	3	0	3	-	0			3
21	0.486	4	0	3	-	0			4
22	0.469	5	0	4	-	1			5
23	0.453	7	0	4	-	1			5
24	0.438	8	0	5	-	1			6
25	0.423	9	0	5	-	1			6
26	0.409	10	0	5	-	1			7
27	0.395	11	0	6	-	1			7
28	0.382	13	0	6	-	1			8
29	0.369	14	0	6	-	1			8
30	0.356	15	0	7	-	2			8
31	0.346	16	0	7	-	2			9
32	0.336	17	0	8	-	2			9
33	0.326	19	0	8	-	2			9
34	0.317	20	0	8	-	2			10
35	0.307	21	0	9	-	2			10
36	0.298	22	0	9	-	2			10
37	0.290	23	0	10	-	3			10
38	0.281	25	0	10	-	3			11
39	0.273	26	0	10	-	3			11
40	0.265	27	0	11	-	3			11
41	0.257	28	0	11	-	3			11
42	0.250	29	0	12	-	3			11
43	0.243	31	0	12	-	3			11
44	0.236	32	0	12	-	3			11
45	0.229	33	0	13	-	4			11
46	0.222	34	0	13	-	4			11
47	0.216	36	0	13	-	4			11
48	0.209	37	0	14	-	4			11
49	0.203	38	0	14	-	4			11
50	0.197	56	1	15	-	6			15
51	0.192	74	1	15	-	8			19
52	0.186	92	1	16	-	10			22
53	0.181	110	2	16	-	12			25
54	0.175	128	2	17	-	14			28
55	0.170	146	2	18	-	16			31
56	0.165	164	3	18	-	18			33
57	0.160	182	3	19	-	20			36
58	0.156	200	3	19	-	22			38
59	0.151	218	4	20	-	24			40
60	0.147	236	4	20	-	26			42
61	0.143	254	4	21	-	28			44
62	0.138	272	5	21	-	30			45
63	0.134	290	5	22	-	32			47
64	0.130	308	5	22	-	34			48
65	0.127	326	6	23	-	35			49
66	0.123	344	6	24	-	37			51
67	0.119	362	6	24	-	39			52
68	0.116	380	7	25	-	41			52
69	0.112	398	7	25	-	43			53
70	0.109	416	7	26	-	45			54
71	0.106	434	8	26	-	47			55
72	0.103	452	8	27	-	49			55
73	0.100	470	8	27	-	51			56
74	0.097	488	9	28	-	53			56
75	0.094	506	9	28	-	55			56
76	0.092	524	9	29	-	57			57
77	0.090	542	10	30	-	59			57
78	0.087	560	10	30	-	61			58
79	0.085	578	10	31	-	63			58
80	0.083	596	11	31	-	65			59
81	0.081	614	11	32	-	67			59
82	0.079	632	11	32	-	69			59
83	0.077	650	12	33	-	71			59
84	0.075	668	12	33	-	73			59
85	0.074	686	12	34	-	75			59
86	0.072	704	13	35	-	77			59
87	0.070	722	13	35	-	79			59
88	0.068	740	13	36	-	81			59
89	0.067	758	14	36	-	83			59
90	0.065	776	14	37	-	85			59
91	0.063	794	14	37	-	86			59
92	0.062	812	15	38	-	88			59
93	0.060	830	15	38	-	90			59
94	0.059	848	15	39	-	92			59
95	0.057	866	16	39	-	94			58
96	0.056	884	16	40	-	96			58
97	0.055	902	16	41	-	98			58
98	0.053	920	17	41	-	100			58
99	0.052	938	17	42	-	102			57
		25490.51	444.33	1708.87	0.00	2775.03			4011.59



Sheet Nr.

Client/Authority
Environment Agency

Project name
Exe Estuary Strategy - FCRMU10

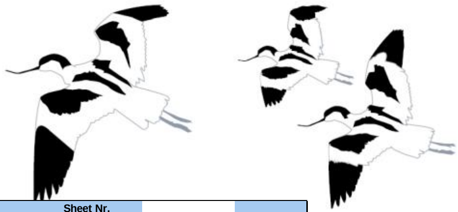
Option:
Do nothing

Project reference 0
Base date for estimates (year 0) Q2 2010
Scaling factor (e.g. £m, £k, £) £k
Discount rate Variable

	AAD Year 0	AAD Year 19	AAD Year 49	AAD Year 99	
	0	**19**	**49**	**99**	
Residential property	0	0	0	0	**£k**
Ind/commercial (direct)	0	0	0	0	**£k**
Temp Acc	0	0	0	0	**£k**
Traffic related	0	0	0	0	**£k**
Emergency services	0	0	0	0	**£k**
Agricultural	0	0	0	0	**£k**
	0	0	0	0	
PV Total Damage	166				**£k**
Total Write-off	166				**£k**

Prepared (date) 13/09/2012
Printed 18/12/2012
Prepared by AMC
Checked by PJC
Checked date 18/12/2012

		AAD Post Breach					£ 166	£ -	£ 166
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		-	**-**	**-**	**-**	**-**			
0	1.000	-	-	-	-	-	166		166
1	0.966	-	-	-	-	-			0
2	0.934	-	-	-	-	-			0
3	0.902	-	-	-	-	-			0
4	0.871	-	-	-	-	-			0
5	0.842	-	-	-	-	-			0
6	0.814	-	-	-	-	-			0
7	0.786	-	-	-	-	-			0
8	0.759	-	-	-	-	-			0
9	0.734	-	-	-	-	-			0
10	0.709	-	-	-	-	-			0
11	0.685	-	-	-	-	-			0
12	0.662	-	-	-	-	-			0
13	0.639	-	-	-	-	-			0
14	0.618	-	-	-	-	-			0
15	0.597	-	-	-	-	-			0
16	0.577	-	-	-	-	-			0
17	0.557	-	-	-	-	-			0
18	0.538	-	-	-	-	-			0
19	0.520	-	-	-	-	-			0
20	0.503	-	-	-	-	-			0
21	0.486	-	-	-	-	-			0
22	0.469	-	-	-	-	-			0
23	0.453	-	-	-	-	-			0
24	0.438	-	-	-	-	-			0
25	0.423	-	-	-	-	-			0
26	0.409	-	-	-	-	-			0
27	0.395	-	-	-	-	-			0
28	0.382	-	-	-	-	-			0
29	0.369	-	-	-	-	-			0
30	0.356	-	-	-	-	-			0
31	0.346	-	-	-	-	-			0
32	0.336	-	-	-	-	-			0
33	0.326	-	-	-	-	-			0
34	0.317	-	-	-	-	-			0
35	0.307	-	-	-	-	-			0
36	0.298	-	-	-	-	-			0
37	0.290	-	-	-	-	-			0
38	0.281	-	-	-	-	-			0
39	0.273	-	-	-	-	-			0
40	0.265	-	-	-	-	-			0
41	0.257	-	-	-	-	-			0
42	0.250	-	-	-	-	-			0
43	0.243	-	-	-	-	-			0
44	0.236	-	-	-	-	-			0
45	0.229	-	-	-	-	-			0
46	0.222	-	-	-	-	-			0
47	0.216	-	-	-	-	-			0
48	0.209	-	-	-	-	-			0
49	0.203	-	-	-	-	-			0
50	0.197	-	-	-	-	-			0
51	0.192	-	-	-	-	-			0
52	0.186	-	-	-	-	-			0
53	0.181	-	-	-	-	-			0
54	0.175	-	-	-	-	-			0
55	0.170	-	-	-	-	-			0
56	0.165	-	-	-	-	-			0
57	0.160	-	-	-	-	-			0
58	0.156	-	-	-	-	-			0
59	0.151	-	-	-	-	-			0
60	0.147	-	-	-	-	-			0
61	0.143	-	-	-	-	-			0
62	0.138	-	-	-	-	-			0
63	0.134	-	-	-	-	-			0
64	0.130	-	-	-	-	-			0
65	0.127	-	-	-	-	-			0
66	0.123	-	-	-	-	-			0
67	0.119	-	-	-	-	-			0
68	0.116	-	-	-	-	-			0
69	0.112	-	-	-	-	-			0
70	0.109	-	-	-	-	-			0
71	0.106	-	-	-	-	-			0
72	0.103	-	-	-	-	-			0
73	0.100	-	-	-	-	-			0
74	0.097	-	-	-	-	-			0
75	0.094	-	-	-	-	-			0
76	0.092	-	-	-	-	-			0
77	0.090	-	-	-	-	-			0
78	0.087	-	-	-	-	-			0
79	0.085	-	-	-	-	-			0
80	0.083	-	-	-	-	-			0
81	0.081	-	-	-	-	-			0
82	0.079	-	-	-	-	-			0
83	0.077	-	-	-	-	-			0
84	0.075	-	-	-	-	-			0
85	0.074	-	-	-	-	-			0
86	0.072	-	-	-	-	-			0
87	0.070	-	-	-	-	-			0
88	0.068	-	-	-	-	-			0
89	0.067	-	-	-	-	-			0
90	0.065	-	-	-	-	-			0
91	0.063	-	-	-	-	-			0
92	0.062	-	-	-	-	-			0
93	0.060	-	-	-	-	-			0
94	0.059	-	-	-	-	-			0
95	0.057	-	-	-	-	-			0
96	0.056	-	-	-	-	-			0
97	0.055	-	-	-	-	-			0
98	0.053	-	-	-	-	-			0
99	0.052	-	-	-	-	-			0
		0.00	0.00	0.00	0.00	0.00			166.13



Sheet Nr.

Client/Authority
Environment Agency

Project name
Exe Estuary Strategy - FCRMU11

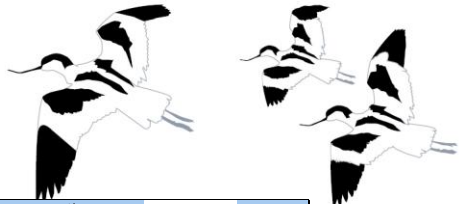
Option:
Do nothing

Project reference	0
Base date for estimates (year 0)	Q2 2010
Scaling factor (e.g. £m, £k, £)	£k
Discount rate	Variable

	AAD Year 0	AAD Year 19	AAD Year 49	AAD Year 99	
	0	**19**	**49**	**99**	
Residential property	0	0	0	0	**£k**
Ind/commercial (direct)	0	0	0	14	**£k**
Temp Acc	1	1	2	6	**£k**
Traffic related	0	0	0	0	**£k**
Emergency services	0	0	0	1	**£k**
Agricultural	0	0	0	0	**£k**
	1	1	2	22	
PV Total Damage	703				**£k**
Total Write-off	621				**£k**

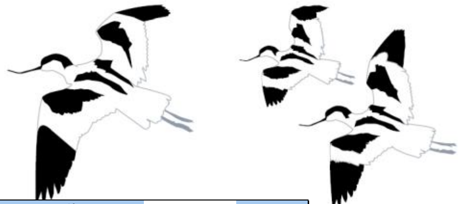
Prepared (date)	13/09/2012
Printed	18/12/2012
Prepared by	AMC
Checked by	PJC
Checked date	18/12/2012

		AAD Post Breach					**£ 621**	**£ -**	**£ 703**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		1	**30**	**48**	**-**	**3**			
0	1.000	-	0	1	-	0	621		622
1	0.966	-	0	1	-	0			1
2	0.934	-	0	1	-	0			1
3	0.902	-	0	1	-	0			1
4	0.871	-	0	1	-	0			1
5	0.842	-	0	1	-	0			1
6	0.814	-	0	1	-	0			1
7	0.786	-	0	1	-	0			1
8	0.759	-	0	1	-	0			1
9	0.734	-	0	1	-	0			1
10	0.709	-	0	1	-	0			1
11	0.685	-	0	1	-	0			1
12	0.662	-	0	1	-	0			1
13	0.639	-	0	1	-	0			1
14	0.618	-	0	1	-	0			1
15	0.597	-	0	1	-	0			1
16	0.577	-	0	1	-	0			1
17	0.557	-	0	1	-	0			1
18	0.538	-	0	1	-	0			1
19	0.520	-	0	1	-	0			1
20	0.503	0	0	1	-	0			1
21	0.486	0	0	1	-	0			1
22	0.469	0	0	1	-	0			1
23	0.453	0	0	1	-	0			1
24	0.438	0	0	1	-	0			1
25	0.423	0	0	1	-	0			1
26	0.409	0	0	1	-	0			1
27	0.395	0	0	1	-	0			1
28	0.382	0	0	1	-	0			1
29	0.369	0	0	1	-	0			1
30	0.356	0	0	1	-	0			1
31	0.346	0	0	1	-	0			0
32	0.336	0	0	1	-	0			0
33	0.326	0	0	1	-	0			0
34	0.317	0	0	1	-	0			0
35	0.307	0	0	1	-	0			0
36	0.298	0	0	1	-	0			0
37	0.290	0	0	1	-	0			0
38	0.281	0	0	2	-	0			0
39	0.273	0	0	2	-	0			0
40	0.265	0	0	2	-	0			0
41	0.257	0	0	2	-	0			0
42	0.250	0	0	2	-	0			0
43	0.243	0	0	2	-	0			0
44	0.236	0	0	2	-	0			0
45	0.229	0	0	2	-	0			0
46	0.222	0	0	2	-	0			0
47	0.216	0	0	2	-	0			0
48	0.209	0	0	2	-	0			0
49	0.203	0	0	2	-	0			0
50	0.197	0	0	2	-	0			0
51	0.192	0	1	2	-	0			1
52	0.186	0	1	2	-	0			1
53	0.181	0	1	2	-	0			1
54	0.175	0	2	2	-	0			1
55	0.170	0	2	2	-	0			1
56	0.165	0	2	2	-	0			1
57	0.160	0	2	3	-	0			1
58	0.156	0	3	3	-	0			1
59	0.151	0	3	3	-	0			1
60	0.147	0	3	3	-	0			1
61	0.143	0	3	3	-	0			1
62	0.138	0	4	3	-	0			1
63	0.134	0	4	3	-	0			1
64	0.130	0	4	3	-	0			1
65	0.127	0	4	3	-	0			1
66	0.123	0	5	3	-	1			1
67	0.119	0	5	3	-	1			1
68	0.116	0	5	3	-	1			1
69	0.112	0	6	4	-	1			1
70	0.109	0	6	4	-	1			1
71	0.106	0	6	4	-	1			1
72	0.103	0	6	4	-	1			1
73	0.100	0	7	4	-	1			1
74	0.097	0	7	4	-	1			1
75	0.094	0	7	4	-	1			1
76	0.092	0	7	4	-	1			1
77	0.090	0	8	4	-	1			1
78	0.087	0	8	4	-	1			1
79	0.085	0	8	4	-	1			1
80	0.083	0	8	5	-	1			1
81	0.081	0	9	5	-	1			1
82	0.079	0	9	5	-	1			1
83	0.077	0	9	5	-	1			1
84	0.075	0	10	5	-	1			1
85	0.074	0	10	5	-	1			1
86	0.072	0	10	5	-	1			1
87	0.070	0	10	5	-	1			1
88	0.068	0	11	5	-	1			1
89	0.067	0	11	5	-	1			1
90	0.065	0	11	5	-	1			1
91	0.063	0	11	6	-	1			1
92	0.062	0	12	6	-	1			1
93	0.060	0	12	6	-	1			1
94	0.059	0	12	6	-	1			1
95	0.057	0	12	6	-	1			1
96	0.056	0	13	6	-	1			1
97	0.055	0	13	6	-	1			1
98	0.053	0	13	6	-	1			1
99	0.052	0	14	6	-	1			1
		6.90	353.24	266.75	0.00	38.53			703.06



						Sheet Nr.		
Client/Authority								
Environment Agency								
Project name		**Option:**						
Exe Estuary Strategy - FCRMU12		Do nothing						
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**		
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**		
Scaling factor (e.g. £m, £k, £)	£k	Residential property	2	6	101	2,358 **£k**	Prepared (date)	13/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	4	315 **£k**	Printed	18/12/2012
		Temp Acc	13	21	53	129 **£k**	Prepared by	AMC
		Traffic related	0	0	0	0 **£k**	Checked by	PJC
		Emergency services	0	0	6	150 **£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0 **£k**		
			15	27	164	2,951		
		PV Total Damage	16,429			**£k**		
		Total Write-off	8,497			**£k**		

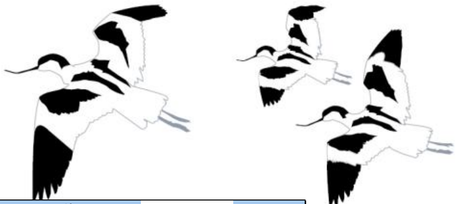
		AAD Post Breach					**£ 8,497**	**£ -**	**£ 16,429**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		5,837	**700**	**1,028**	**-**	**366**			
0	1.000	2	0	13	-	0	8,497		8513
1	0.966	2	0	14	-	0			15
2	0.934	2	0	14	-	0			15
3	0.902	2	0	14	-	0			15
4	0.871	3	0	15	-	0			15
5	0.842	3	0	15	-	0			15
6	0.814	3	0	16	-	0			15
7	0.786	3	0	16	-	0			15
8	0.759	3	0	16	-	0			15
9	0.734	4	0	17	-	0			15
10	0.709	4	0	17	-	0			15
11	0.685	4	0	18	-	0			15
12	0.662	4	0	18	-	0			15
13	0.639	4	0	18	-	0			15
14	0.618	5	0	19	-	0			15
15	0.597	5	0	19	-	0			15
16	0.577	5	0	20	-	0			14
17	0.557	5	0	20	-	0			14
18	0.538	5	0	20	-	0			14
19	0.520	6	0	21	-	0			14
20	0.503	9	0	22	-	1			16
21	0.486	12	0	23	-	1			17
22	0.469	15	1	24	-	1			19
23	0.453	18	1	25	-	1			20
24	0.438	22	1	26	-	1			22
25	0.423	25	1	27	-	1			23
26	0.409	28	1	28	-	2			24
27	0.395	31	1	29	-	2			25
28	0.382	34	1	30	-	2			26
29	0.369	37	1	32	-	2			27
30	0.356	41	2	33	-	2			27
31	0.346	44	2	34	-	3			28
32	0.336	47	2	35	-	3			29
33	0.326	50	2	36	-	3			30
34	0.317	53	2	37	-	3			30
35	0.307	57	2	38	-	3			31
36	0.298	60	2	39	-	3			31
37	0.290	63	2	40	-	4			32
38	0.281	66	2	41	-	4			32
39	0.273	69	3	42	-	4			32
40	0.265	72	3	43	-	4			33
41	0.257	76	3	45	-	4			33
42	0.250	79	3	46	-	5			33
43	0.243	82	3	47	-	5			33
44	0.236	85	3	48	-	5			33
45	0.229	88	3	49	-	5			33
46	0.222	92	3	50	-	5			33
47	0.216	95	4	51	-	6			33
48	0.209	98	4	52	-	6			33
49	0.203	101	4	53	-	6			33
50	0.197	146	10	55	-	9			43
51	0.192	191	16	56	-	12			53
52	0.186	237	22	58	-	15			62
53	0.181	282	29	59	-	17			70
54	0.175	327	35	61	-	20			78
55	0.170	372	41	62	-	23			85
56	0.165	417	47	64	-	26			92
57	0.160	462	54	65	-	29			98
58	0.156	507	60	67	-	32			104
59	0.151	552	66	68	-	35			109
60	0.147	598	72	70	-	38			114
61	0.143	643	79	71	-	40			119
62	0.138	688	85	73	-	43			123
63	0.134	733	91	74	-	46			127
64	0.130	778	97	76	-	49			130
65	0.127	823	103	77	-	52			134
66	0.123	868	110	79	-	55			137
67	0.119	913	116	80	-	58			139
68	0.116	959	122	82	-	61			142
69	0.112	1,004	128	83	-	63			144
70	0.109	1,049	135	85	-	66			146
71	0.106	1,094	141	86	-	69			147
72	0.103	1,139	147	88	-	72			149
73	0.100	1,184	153	89	-	75			150
74	0.097	1,229	159	91	-	78			151
75	0.094	1,275	166	93	-	81			152
76	0.092	1,320	172	94	-	84			153
77	0.090	1,365	178	96	-	86			155
78	0.087	1,410	184	97	-	89			156
79	0.085	1,455	191	99	-	92			157
80	0.083	1,500	197	100	-	95			158
81	0.081	1,545	203	102	-	98			158
82	0.079	1,590	209	103	-	101			159
83	0.077	1,636	216	105	-	104			159
84	0.075	1,681	222	106	-	107			160
85	0.074	1,726	228	108	-	109			160
86	0.072	1,771	234	109	-	112			160
87	0.070	1,816	240	111	-	115			160
88	0.068	1,861	247	112	-	118			160
89	0.067	1,906	253	114	-	121			160
90	0.065	1,951	259	115	-	124			159
91	0.063	1,997	265	117	-	127			159
92	0.062	2,042	272	118	-	130			159
93	0.060	2,087	278	120	-	132			158
94	0.059	2,132	284	121	-	135			158
95	0.057	2,177	290	123	-	138			157
96	0.056	2,222	297	124	-	141			156
97	0.055	2,267	303	126	-	144			155
98	0.053	2,312	309	127	-	147			155
99	0.052	2,358	315	129	-	150			154
		64321.45	8194.96	6051.19	0.00	4060.92			16428.80



		Sheet Nr.	
Client/Authority			
Environment Agency			
Project name	**Option:**		
Exe Estuary Strategy - FCRMU13	Do nothing		
Project reference	0		
Base date for estimates (year 0)	Q2 2010		
Scaling factor (e.g. £m, £k, £)	£k	Prepared (date)	13/09/2012
Discount rate	Variable	Printed	18/12/2012
		Prepared by	AMC
		Checked by	PJC
		Checked date	18/12/2012

	AAD Year 0	AAD Year 19	AAD Year 49	AAD Year 99	
	0	**19**	**49**	**99**	
Residential property	0	0	9	224	**£k**
Ind/commercial (direct)	0	0	0	1	**£k**
Temp Acc	2	3	5	11	**£k**
Traffic related	0	0	0	0	**£k**
Emergency services	0	0	0	13	**£k**
Agricultural	0	0	0	0	**£k**
	2	4	14	248	
PV Total Damage	856				**£k**
Total Write-off	162				**£k**

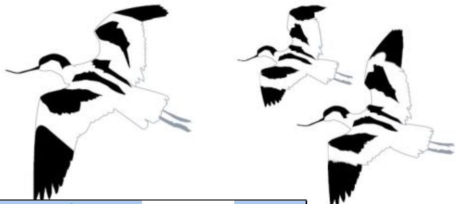
		AAD Post Breach					**£ 162**	**£ -**	**£ 856**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		546	**1**	**116**	**-**	**31**			
0	1.000	0	-	2	-	0	162		164
1	0.966	0	-	2	-	0			2
2	0.934	0	-	2	-	0			2
3	0.902	0	-	2	-	0			2
4	0.871	0	-	2	-	0			2
5	0.842	0	-	2	-	0			2
6	0.814	0	-	2	-	0			2
7	0.786	0	-	3	-	0			2
8	0.759	0	-	3	-	0			2
9	0.734	0	-	3	-	0			2
10	0.709	0	-	3	-	0			2
11	0.685	0	-	3	-	0			2
12	0.662	0	-	3	-	0			2
13	0.639	0	-	3	-	0			2
14	0.618	0	-	3	-	0			2
15	0.597	0	-	3	-	0			2
16	0.577	0	-	3	-	0			2
17	0.557	0	-	3	-	0			2
18	0.538	0	-	3	-	0			2
19	0.520	0	-	3	-	0			2
20	0.503	1	0	3	-	0			2
21	0.486	1	0	3	-	0			2
22	0.469	1	0	3	-	0			2
23	0.453	1	0	3	-	0			2
24	0.438	2	0	4	-	0			2
25	0.423	2	0	4	-	0			2
26	0.409	2	0	4	-	0			2
27	0.395	3	0	4	-	0			3
28	0.382	3	0	4	-	0			3
29	0.369	3	0	4	-	0			3
30	0.356	3	0	4	-	0			3
31	0.346	4	0	4	-	0			3
32	0.336	4	0	4	-	0			3
33	0.326	4	0	4	-	0			3
34	0.317	5	0	4	-	0			3
35	0.307	5	0	4	-	0			3
36	0.298	5	0	4	-	0			3
37	0.290	5	0	4	-	0			3
38	0.281	6	0	4	-	0			3
39	0.273	6	0	4	-	0			3
40	0.265	6	0	4	-	0			3
41	0.257	7	0	5	-	0			3
42	0.250	7	0	5	-	0			3
43	0.243	7	0	5	-	0			3
44	0.236	7	0	5	-	0			3
45	0.229	8	0	5	-	0			3
46	0.222	8	0	5	-	0			3
47	0.216	8	0	5	-	0			3
48	0.209	9	0	5	-	0			3
49	0.203	9	0	5	-	0			3
50	0.197	13	0	5	-	1			4
51	0.192	17	0	5	-	1			5
52	0.186	22	0	5	-	1			5
53	0.181	26	0	5	-	1			6
54	0.175	30	0	6	-	2			7
55	0.170	35	0	6	-	2			7
56	0.165	39	0	6	-	2			8
57	0.160	43	0	6	-	2			8
58	0.156	48	0	6	-	3			9
59	0.151	52	0	6	-	3			9
60	0.147	56	0	6	-	3			10
61	0.143	60	0	6	-	3			10
62	0.138	65	0	6	-	4			10
63	0.134	69	0	7	-	4			11
64	0.130	73	0	7	-	4			11
65	0.127	78	0	7	-	4			11
66	0.123	82	0	7	-	5			12
67	0.119	86	0	7	-	5			12
68	0.116	91	0	7	-	5			12
69	0.112	95	0	7	-	5			12
70	0.109	99	0	7	-	6			12
71	0.106	103	0	7	-	6			12
72	0.103	108	0	8	-	6			13
73	0.100	112	0	8	-	6			13
74	0.097	116	0	8	-	7			13
75	0.094	121	0	8	-	7			13
76	0.092	125	0	8	-	7			13
77	0.090	129	0	8	-	7			13
78	0.087	134	0	8	-	8			13
79	0.085	138	0	8	-	8			13
80	0.083	142	0	8	-	8			13
81	0.081	146	0	9	-	8			13
82	0.079	151	0	9	-	8			13
83	0.077	155	0	9	-	9			13
84	0.075	159	0	9	-	9			13
85	0.074	164	0	9	-	9			13
86	0.072	168	0	9	-	9			13
87	0.070	172	1	9	-	10			13
88	0.068	177	1	9	-	10			13
89	0.067	181	1	9	-	10			13
90	0.065	185	1	10	-	10			13
91	0.063	189	1	10	-	11			13
92	0.062	194	1	10	-	11			13
93	0.060	198	1	10	-	11			13
94	0.059	202	1	10	-	11			13
95	0.057	207	1	10	-	12			13
96	0.056	211	1	10	-	12			13
97	0.055	215	1	10	-	12			13
98	0.053	220	1	10	-	12			13
99	0.052	224	1	11	-	13			13
		6071.58	17.48	569.42	0.00	340.99			856.30



						Sheet Nr.	
Client/Authority							
Environment Agency							
Project name		**Option:**					
Exe Estuary Strategy - FCRMU14		Do nothing					
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**	
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**	

Scaling factor (e.g. £m, £k, £)	£k	Residential property	2	4	203	3,644 **£k**	Prepared (date) 14/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	2	149 **£k**	Printed 18/12/2012
		Temp Acc	2	8	86	141 **£k**	Prepared by AMC
		Traffic related	3	13	0	0 **£k**	Checked by PJC
		Emergency services	0	0	22	406 **£k**	Checked date 18/12/2012
		Agricultural	0	0	0	0 **£k**	
			7	26	312	4,340	
		PV Total Damage	27,158			**£k**	
		Total Write-off	15,433			**£k**	

		AAD Post Breach					**£ 15,433**	**£ -**	**£ 27,158**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		9,306	**330**	**1,058**	**-**	**1,031**			
0	1.000	2	0	2		0	15,433		15437
1	0.966	2	0	2		0			4
2	0.934	2	0	3		0			5
3	0.902	2	0	3		0			5
4	0.871	2	0	3		0			5
5	0.842	2	0	4		0			5
6	0.814	2	0	4		0			5
7	0.786	3	0	4		0			6
8	0.759	3	0	5		0			6
9	0.734	3	0	5		0			6
10	0.709	3	0	5		0			6
11	0.685	3	0	6		0			6
12	0.662	3	0	6		0			6
13	0.639	3	0	6		0			6
14	0.618	3	0	7		0			6
15	0.597	4	0	7		0			7
16	0.577	4	0	7		0			7
17	0.557	4	0	8		0			7
18	0.538	4	0	8		0			7
19	0.520	4	0	8		0			7
20	0.503	11	0	11		1			11
21	0.486	17	0	13		2			16
22	0.469	24	0	16		3			20
23	0.453	31	0	19		3			24
24	0.438	37	0	21		4			27
25	0.423	44	0	24		5			31
26	0.409	50	0	26		5			34
27	0.395	57	1	29		6			37
28	0.382	64	1	31		7			39
29	0.369	70	1	34		8			42
30	0.356	77	1	37		8			44
31	0.346	84	1	39		9			46
32	0.336	90	1	42		10			48
33	0.326	97	1	44		10			50
34	0.317	103	1	47		11			51
35	0.307	110	1	50		12			53
36	0.298	117	1	52		13			54
37	0.290	123	1	55		13			56
38	0.281	130	1	57		14			57
39	0.273	137	1	60		15			58
40	0.265	143	1	63		15			59
41	0.257	150	1	65		16			60
42	0.250	156	1	68		17			61
43	0.243	163	1	70		18			61
44	0.236	170	1	73		18			62
45	0.229	176	1	75		19			62
46	0.222	183	2	78		20			63
47	0.216	190	2	81		20			63
48	0.209	196	2	83		21			63
49	0.203	203	2	86	-	22			63
50	0.197	272	5	87	-	30			77
51	0.192	340	8	88	-	37			91
52	0.186	409	11	89	-	45			103
53	0.181	478	13	90	-	53			115
54	0.175	547	16	91	-	60			125
55	0.170	616	19	92	-	68			135
56	0.165	685	22	94	-	76			145
57	0.160	753	25	95	-	83			153
58	0.156	822	28	96	-	91			162
59	0.151	891	31	97	-	99			169
60	0.147	960	34	98	-	106			176
61	0.143	1,029	37	99	-	114			182
62	0.138	1,098	40	100	-	122			188
63	0.134	1,166	43	101	-	129			193
64	0.130	1,235	46	102	-	137			198
65	0.127	1,304	49	104	-	145			203
66	0.123	1,373	52	105	-	152			207
67	0.119	1,442	55	106	-	160			210
68	0.116	1,511	58	107	-	168			214
69	0.112	1,579	61	108	-	175			216
70	0.109	1,648	64	109	-	183			219
71	0.106	1,717	67	110	-	191			221
72	0.103	1,786	69	111	-	199			223
73	0.100	1,855	72	112	-	206			224
74	0.097	1,924	75	114	-	214			226
75	0.094	1,992	78	115	-	222			227
76	0.092	2,061	81	116	-	229			229
77	0.090	2,130	84	117	-	237			230
78	0.087	2,199	87	118	-	245			232
79	0.085	2,268	90	119	-	252			233
80	0.083	2,337	93	120	-	260			234
81	0.081	2,405	96	121	-	268			235
82	0.079	2,474	99	122	-	275			235
83	0.077	2,543	102	124	-	283			236
84	0.075	2,612	105	125	-	291			236
85	0.074	2,681	108	126	-	298			236
86	0.072	2,749	111	127	-	306			236
87	0.070	2,818	114	128	-	314			236
88	0.068	2,887	117	129	-	321			236
89	0.067	2,956	120	130	-	329			236
90	0.065	3,025	123	131	-	337			235
91	0.063	3,094	126	132	-	344			235
92	0.062	3,162	128	133	-	352			234
93	0.060	3,231	131	135	-	360			233
94	0.059	3,300	134	136	-	367			232
95	0.057	3,369	137	137	-	375			231
96	0.056	3,438	140	138	-	383			230
97	0.055	3,507	143	139	-	391			229
98	0.053	3,575	146	140	-	398			227
99	0.052	3,644	149	141	-	406			226
		101158.07	3871.26	7256.15	0.00	11238.14			27158.07

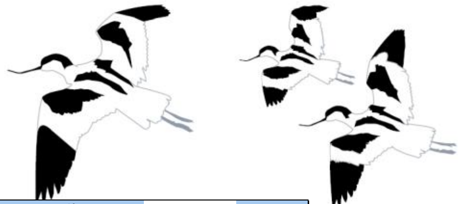


Sheet Nr.

Client/Authority
Environment Agency
Project name **Option:**
Exe Estuary Strategy - FCRMU15 Do nothing

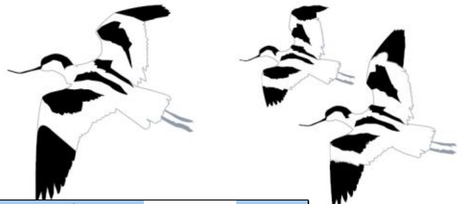
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**			
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**			
Scaling factor (e.g. £m, £k, £)	£k	Residential property	0	0	3	184	**£k**	Prepared (date)	14/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	0	16	**£k**	Printed	18/12/2012
		Temp Acc	0	2	21	28	**£k**	Prepared by	AMC
		Railway Costs	2	5	40	0	**£k**	Checked by	PJC
		Emergency services	0	0	0	21	**£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0	**£k**		
			2	7	65	249			
		PV Total Damage	10,663				**£k**		
		Total Write-off	9,673				**£k**		

		AAD Post Breach					**£ 9,673**	**£ -**	**£ 10,663**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Railway Costs AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		418	**35**	**241**	**247**	**48**			
0	1.000	0	0	0	2	0	9,673		9676
1	0.966	0	0	0	2	0			3
2	0.934	0	0	0	2	0			3
3	0.902	0	0	1	3	0			3
4	0.871	0	0	1	3	0			3
5	0.842	0	0	1	3	0			3
6	0.814	0	0	1	3	0			3
7	0.786	0	0	1	3	0			3
8	0.759	0	0	1	3	0			3
9	0.734	0	0	1	3	0			3
10	0.709	0	0	1	4	0			3
11	0.685	0	0	1	4	0			3
12	0.662	0	0	1	4	0			4
13	0.639	0	0	1	4	0			4
14	0.618	0	0	1	4	0			4
15	0.597	0	0	2	4	0			4
16	0.577	0	0	2	5	0			4
17	0.557	0	0	2	5	0			4
18	0.538	0	0	2	5	0			4
19	0.520	0	0	2	5	0			4
20	0.503	0	0	3	6	0			5
21	0.486	0	0	3	7	0			5
22	0.469	0	0	4	8	0			6
23	0.453	1	0	4	10	0			7
24	0.438	1	0	5	11	0			7
25	0.423	1	0	6	12	0			8
26	0.409	1	0	6	13	0			8
27	0.395	1	0	7	14	0			9
28	0.382	1	0	8	15	0			9
29	0.369	1	0	8	17	0			10
30	0.356	1	0	9	18	0			10
31	0.346	1	0	10	19	0			10
32	0.336	2	0	10	20	0			11
33	0.326	2	0	11	21	0			11
34	0.317	2	0	11	22	0			11
35	0.307	2	0	12	24	0			12
36	0.298	2	0	13	25	0			12
37	0.290	2	0	13	26	0			12
38	0.281	2	0	14	27	0			12
39	0.273	2	0	15	28	0			12
40	0.265	2	0	15	29	0			13
41	0.257	2	0	16	30	0			13
42	0.250	3	0	17	32	0			13
43	0.243	3	0	17	33	0			13
44	0.236	3	0	18	34	0			13
45	0.229	3	0	18	35	0			13
46	0.222	3	0	19	36	0			13
47	0.216	3	0	20	37	0			13
48	0.209	3	0	20	39	0			13
49	0.203	3	0	21	40	0			13
50	0.197	7	1	21	-	1			6
51	0.192	11	1	21	-	1			6
52	0.186	14	1	21	-	2			7
53	0.181	18	1	22	-	2			8
54	0.175	21	2	22	-	2			8
55	0.170	25	2	22	-	3			9
56	0.165	29	2	22	-	3			9
57	0.160	32	3	22	-	4			10
58	0.156	36	3	22	-	4			10
59	0.151	40	3	22	-	5			11
60	0.147	43	4	22	-	5			11
61	0.143	47	4	23	-	5			11
62	0.138	50	4	23	-	6			12
63	0.134	54	5	23	-	6			12
64	0.130	58	5	23	-	7			12
65	0.127	61	5	23	-	7			12
66	0.123	65	5	23	-	8			12
67	0.119	68	6	23	-	8			13
68	0.116	72	6	24	-	8			13
69	0.112	76	6	24	-	9			13
70	0.109	79	7	24	-	9			13
71	0.106	83	7	24	-	10			13
72	0.103	87	7	24	-	10			13
73	0.100	90	8	24	-	10			13
74	0.097	94	8	24	-	11			13
75	0.094	97	8	24	-	11			13
76	0.092	101	9	25	-	12			13
77	0.090	105	9	25	-	12			13
78	0.087	108	9	25	-	13			14
79	0.085	112	9	25	-	13			14
80	0.083	116	10	25	-	13			14
81	0.081	119	10	25	-	14			14
82	0.079	123	10	25	-	14			14
83	0.077	126	11	25	-	15			14
84	0.075	130	11	26	-	15			14
85	0.074	134	11	26	-	16			14
86	0.072	137	12	26	-	16			14
87	0.070	141	12	26	-	16			14
88	0.068	145	12	26	-	17			14
89	0.067	148	13	26	-	17			14
90	0.065	152	13	26	-	18			14
91	0.063	155	13	27	-	18			14
92	0.062	159	13	27	-	18			13
93	0.060	163	14	27	-	19			13
94	0.059	166	14	27	-	19			13
95	0.057	170	14	27	-	20			13
96	0.056	173	15	27	-	20			13
97	0.055	177	15	27	-	21			13
98	0.053	181	15	27	-	21			13
99	0.052	184	16	28	-	21			13
		4838.59	405.80	1593.78	757.99	561.15			10663.29



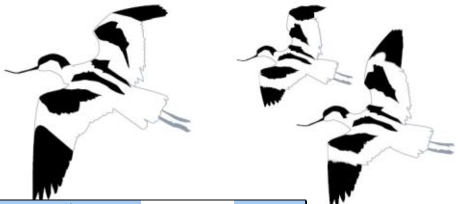
								Sheet Nr.	
Client/Authority									
Environment Agency									
Project name		**Option:**							
Exe Estuary Strategy - FCRMU16		Do nothing							
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**			
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**			
Scaling factor (e.g. £m, £k, £)	£k	Residential property	6	16	287	5,547	**£k**	Prepared (date)	14/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	0	23	**£k**	Printed	18/12/2012
		Temp Acc	5	198	232	262	**£k**	Prepared by	AMC
		Railway Costs	2	40	3,641	0	**£k**	Checked by	PJC
		Emergency services	1	2	31	596	**£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0	**£k**		
			13	255	4,191	6,428			
		PV Total Damage	145,535				**£k**		
		Total Write-off	107,491				**£k**		

		AAD Post Breach					**£ 114,691**	**£ -**	**£ 145,535**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Railway Costs AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		14,145	**51**	**4,699**	**16,167**	**1,519**			
0	1.000	6	0	5	2	1	107,491		107504
1	0.966	6	0	15	4	1			25
2	0.934	7	0	25	6	1			36
3	0.902	7	0	35	8	1			46
4	0.871	8	0	46	10	1			56
5	0.842	8	0	56	12	1			65
6	0.814	9	0	66	14	1			73
7	0.786	9	0	76	16	1			81
8	0.759	10	0	86	18	1			87
9	0.734	11	0	96	20	1			94
10	0.709	11	0	106	22	1			100
11	0.685	12	0	117	24	1			105
12	0.662	12	0	127	26	1			110
13	0.639	13	0	137	28	1			114
14	0.618	13	0	147	30	1			118
15	0.597	14	0	157	32	1			122
16	0.577	14	0	167	34	2			125
17	0.557	15	0	178	36	2			128
18	0.538	15	0	188	38	2			131
19	0.520	16	0	198	40	2			133
20	0.503	25	0	199	160	3			194
21	0.486	34	0	200	280	4			251
22	0.469	43	0	201	400	5			304
23	0.453	52	0	202	520	6			354
24	0.438	61	0	204	640	7			399
25	0.423	70	0	205	760	8			441
26	0.409	79	0	206	880	8			480
27	0.395	88	0	207	1,000	9			515
28	0.382	97	0	208	1,120	10			548
29	0.369	106	0	209	1,240	11			578
30	0.356	115	0	210	1,360	12			605
31	0.346	124	0	211	1,480	13			633
32	0.336	133	0	213	1,600	14			658
33	0.326	142	0	214	1,720	15			682
34	0.317	151	0	215	1,840	16			704
35	0.307	160	0	216	1,960	17			723
36	0.298	170	0	217	2,080	18			742
37	0.290	179	0	218	2,200	19			758
38	0.281	188	0	219	2,321	20			773
39	0.273	197	0	220	2,441	21			786
40	0.265	206	0	221	2,561	22			798
41	0.257	215	0	223	2,681	23			808
42	0.250	224	0	224	2,801	24			818
43	0.243	233	0	225	2,921	25			826
44	0.236	242	0	226	3,041	26			833
45	0.229	251	0	227	3,161	27			838
46	0.222	260	0	228	3,281	28			843
47	0.216	269	0	229	3,401	29			847
48	0.209	278	0	230	3,521	30			850
49	0.203	287	0	232	3,641	31	7,200		2314
50	0.197	392	1	232	-	42			132
51	0.192	497	1	233	-	53			150
52	0.186	603	2	233	-	65			168
53	0.181	708	2	234	-	76			184
54	0.175	813	3	235	-	87			199
55	0.170	918	3	235	-	99			214
56	0.165	1,023	3	236	-	110			227
57	0.160	1,129	4	236	-	121			239
58	0.156	1,234	4	237	-	132			250
59	0.151	1,339	5	238	-	144			261
60	0.147	1,444	5	238	-	155			271
61	0.143	1,549	6	239	-	166			279
62	0.138	1,655	6	239	-	178			288
63	0.134	1,760	7	240	-	189			295
64	0.130	1,865	7	241	-	200			302
65	0.127	1,970	8	241	-	212			308
66	0.123	2,076	8	242	-	223			313
67	0.119	2,181	8	242	-	234			318
68	0.116	2,286	9	243	-	246			323
69	0.112	2,391	9	244	-	257			326
70	0.109	2,496	10	244	-	268			330
71	0.106	2,602	10	245	-	279			333
72	0.103	2,707	11	245	-	291			335
73	0.100	2,812	11	246	-	302			337
74	0.097	2,917	12	247	-	313			339
75	0.094	3,022	12	247	-	325			340
76	0.092	3,128	13	248	-	336			342
77	0.090	3,233	13	248	-	347			344
78	0.087	3,338	13	249	-	359			346
79	0.085	3,443	14	250	-	370			348
80	0.083	3,548	14	250	-	381			349
81	0.081	3,654	15	251	-	393			350
82	0.079	3,759	15	251	-	404			351
83	0.077	3,864	16	252	-	415			352
84	0.075	3,969	16	253	-	426			352
85	0.074	4,074	17	253	-	438			352
86	0.072	4,180	17	254	-	449			352
87	0.070	4,285	18	254	-	460			351
88	0.068	4,390	18	255	-	472			351
89	0.067	4,495	18	256	-	483			350
90	0.065	4,601	19	256	-	494			349
91	0.063	4,706	19	257	-	506			348
92	0.062	4,811	20	258	-	517			347
93	0.060	4,916	20	258	-	528			346
94	0.059	5,021	21	259	-	540			344
95	0.057	5,127	21	259	-	551			343
96	0.056	5,232	22	260	-	562			341
97	0.055	5,337	22	261	-	573			339
98	0.053	5,442	23	261	-	585			337
99	0.052	5,547	23	262	-	596			335
		153384.76	599.58	20835.65	57429.33	16476.33			145534.89



								Sheet Nr.	
Client/Authority									
Environment Agency									
Project name		**Option:**							
Exe Estuary Strategy - FCRMU17		Do nothing							
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**			
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**			
Scaling factor (e.g. £m, £k, £)	£k	Residential property	1	2	33	697	**£k**	Prepared (date)	14/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	1	60	**£k**	Printed	18/12/2012
		Temp Acc	12	29	41	61	**£k**	Prepared by	AMC
		Traffic related	0	0	0	89	**£k**	Checked by	PJC
		Emergency services	0	0	4	81	**£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0	**£k**		
			13	32	78	988			
		PV Total Damage	9,893				**£k**		
		Total Write-off	6,918				**£k**		

		AAD Post Breach					**£ 6,918**	**£ -**	**£ 9,893**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Traffic related AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		1,752	**134**	**886**	**-**	**202**			
0	1.000	1	0	12		0	6,918		6931
1	0.966	1	0	13		0			13
2	0.934	1	0	14		0			14
3	0.902	1	0	15		0			14
4	0.871	1	0	16		0			15
5	0.842	1	0	17		0			15
6	0.814	1	0	17		0			15
7	0.786	1	0	18		0			16
8	0.759	1	0	19		0			16
9	0.734	1	0	20		0			16
10	0.709	1	0	21		0			16
11	0.685	1	0	22		0			16
12	0.662	2	0	23		0			16
13	0.639	2	0	24		0			16
14	0.618	2	0	25		0			16
15	0.597	2	0	26		0			16
16	0.577	2	0	27		0			16
17	0.557	2	0	27		0			16
18	0.538	2	0	28		0			16
19	0.520	2	0	29		0			16
20	0.503	3	0	30		0			17
21	0.486	4	0	30		0			17
22	0.469	5	0	30		1			17
23	0.453	6	0	31		1			17
24	0.438	7	0	31		1			17
25	0.423	8	0	32		1			17
26	0.409	9	0	32		1			17
27	0.395	10	0	32		1			17
28	0.382	11	0	33		1			17
29	0.369	12	0	33		1			17
30	0.356	13	0	34		1			17
31	0.346	14	0	34		2			17
32	0.336	15	0	34		2			17
33	0.326	16	0	35		2			17
34	0.317	17	0	35		2			17
35	0.307	18	0	35		2			17
36	0.298	19	0	36		2			17
37	0.290	20	0	36		2			17
38	0.281	21	0	37		2			17
39	0.273	23	1	37		2			17
40	0.265	24	1	37		3			17
41	0.257	25	1	38		3			17
42	0.250	26	1	38		3			17
43	0.243	27	1	39		3			17
44	0.236	28	1	39		3			17
45	0.229	29	1	39		3			16
46	0.222	30	1	40		3			16
47	0.216	31	1	40		3			16
48	0.209	32	1	40		3			16
49	0.203	33	1	41		4			16
50	0.197	46	2	41		5			19
51	0.192	59	3	42		7			21
52	0.186	73	4	42		8			24
53	0.181	86	6	43		10			26
54	0.175	99	7	43		11			28
55	0.170	112	8	43		13			30
56	0.165	126	9	44		14			32
57	0.160	139	10	44		16			34
58	0.156	152	12	45		18			35
59	0.151	166	13	45		19			37
60	0.147	179	14	45		21			38
61	0.143	192	15	46		22			39
62	0.138	205	16	46		24			40
63	0.134	219	17	47		25			41
64	0.130	232	19	47		27			42
65	0.127	245	20	47		28			43
66	0.123	259	21	48		30			44
67	0.119	272	22	48		31			45
68	0.116	285	23	49		33			45
69	0.112	298	25	49		35			46
70	0.109	312	26	49		36			46
71	0.106	325	27	50		38			47
72	0.103	338	28	50		39			47
73	0.100	352	29	51		41			47
74	0.097	365	31	51		42			47
75	0.094	378	32	52		44			48
76	0.092	391	33	52		45			48
77	0.090	405	34	52		47			48
78	0.087	418	35	53		49			49
79	0.085	431	37	53		50			49
80	0.083	444	38	54		52			49
81	0.081	458	39	54		53			49
82	0.079	471	40	54		55			49
83	0.077	484	41	55		56			49
84	0.075	498	43	55		58			49
85	0.074	511	44	56		59			49
86	0.072	524	45	56		61			49
87	0.070	537	46	56		62			49
88	0.068	551	47	57		64			49
89	0.067	564	49	57		66			49
90	0.065	577	50	58		67			49
91	0.063	591	51	58		69			49
92	0.062	604	52	59		70			49
93	0.060	617	53	59		72			48
94	0.059	630	55	59		73			48
95	0.057	644	56	60		75			48
96	0.056	657	57	60		76			48
97	0.055	670	58	61		78			47
98	0.053	684	59	61		79			47
99	0.052	697	60	61		81			47
		19135.82	1573.10	4038.96	0.00	2215.85			9892.72



								Sheet Nr.	
Client/Authority									
Environment Agency									
Project name		**Option:**							
Exe Estuary Strategy - FCRMU18		Do nothing							
Project reference	0		**AAD Year 0**	**AAD Year 19**	**AAD Year 49**	**AAD Year 99**			
Base date for estimates (year 0)	Q2 2010		**0**	**19**	**49**	**99**			
Scaling factor (e.g. £m, £k, £)	£k	Residential property	0	1	74	1,182	**£k**	Prepared (date)	14/09/2012
Discount rate	Variable	Ind/commercial (direct)	0	0	0	0	**£k**	Printed	18/12/2012
		Temp Acc	0	0	5	14	**£k**	Prepared by	AMC
		Railway Costs	2	40	3,641	0	**£k**	Checked by	PJC
		Emergency services	0	0	8	127	**£k**	Checked date	18/12/2012
		Agricultural	0	0	0	0	**£k**		
			3	41	3,728	1,323			
		PV Total Damage	21,482				**£k**		
		Total Write-off	9,000				**£k**		

		AAD Post Breach					**£ 9,000**	**£ -**	**£ 21,482**
Year	**Discount Factor**	**Residential property AAD**	**Ind/commercial (direct) AAD**	**Temp Acc**	**Railway Costs AAD**	**Emergency services AAD**	**Property Write-off**		**PV damages**
		3,082	**0**	**74**	**16,167**	**330**			
0	1.000	0	-	0	2	0			3
1	0.966	0	-	0	4	0			5
2	0.934	1	-	0	6	0			6
3	0.902	1	-	0	8	0			8
4	0.871	1	-	0	10	0			10
5	0.842	1	-	0	12	0			11
6	0.814	1	-	0	14	0			12
7	0.786	1	-	0	16	0			13
8	0.759	1	-	0	18	0			15
9	0.734	1	-	0	20	0			16
10	0.709	1	-	0	22	0			16
11	0.685	1	-	0	24	0			17
12	0.662	1	-	0	26	0			18
13	0.639	1	-	0	28	0			19
14	0.618	1	-	0	30	0			19
15	0.597	1	-	0	32	0			20
16	0.577	1	-	0	34	0			20
17	0.557	1	-	0	36	0			21
18	0.538	1	-	0	38	0			21
19	0.520	1	-	0	40	0			22
20	0.503	4	-	0	160	0			83
21	0.486	6	-	1	280	1			139
22	0.469	9	-	1	400	1			192
23	0.453	11	-	1	520	1			242
24	0.438	13	-	1	640	1			287
25	0.423	16	-	1	760	2			330
26	0.409	18	-	1	880	2			369
27	0.395	21	-	2	1,000	2			405
28	0.382	23	-	2	1,120	2			438
29	0.369	26	-	2	1,240	3			468
30	0.356	28	-	2	1,360	3			496
31	0.346	31	-	2	1,480	3			524
32	0.336	33	-	2	1,600	4			550
33	0.326	35	-	3	1,720	4			575
34	0.317	38	-	3	1,840	4			597
35	0.307	40	-	3	1,960	4			617
36	0.298	43	-	3	2,080	5			636
37	0.290	45	-	3	2,200	5			653
38	0.281	48	-	3	2,321	5			668
39	0.273	50	-	4	2,441	5			682
40	0.265	52	-	4	2,561	6			695
41	0.257	55	-	4	2,681	6			707
42	0.250	57	-	4	2,801	6			717
43	0.243	60	-	4	2,921	6			726
44	0.236	62	-	4	3,041	7			733
45	0.229	65	-	5	3,161	7			740
46	0.222	67	-	5	3,281	7			746
47	0.216	69	-	5	3,401	7			751
48	0.209	72	-	5	3,521	8			755
49	0.203	74	-	5	3,641	8	9,000		2586
50	0.197	96	0	5	-	10			22
51	0.192	119	0	6	-	13			26
52	0.186	141	0	6	-	15			30
53	0.181	163	0	6	-	17			34
54	0.175	185	0	6	-	20			37
55	0.170	207	0	6	-	22			40
56	0.165	229	0	6	-	25			43
57	0.160	252	0	7	-	27			46
58	0.156	274	0	7	-	29			48
59	0.151	296	0	7	-	32			51
60	0.147	318	0	7	-	34			53
61	0.143	340	0	7	-	36			55
62	0.138	362	0	7	-	39			57
63	0.134	384	0	8	-	41			58
64	0.130	407	0	8	-	44			60
65	0.127	429	0	8	-	46			61
66	0.123	451	0	8	-	48			62
67	0.119	473	0	8	-	51			64
68	0.116	495	0	9	-	53			65
69	0.112	517	0	9	-	55			65
70	0.109	540	0	9	-	58			66
71	0.106	562	0	9	-	60			67
72	0.103	584	0	9	-	62			68
73	0.100	606	0	9	-	65			68
74	0.097	628	0	10	-	67			68
75	0.094	650	0	10	-	70			69
76	0.092	673	0	10	-	72			69
77	0.090	695	0	10	-	74			70
78	0.087	717	0	10	-	77			70
79	0.085	739	0	10	-	79			71
80	0.083	761	0	11	-	81			71
81	0.081	783	0	11	-	84			71
82	0.079	805	0	11	-	86			72
83	0.077	828	0	11	-	89			72
84	0.075	850	0	11	-	91			72
85	0.074	872	0	12	-	93			72
86	0.072	894	0	12	-	96			72
87	0.070	916	0	12	-	98			72
88	0.068	938	0	12	-	100			72
89	0.067	961	0	12	-	103			72
90	0.065	983	0	12	-	105			72
91	0.063	1,005	0	13	-	108			71
92	0.062	1,027	0	13	-	110			71
93	0.060	1,049	0	13	-	112			71
94	0.059	1,071	0	13	-	115			71
95	0.057	1,094	0	13	-	117			70
96	0.056	1,116	0	13	-	119			70
97	0.055	1,138	0	14	-	122			70
98	0.053	1,160	0	14	-	124			69
99	0.052	1,182	0	14	-	127			69
		33154.02	5.67	574.03	57429.33	3548.09			21482.00

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