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Technical note

Project	Dawlish Warren & Exmouth Beach Recharge Study	**Date**	13 February 2012
Note	Standard of Protection against Wave Overtopping	**Ref**	GEEGAW TN07
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1 Introduction

This technical note summarises the assessment of the standard of protection from wave overtopping of the typical defence sections along Dawlish Warren spit and Exmouth Beach. These sections were identified using beach profiles obtained from the Plymouth Coastal Observatory (PCO).

Empirical overtopping relationships that best represented the defence type along each section were applied to estimate the existing standard of protection based on the methods presented in the EurOtop manual (EA 2007). In addition to these empirical overtopping relationships, the CLASH Neural Network tool has also been used to verify the results. This note consists of the following sections:

- Analysis inputs;
- Overtopping methodologies;
- Overtopping discharges;
- Current standards of protection;
- Conclusions and;
- Limitations.

2 Analysis Inputs

2.1 Wave climate and water levels

Joint probability analysis (JPA) has been carried out for this study for 4no. locations along the Dawlish Warren spit frontage and 4no. locations along Exmouth Beach.

Offshore wave and water level parameters have been transformed inshore using the Goda method as presented in The Rock Manual (CIRIA 2007).

All waves are assumed to be travelling in a direction perpendicular to the defences to give a worst case overtopping discharges which will allow for future changes in bathymetry.

2.2 Climate change

(a) Sea level rise

Relative sea level rise estimates have been downloaded from the UK Climate Projections web site (UKCP09). The Costal Flood Boundary Conditions for UK Mainland and Islands project (EA 2011) defines relative sea level rise as:

> *"UKCP09 relative sea level rise projections account for future land level movements. They also, for the first time, account for regional oceanographic effects. These regional effects arise from the difference in change in sea level for the region immediately surrounding the UK compared to the global mean."*

Three probability bands are provided 5% 50% and 95%iles. The data was downloaded for the medium emissions scenario as EA (2011) recommends the use of the 95%ile predictions as described below.

> *"It is recommended that RMAs do not use the central estimates of relative sea level rise from UKCP09 as the change factor for their investment decisions. Instead, it is recommended that the upper confidence band (95 percentile) medium emission projection is used"*

Overtopping has been calculated for year 0 (2011), year 50 (2061) and year 100 (2111). The data downloaded from the UKCP09 website is limited to year 2100 and as such needs to be extrapolated from year 2100 as recommended in EA (2011).

> *"When taking projections from UKCP09, change up to 2115 should be derived by extrapolating beyond 2100"*

The following sea level rise allowances have been used in the overtopping analysis.

SLR for use in overtopping calculations		**Calculation (m)**
Year	**SLR from 2011 (m)**	-
2011	0.000	-
2061	0.320	0.421 – 0.101
2111	0.755	0.856 (linear extrapolation) – 0.101

Table 1: Sea level rise allowances

To allow comparison with the sea level rise estimates provided in the Draft Coastal Processes report the following table contains sea level rise from UKCP09's Baseline of 1990 and the 2110 Baseline in Halcrow (2011, draft) for years 2030, 2060 and 2100.

Scenario	UKCP09	Halcrow (2011, draft)	Calculation
Year	From 1990 (m)	From 2110 (m)	-
2030	0.210	0.114	0.210 – 0.096
2060	0.413	0.317	0.413 – 0.096
2110	0.846 (linear extrapolation)	0.750	0.846 – 0.096

Table 2: Comparison of sea level rise allowances

(b) Storm surge

The Costal Flood Boundary Conditions project (EA 2011) provides the expected change to storm surge (table 4, pg 17). The extract provided below suggests that as a rigorous assessment of current extreme water levels has been carried out, extreme water levels plus sea level rise can be used.

> *"Surge and mean sea level changes can be taken to be additive and change to extreme coastal water levels can be evaluated by adding the mean relative sea level change to the current extreme coastal water level"*

Furthermore, it should be noted that the following statement was recorded from a meeting between Atkins-Halcrow and the Environment Agency on the Exe Estuary Flood Risk Management Strategy:

> *"With regard to the surge increase, Atkins-Halcrow (2011) met with representatives from the Environment Agency (and others), and it is apparent that the uncertainty with surge increase is even greater than for sea level rise, for example, it could be anything from zero increase to 0.7m." Source: (Atkins, pers. comm, 2011).*

(c) Wave climate

The Costal Flood Boundary Conditions project (EA 2011) highlights the significant uncertainty in future wave climate and suggest sensitivity analysis is carried out.

> *"Given the significant uncertainty both to the future position of the storm track over the UK and the projections of wave climate within UKCP09, it is recommended that RMAs employ a sensitivity analysis to understand the impact on flood risk and coastal change, and the form of any feasible options"*

A sensitivity check on the results has been undertaken based on an assumed 10% increase in wave heights for selection of the worst case overtopping discharges. This approach is commensurate with the previous Flood and Coastal Defence Project Appraisal Guidance Defra 2006).

2.3 Wave heights at the toe

The Goda method (CIRIA 2007) for transforming inshore wave heights uses beach toe levels taken from beach profiles and the average beach slope taken from a bathymetric survey recorded in 2011.

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2.4 Beach profiles locations

For the analysis of the overtopping discharge 8no. overtopping locations sections were considered based on the joint probability (JPA) locations calculated as part of this study. At Exmouth beach this consists of 3no. sections of hard defence and 1no. dune. At Dawlish this consists of 4no. sections of sand dune, the hard defences at the proximal end of Dawlish Warren spit have not been considered as part of this analysis. The beach profiles used for each location were for the following dates: most recently surveyed profiles, 21-1-11, and 3 post storm profiles for the following events:

- 21st January 2011 (most recent profile)
- 23rd
- October 2009 (post storm)
- 6th March 2010 (post storm)
- October 2010 (post storm)

Details of beach profiles, JPA locations and structure types are presented in Table 3.

JPA	Easting	Northing	Beach	Structure type
6	301500	79500	6a01767	Vertical seawall
7	301000	79600	6a01776	Vertical seawall
8	300500	79750	6a01792	Sand dune backed with seawall
9	300000	80200	6a01808	Revetment with vertical crest wall
12	299650	80000	6b00011	Sand dune
13	299400	79500	6b00021	Sand dune
14	299000	79000	6b00034	Sand dune
15	298700	78500	6b00042	Sand dune

Table 3: Beach profile locations and defence types

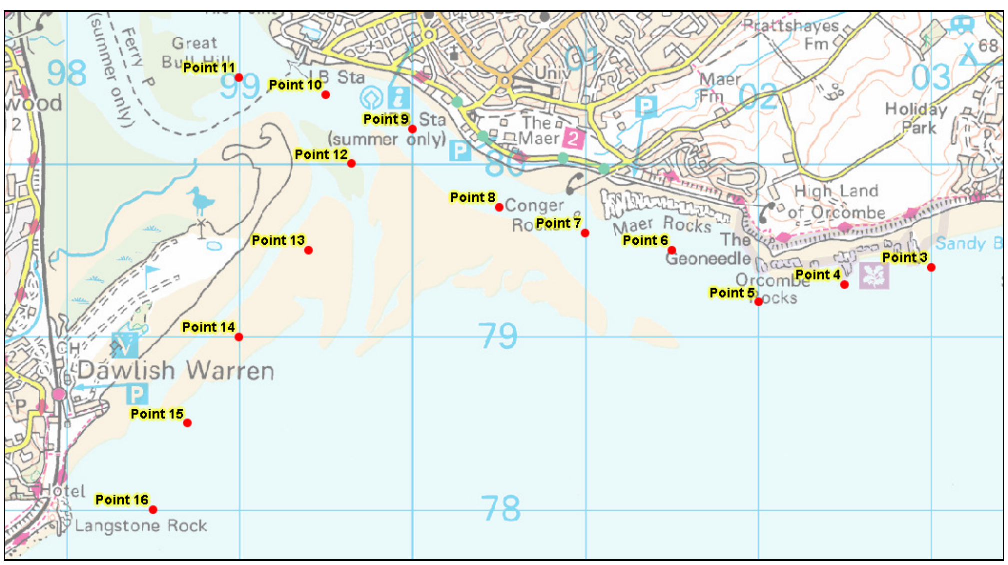

Figure 1: Plan of study area

2.5 Beach Profile Dimensions

Defence section parameters were extracted from beach profiles recorded on the dates detailed in Table 4.

	Beach profile survey dates	
	Dawlish Warren Spit	**Exmouth Beach**
Most recent survey	22-1-2011	23-1-11
October 2010 (post storm)	14-10-2010	7-11-2010
March 2010 (post storm)	06-03-2010	8-9-2010

Table 4: Beach profile survey dates

3 Overtopping Methodologies

The overtopping methodologies recommended in the EurOtop Manual were used for all profiles. For all defence types probabilistic calculation methods have been used this provides the mean (50 percentile) overtopping discharge.

3.1 Sand dunes

The Van der Meer equation for overtopping of bermed structures was used for the sand dune sections. Sand beaches can become quite compact, which facilitates the ease of run up; roughness coefficient of 1 was therefore used which is considered marginally conservative. Along Dawlish Warren spit there are sections of gabion revetment buried within the dunes, these have not been taken account of within this analysis as it has been assumed that the revetment will remain covered by beach material.

3.2 Seawall [vertical wall]

Section 7 of the EurOtop manual deals with vertical wall defences and was used to determine the overtopping discharges for these sections.

3.3 Seawall [revetment with wave return wall]

Section 5 of the EurOtop manual deals with smooth impermeable revetments and was used to determine the overtopping discharge for these sections. A roughness coefficient of 1 was used to represent the smooth concrete revetment.

3.4 Neural Network

As part of the EurOtop project a neural network database (CLASH database) was set up, this uses known overtopping discharges of particular structures to estimate the overtopping discharge for any structure type. The extract below from the Halcrow overtopping guidance note explains the method and limitations of the neural network.

The Neural Network (NN) is an intelligent database tool that considers a list of 15 hydraulic and structural input parameters, and through interrogation of the CLASH database returns an overtopping *result based upon interpolation of the 'best fitting' empirical measurements. Whilst the use of Neural Networks is a valid method for consideration it is something of a 'black box' approach and offers little scope for the user to understand how the output was determined and hence assess the validity of the results. Whilst in some cases the NN returns reasonable results, these are often structures where empirical methods are easy to undertake. Furthermore the CLASH network was only developed using data sets with recorded overtopping data (tests with "no overtopping" were not considered) and therefore this network always returns a quantitative prediction of overtopping, even in the range when no overtopping should be expected. The NN is often proposed because of a lack of valid or appropriate empirical methods and in particular for more unusual overtopping situations. However, the setup of the NN tool is based upon fairly standard defence types, and therefore when assessing atypical structures confidence in the NN is reduced.*

3.5 Overtopping thresholds for sand dunes.

The EurOtop manual (EA, 2007) does not provide overtopping thresholds for sand dune defences. A rate of 50 l/s/m is provided for reclamation cover i.e. a sand type defence crest, this value had been used to determine the standard of protection for the dune frontages.
It should be noted that under extreme conditions sand dunes are more likely to be breached through erosion to the front face rather than from overtopping discharge to the rear.

Table 3.5: Limits for overtopping for damage to the defence crest or rear slope

Hazard type and reason	Mean discharge q (l/s/m)
Embankment seawalls / sea dikes	
No damage if crest and rear slope are well protected	50-200
No damage to crest and rear face of grass covered embankment of clay	1-10
No damage to crest and rear face of embankment if not protected	0.1
Promenade or revetment seawalls	
Damage to paved or armoured promenade behind seawall	200
Damage to grassed or lightly protected promenade or reclamation cover	50

Extract 1. EurOtop tolerable overtopping discharges for structural damage

3.6 Overtopping thresholds

The standard of protection for these sections will be calculated for structural damage (50 l/s/m) and public safety (0.1 l/s/m) as detailed in the EurOtop manual, see extract 2.

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Table 3.2: Limits for overtopping for pedestrians

Hazard type and reason	Mean discharge q (l/s/m)	Max volume[(1)] V_{max} (l/m)
Trained staff, well shod and protected, expecting to get wet, overtopping flows at lower levels only, no falling jet, low danger of fall from walkway	1 – 10	500 at low level
Aware pedestrian, clear view of the sea, not easily upset or frightened, able to tolerate getting wet, wider walkway[(2)].	0.1	20 – 50 at high level or velocity

[(1)] Note: These limits relate to overtopping velocities well below $v_c \approx 10$ m/s. Lower volumes may be required if the overtopping process is violent and/or overtopping velocities are higher.
[(2)] Note: Not all of these conditions are required, nor should failure of one condition on its own require the use of a more severe limit

Extract 2: EurOtop tolerable overtopping discharges for public safety.

4 *Existing Overtopping Discharge*

Table 5 details the worst case overtopping discharges for each frontage considered for the year 0 (2011), year 50 (2061) and year 100 (2111). This worst case is from the JPA combination that produces the worst case overtopping and from the worst case beach dimensions as taken from the following profiles; post October 2009 storm; post March 2010 storm; post October 2010 storm and the most recent profile (22-Jan-11).

4.1 Empirical relationships

The data in Table 5 details the overtopping discharges calculated using empirical overtopping relationships. It can be seen that for the vertical wall sections in 2061 and 2111 the still water level exceeds the defence crest level and as such water will weir over the defence and overtopping calculations are not suitable. The extent of the dunes at extraction point 12 that overtopping calculations at this point are not suitable and return negligible overtopping discharges at all return periods.

Location	Exmouth Beach				Dawlish Warren Spit			
	Point 6 6a01797	Point 7 6a01776	Point 8 6a0179	Point 9 6a01808	Point 12 6b00011	Point 13 6b00021	Point 14 6b00034	Point 15 6b00042
Defence type	Seawall	Seawall	Dune	Seawall	Dune	Dune	Dune	Dune
1	0.03	*N/A*	0.00	0.06	0.00	0.00	0.41	1.70
2	0.08	0.29	0.00	0.14	0.00	0.01	0.72	2.99
5	0.30	3.80	0.00	0.28	0.00	0.01	1.32	5.83
10	0.74	5.48	0.00	0.41	0.00	0.02	1.93	9.46
20	1.77	10.31	0.00	0.55	0.00	0.03	2.61	13.63
50	5.84	15.90	0.00	1.02	0.00	0.05	3.78	22.37
100	35.75	21.04	0.01	1.52	0.00	0.06	4.56	27.13
200	271	37.20	0.01	2.22	0.00	0.09	5.58	35.38
500	1396	104	0.02	2.60	0.00	0.21	10.92	46.56

Table 5a: Empirical relationship for overtopping discharge for year 0 (2011) (l/s/m)

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Location	Exmouth Beach				Dawlish Warren Spit			
	Point 6 6a01797	Point 7 6a01776	Point 8 6a0179	Point 9 6a01808	Point 12 6b00011	Point 13 6b00021	Point 14 6b00034	Point 15 6b00042
Defence type	Seawall	Seawall	Dune	Seawall	Dune	Dune	Dune	Dune
1	0.44	3.54	0.00	0.16	0.00	0.01	0.73	2.80
2	0.86	5.67	0.00	0.33	0.00	0.02	1.27	4.82
5	2.46	8.92	0.00	0.65	0.00	0.03	2.21	9.40
10	6.01	13.41	0.00	0.96	0.00	0.05	3.18	14.54
20	15.19	26.32	0.01	1.29	0.00	0.07	4.27	20.70
50	45.80	45.71	0.01	2.39	0.00	0.10	6.01	33.34
100	474	77.77	0.03	3.48	0.00	0.13	7.23	39.48
200	6427	138	0.06	5.12	0.00	0.18	9.23	50.64
500	*SWL*	1268	0.08	6.22	0.00	0.42	16.43	66.96

Table 5b: Empirical relationship for overtopping discharge for year 50 (2061) (l/s/m)

Location	Exmouth Beach				Dawlish Warren Spit			
	Point 6 6a01797	Point 7 6a01776	Point 8 6a0179	Point 9 6a01808	Point 12 6b00011	Point 13 6b00021	Point 14 6b00034	Point 15 6b00042
Defence type	Seawall	Seawall	Dune	Seawall	Dune	Dune	Dune	Dune
1	6.50	10.75	0.00	0.62	0.00	0.02	1.61	5.35
2	12.44	25.99	0.00	1.18	0.00	0.05	2.73	9.00
5	33.35	43.35	0.01	2.06	0.00	0.08	4.48	18.03
10	77.92	79.62	0.02	2.95	0.00	0.13	6.42	26.24
20	240.35	152	0.05	3.8	0.00	0.18	8.35	36.38
50	1115	654	0.10	6.62	0.00	0.27	11.34	56.31
100	*SWL*	3033	0.21	9.42	0.00	0.39	13.79	65.16
200	*SWL*	141827	0.39	15.40	0.00	0.45	18.41	81.80
500	*SWL*	*SWL*	0.50	20.92	0.00	1.07	28.32	108

Notes:

(green)	= Overtopping discharge within critical limits for pedestrian safety
(cyan)	= Overtopping discharge within critical limits for structural damage
SWL	= still water level above defence crest
N/A	= still water level below defence toe level

Table 5c: Empirical relationship for overtopping discharge for year 100 (2111) (l/s/m)

4.2 Neural Network discharges

As stated in section 3.4 the neural network tool is generally used in situations with atypical defence types. The defence types considered in this analysis all have suitable empirical relationships available to determine overtopping. As such the neural network has been used to provide a comparison with the empirical overtopping methods which are considered more reliable.

Discharge q (l/s/m)			
Location	**Point 6 6a01797**	**Point 7 6a01776**	**Point 9 6a01808**
Defence type	Seawall	Seawall	Seawall
Return	2011		
1	*SWL*	*OOR*	0.1177
2	0.1118	*OOR*	0.1284
5	0.4178	*OOR*	0.4016
10	0.9536	*OOR*	0.9594
20	1.963	*OOR*	0.9709
50	5.879	0.4773	1.832
100	38.65	0.9964	2.426
200	94.64	3.347	3.256
500	114	31.6	*OOR*

Notes:

SWL	= Still water level below defence toe
OOR	= Distance between SWL and crest too large, neural network out of range
OOR	= Distance between SWL and berm too large, neural network out of range

Table 6: Neural network overtopping discharges

The neural network analysis has only been used for the hard defence structures as the method is not applicable for sand beaches. The outputs of the neural network compare well with the empirical relationships and in some cases are very close this provides additional confidence to the empirical overtopping relationships. It should be noted that overtopping discharges are only accurate to one order of magnitude In all cases the discharges calculated by the empirical relationships are greater than those from the neural network analysis therefore the empirical relationships have been used to determine the standard of protection.

4.3 Climate change sensitivity

EA (2011) does not provide predictions for future change in wave conditions and suggests a sensitivity analysis is carried out. No recommendation is provided for the scale of the sensitivity and so the EA(2006) guidance has been used. The following table provides the overtopping discharges with a 10% wave height increase for the years 2061 and 2111. These calculations have been carried out using the beach profiles recorded in January 2011.

Location	Point 6 6a01797	Point 7 6a01776	Point 8 6a01792	Point 9 6a01808	Point 12 6b00011	Point 13 6b00021	Point 14 6b00034	Point 15 6b00042
	Exmouth Beach				Dawlish Warren Spit			
Defence type	Seawall	Seawall	Dune	Seawall	Dune	Dune	Dune	Dune
RP (years)	2061							
1	0.5	4.9	0.0	0.4	0.0	0.0	2.1	7.1
2	1.0	7.8	0.0	0.7	0.0	0.0	3.4	11.6
5	3.1	12.3	0.0	1.4	0.0	0.0	5.7	20.4
10	6.9	18.5	0.0	2.0	0.0	0.1	7.8	30.7
20	16.5	13.8	0.0	2.6	0.0	0.1	10.2	42.1
50	60.9	67.7	0.0	4.5	0.0	0.2	14.0	65.4
100	644.7	115.3	0.1	6.3	0.0	0.2	16.8	78.3
200	8887.7	206.1	0.1	8.9	0.0	0.3	19.7	98.8
500	*SWL*	1753.4	0.1	10.7	0.0	0.7	36.1	123.3
	2111							
1	6.3	12.0	0.0	1.3	0.0	0.0	2.8	12.5
2	12.8	12.8	0.0	2.4	0.0	0.1	4.6	19.9
5	42.1	21.9	0.0	3.9	0.0	0.1	7.4	35.8
10	104.6	37.9	0.0	5.4	0.0	0.2	10.2	50.8
20	325.3	73.7	0.1	6.8	0.0	0.3	13.1	68.7
50	1528	349	0.2	11.3	0.0	0.4	17.7	102
100	*SWL*	4194	0.3	15.5	0.0	0.6	19.1	119
200	*SWL*	196107	0.6	24.3	0.0	0.7	25.6	148
500	*SWL*	*SWL*	0.8	30.3	0.0	1.6	44.4	187

(green)	= Overtopping discharge within critical limits for pedestrian safety
(blue)	= Overtopping discharge within critical limits for structural damage
SWL	= SWL above defence crest

Table 7: Sensitivity of 10% wave height increase to overtopping discharges

The increase of 10% to wave height does not make a significant difference to the overtopping discharges, all results are within the same order of magnitude with an average increase of 30%.

5 Existing Standards of Protection

The standard of protection for each defence has been calculated for structural stability and public safety. As stated in Section 3.5 the public safety limit of 0.1 l/s/m has been applied for all frontages. Structural stability has been calculated using 50 l/s/m for all defence types. The standards of protection have been derived from the empirical relationship overtopping discharges as detailed in Section 4.1.

Location	**Exmouth Beach**				**Dawlish Warren Spit**			
	Point 6 6a01797	**Point 7 6a01776**	**Point 8 6a01792**	**Point 9 6a01808**	**Point 12 6b00011**	**Point 13 6b00021**	**Point 14 6b00034**	**Point 15 6b00042**
Defence type	Seawall	Seawall	Dune	Seawall	Dune	Dune	Dune	Dune
	2011							
Damage	1:100	1:200	>1:500	>1:500	>1:500	>1:500	>1:500	>1:500
	2061							
Public	<1:1	<1:1	>1:500	<1:1	(1)	(1)	(1)	(1)
Damage	1:50	1:50	>1:500	>1:500	>1:500	>1:500	>1:500	1:100
	2111							
Public	<1:1	<1:1	1:50	<1:1	(1)	(1)	(1)	(1)
Damage	1:5	1:5	>1:500	>1:500	>1:500	>1:500	>1:500	1:20

The standards of protection are the highest return period that is within the overtopping threshold, actual standards of protection may therefore be higher.
(1) Standard of protection for public safety is not considered appropriate as there is no formal access to the rear of the dunes.

Table 8 – Current standard of protection of existing defences (1:x years)

The current standards of protection for the hard defences along the Dawlish Warren spit and Exmouth frontages is less than 1 in 2 for public safety and 1 in 100 or greater for structural damage. The standard of protection for the Dawlish Warren dunes is greater than 1 in 500 in 2011. In 2111 the standard of protection varies along the length, at the distal end the standard of protection is at least 1:500, this area has wide dunes and has been seen to be accreting. At the proximal end of the dunes the standard of protection reduces to 1:20.

The standards of protection detailed are those for a single event based on the current beach dimensions. Erosion of the dunes over time from successive could lead to a reduction in the standard of protection.

6 Proposed Overtopping Discharge (Beach Recharge)

The empirical overtopping methodologies detailed in Section 3 have been used to determine the overtopping discharges following the placement of recharge material. This has been carried out for 3 profiles, point 6 at the eastern end of Exmouth beach and points 14 and 15 at the central and western ends of Dawlish Warren spit respectively.

The overtopping calculations for the vertical wall section were updated by modifying the structure toe level. The wave conditions at the toe were also modified by changing the beach slope and beach crest level. For the dune sections only the defence parameters within the overtopping calculations needed updating as beach slope was included as part of the lower slope of the structure.

Table 9 details the overtopping discharges following proposed recharge and includes a columns on the right showing existing overtopping discharges (calculation in Section 4) for ease of comparison.

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2011						
Return Period	Recharged Profile			Existing Profile		
	Point 6 6a01797	**Point 14 6b00034**	**Point 15 6b00042**	**Point 6 6a01797**	**Point 14 6b00034**	**Point 15 6b00042**
	Seawall	Dune	Dune	Seawall	Dune	Dune
1	0.00	0.00	0.00	0.03	0.41	1.7
2	0.00	0.00	0.00	0.08	0.72	2.99
5	0.00	0.00	0.00	0.3	1.32	5.83
10	0.02	0.00	0.00	0.74	1.93	9.46
20	0.13	0.00	0.00	1.77	2.61	13.63
50	0.67	0.00	0.00	5.84	3.78	22.37
100	6.36	0.00	0.00	35.75	4.56	27.13
200	62.41	0.00	0.00	271	5.58	35.38
500	594.76	0.00	0.00	1396	10.92	46.56

Notes:

(green)	= Overtopping discharge within critical limits for pedestrian safety
(blue)	= Overtopping discharge within critical limits for structural damage
SWL	= SWL above defence crest

Table 9c: Overtopping volumes per event following proposed recharge in year 0 (2011) (m3/s/m run of defence)

2061						
Return Period	Recharged Profile			Existing Profile		
	Point 6 6a01797	**Point 14 6b00034**	**Point 15 6b00042**	**Point 6 6a01797**	**Point 14 6b00034**	**Point 15 6b00042**
	Seawall	**Seawall**	**Seawall**	**Seawall**	**Seawall**	**Seawall**
1	0.00	0.00	0.00	0.44	0.73	2.8
2	0.02	0.00	0.00	0.86	1.27	4.82
5	0.15	0.00	0.00	2.46	2.21	9.4
10	0.49	0.00	0.00	6.01	3.18	14.54
20	1.53	0.00	0.00	15.19	4.27	20.7
50	7.43	0.00	0.00	45.8	6.01	33.34
100	103.34	0.00	0.00	474	7.23	39.48
200	2066.85	0.00	0.00	6427	9.23	50.64
500	SWL	0.06	0.00	*SWL*	16.43	66.96

Table 9b: Overtopping volumes per event following proposed recharge in year 50 (2061) (m^3/s/m run of defence)

2111						
Return Period	Recharged Profile			Existing Profile		
	Point 6 6a01797	**Point 14 6b00034**	**Point 15 6b00042**	**Point 6 6a01797**	**Point 14 6b00034**	**Point 15 6b00042**
	Seawall	Dune	Dune	Seawall	Dune	Dune
1	0.43	0.00	0.00	6.5	1.61	5.35
2	1.10	0.00	0.00	12.44	2.73	9
5	4.78	0.00	0.00	33.35	4.48	18.03
10	13.73	0.00	0.00	77.92	6.42	26.24
20	59.30	0.00	0.00	240.35	8.35	36.38
50	406.92	0.07	0.00	1115	11.34	56.31
100	SWL	0.10	0.00	*SWL*	13.79	65.16
200	SWL	0.68	0.00	*SWL*	18.41	81.8
500	SWL	3.99	0.00	*SWL*	28.32	108

Table 9c: Overtopping volumes per event following proposed recharge in year 100 (2111) ($m^3/s/m$ run of defence)

7 Proposed Standard of Protection (Beach Recharge)

Table 10 details the standard of protection provided by the defences following recharge. The existing standard of protection (as calculation in Section 5) has been included at the bottom of the table for ease of comparison.

Recharged Profile			
Location	**Point 6 6a01797**	**Point 14 6b00034**	**Point 15 6b00042**
Defence type	Seawall	Dune	Dune
	2011		
Public safety[(1)]	1:10	(1)	(1)
Damage	1:100	>1:500	>1:500
	2061		
Public safety[(1)]	1:2	(1)	(1)
Damage stability	1:50	>1:500	>1:500
	2111		
Public safety[(1)]	<1:1	(1)	(1)
Damage stability	1:10	>1:500	>1:500
Existing Profile			
Location	**Point 6 6a01797**	**Point 14 6b00034**	**Point 15 6b00042**
Defence type	Seawall	Dune	Dune
	2011		
Public safety[(1)]	1:2	(1)	(1)
Damage	1:100	>1:500	>1:500
	2061		
Public safety[(1)]	<1:1	(1)	(1)
Damage stability	1:50	>1:500	1:100
	2111		
Public safety[(1)]	<1:1	(1)	(1)
Damage stability	1:5	>1:500	1:20

The standards of protection are the highest return period that is within the overtopping threshold, actual standards of protection may therefore be higher.
[(1)] Standard of protection for public safety is not considered appropriate as there is no formal access to the rear of the dunes.

Table 10: Overtopping volumes per event following proposed recharge ($m^3/s/m$ run of defence)

8 Conclusions

The assessment of the existing defences along the Dawlish Warren spit and Exmouth frontages provides the current standard of protection for wave overtopping for 8no. typical cross sections. The overtopping modelling considered the joint probability analysis undertaken at each of these locations as part of this study. The associated water levels were increased for climate change using guidance contained within Environment Agency (2011).

The current standard of protection (2011) for structural stability of the seawalls along the two frontages is greater than 1 in 500 at Dawlish Warren spit and 1 in 100 at Exmouth (***Table 8***). However, by year 100 (2111) the standard of protection reduces to 1 in 20 at Dawlish Warren spit and 1:5 at Exmouth, principally due to the effects of sea level rise.

The current standard of protection (2011) provided by the sand dunes along the two frontages is greater than 1 in 500 at both Dawlish Warren spit and Exmouth (***Table 8***). However, by year 100

(2111) this standard drops to 1 in 20 at the proximal end of Dawlish Warren spit and 1:5 at Exmouth. The standard of protection at the distal end of Dawlish Warren spit remains at 1 in 500.

Beach recharge of the Dawlish Warren spit and Exmouth beaches is shown to improve the standard of protection against wave overtopping. At Dawlish Warren the standard of protection in year 100 (2111) improves from 1 in 20 to greater than 1 in 500 at the distal end (***Table 10***). Other areas where protection was previously greater than 1 in 500 year remain greater than 1 in 500 year after beach recharge. At the Exmouth frontage the standard of protection in year 100 (2111) improves from 1 in 5 to 1 in 10.

9 Limitations of the Analysis

It is important to note that the overtopping threshold levels used in this analysis are based on beach profiles recorded in January 2011 and the post storm events for storms in October 2009, March 2011 and October 2010. Should beach dimensions reduce to lower than the recorded profiles prior to an event the standard of protection against wave overtopping will be reduced.

The methods use to determine the standard of protection against wave overtopping of the dunes has been assessed base on critical limits for erosion of the rear face. The methods used consider the dune profile to be fixed and therefore do not allow for erosion of the foreshore or dune face due to the action of waves. As the action of waves is likely to be a principle mechanism of breach this also needs to be considered to gain a complete understanding of the standard of protection provided by the dunes. Numerical modelling of cross shore sediment movements has been undertaken as part of this Beach Recharge Technical Appraisal study to determine the standard of protection against breach of the dunes. This study is concluded in the shoreline change numerical modelling report

10 References

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