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Advice on Options for Sand Dune Management for Flood and Coastal Defence Volume 1: Main Report

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Report No 207

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Crynodeb Gweithredol

Mae twyni tywod arfordirol yn systemau tirffurf pwysig yng Nghymru ac yn arwyddocaol o safbwyntiau rheoli risg llifogydd arfordirol, cadwraeth natur, adloniant, defnydd economaidd a milwrol, a diddordeb hanesyddol / archaeolegol. Mae tua 30% o arwynebedd gwreiddiol twyni tywod yng Nghymru wedi cael ei golli i ddatblygiad ac erydiad ers 1900, ac mae'r rhan fwyaf o'r gweddill wedi ei or-sefydlogi gan lystyfiant yn yr 50 mlynedd diwethaf, gan arwain at golled sylweddol mewn bioamrywiaeth. I ymdrin â'r her hon, mae Cyfoeth Naturiol Cymru wedi cymryd camau gan gynnwys treialon i gynyddu dynamiaeth systemau twyni. Fodd bynnag, mae hyn wedi codi cwestiynau ynghylch a allai ymyriadau o'r fath gyfaddawdu swyddogaeth twyni wrth amddiffyn rhag llifogydd, a beth yw'r dulliau mwyaf priodol o reoli twyni mewn ardaloedd lle mai 'Cynnal y Llinell' yw'r polisi rheoli'r traethlin (SMP).

Mae'r adroddiad hwn, a gafodd ei gomisiynu gan Cyfoeth Naturiol Cymru a'i baratoi gan Kenneth Pye Associates Ltd ar y cyd â Royal Haskoning DHV, yn diweddarau gwaith blaenorol ar systemau twyni Cymru gan y cyrff hyn a gafodd ei gynnal yn y 1990au a'r 2000oedd cynnar. Mae'n cynnig asesiad o gyd-destun amgylcheddol, cymeriad geomorffolegol, cyd-destun SMP ac arwyddocad 87 o systemau twyni yng Nghymru, y mae rhai ohonynt wedi eu his-rannu'n unedau polisi SMP ar wahân. Mae arwyddocad ymarferol pob system twyni wedi ei asesu, gan ddyrannu sgôr 'arwyddocad' gyffredinol er mwyn cynnig mesur ansoddol o werth aml-swyddogaeth pob system twyni.

Mae'r dulliau sydd ar gael i reoli twyni arfordirol wedi cael eu hadolygu, a'u addasrwydd mewn gwahanol cyd-destunau wedi ei asesu. Y casgliad yw y dylai'r technegau rheoli twyni a ddewisir gymryd i ystyriaeth bwriad polisi SMP2 a phwysigrwydd aml-swyddogaeth system twyni unigol. Ni ddylai 'Cynnal y Llinell' gael ei ddehongli y dylai safle blaenaf twyni aros yn sefydlog ar bob cost. Dylai'r traeth uchaf a blaendwyni gael eu hystyried gyda'i gilydd fel is-systemau rhyng-gysylltiedig a dylai ymagwedd integredig gael ei harfer i gyflawni bwriad 'cynnal y llinell' yn ystod oes pob polisi SMP2. Mae episodau o erydiad blaendwyni, wedi eu dilyn gan ymadfer a thwf egin-dwyni, yn nodwedd naturiol a phwysig system twyni iach. Lle bynnag y bod modd, ni ddylai camau peiriannu gael eu cymryd sy'n ymyrryd â'r rhyngweithio naturiol rhwng traeth a thwyni. Mae sawl techneg ymyrryd rheolaeth 'feddal' ar gael a all gyfyngu cyfraddau erydiad blaendwyni'n effeithiol a/ neu annog adferiad twyni. Pan fydd hyn yn bosibl drwy brosesau naturiol, mae modd defnyddio'r technegau hyn i annog symudiad llinell twyni tuag at y môr, gan greu felly 'clustogfa' yn erbyn digwyddiadau stormydd yn y dyfodol. Mae Cyfrol 1 yr adroddiad yn cynnig trosolwg cenedlaethol a phrif gasgliadau'r astudiaeth; mae'r chwech techneg rheoli twyni mwyaf cyffredin a ddefnyddir i gyflawni polisi cyffredinol Cynnal y Llinell, heb gynnwys maethu traeth ar raddfa fawr a pheiriannu caled, yn cael eu crynhoi mewn atodiad. Mae Cyfrol 2 yn cynnwys gwybodaeth gryno am bob safle twyni. Nod yr adroddiad yw hysbysu cynghorwyr, rheolwyr a rheoleiddwyr o fewn Cyfoeth Naturiol Cymru a chyrrff partner sy'n ymwneud â chydbwyso amcanion rheoli twyni arfordirol, sydd weithiau'n ymddangos yn groes.

Executive Summary

Coastal sand dunes are important landform systems in Wales and are significant from the standpoints of coastal flood risk management, nature conservation, recreation, economic and military use, and historical / archaeological interest. Approximately 30% of the original sand dune area in Wales has been lost to development and erosion since 1900, and most of the remainder has become over-stabilized by vegetation in the past 50 years, resulting in significant loss of biodiversity. To counter this challenge, Natural Resources Wales (NRW) has taken measures including trials to increase dune system dynamism. However, this has raised questions whether such interventions might compromise the flood defence function of dunes, and what the most appropriate dune management approaches are in areas where the shoreline management policy (SMP) is 'Hold the Line'.

This report, commissioned by NRW and prepared by Kenneth Pye Associates Ltd in conjunction with Royal Haskoning DHV, updates previous work on Welsh dune systems by these organizations carried out in the 1990s and early 2000s. It provides an assessment of the environmental setting, geomorphological character, SMP context and significance of 87 Welsh dune systems, some of which are sub-divided into separate SMP policy units. The functional significance of each dune system has been assessed, and an overall 'significance' score assigned to provide a qualitative measure of the multi-functional value of each dune system.

The methods available to manage coastal dunes have been reviewed, and their suitability in different contexts assessed. It is concluded that the choice of dune management techniques should take account both of SMP2 policy intent and the multi-functional importance of an individual dune system. 'Hold the Line' should not be interpreted that a dune toe position should remain fixed at all costs. The upper beach and frontal dunes should be considered together as inter-related sub-systems and an integrated approach taken to deliver the intent of 'hold the line' over each SMP2 policy epoch. Episodes of frontal dune erosion, followed by recovery and growth of embryo dunes, are a natural and important feature of a healthy dune system. Wherever possible, engineering measures should not be taken which interfere with the natural interaction between beach and dunes. Several 'soft' management intervention techniques are available which can effectively limit rates of frontal dune erosion and/ or encourage dune recovery. Where natural processes make it possible, these techniques can be used to encourage seaward movement of the dune line, thereby creating a 'buffer' against future storm events. Volume 1 of the report provides a national overview and the main conclusions of the study; the six most common dune management techniques used to deliver an overall policy of Hold the Line, excluding large-scale beach nourishment and hard engineering, are summarised in an appendix. Volume 2 contains information summaries for each dune site. The report is intended to inform advisors, managers and regulators within NRW and partner organizations concerned with balancing the sometimes apparently conflicting objectives of coastal dune management.

1. Introduction

1.1 Report scope and purpose

Coastal sand dunes in Wales cover a total area of about 8100 ha, representing about 0.3% of the land surface of Wales and 11% of the total UK sand dune resource. Coastal sand dunes are important natural landform systems and also have significance from several other standpoints, including coastal flood risk management, nature conservation, recreation, economic and military use, and as sites historical and/ or archaeological interest. A central management challenge is therefore to balance the competing demands on sand dune systems in terms of the different functions they perform.

This report, commissioned by Natural Resources Wales (NRW) and prepared by Kenneth Pye Associates Ltd (KPAL) in conjunction with Royal Haskoning DHV (RHDHV), extends and updates previous work on Welsh sand dune systems by Posford Duvivier (1996) and Pye et al. (2007). The report provides a new assessment of the environmental setting, geomorphological character, shoreline management plan (SMP) context and significance of Welsh dune systems. The multi-functional significance of each Welsh dune system has been assessed, together with the statement and intent of the second generation shoreline management plan (SMP2) policies which relate to each system.

The methods available to manage coastal dunes and associated beach frontages have been reviewed, and their suitability for application in different circumstances has been assessed. The five most commonly used dune management techniques to deliver a policy of Hold the Line, excluding wider coastal management techniques such as hard defences and large-scale beach nourishment, are summarised as Factsheets in an appendix to Volume 1 of the report. Consideration of the most appropriate management techniques has taken account of the fact that NRW does not consider that monocultures of forest, marram or sea buckthorn would be appropriate, or the introduction of what could be considered to create litter (e.g. plastic Christmas trees), or the use of fixed hard engineering solutions such as concrete seawalls except for in exceptional circumstances which would require detailed justification in terms of sustainability.

This report is intended to inform advisors, managers and regulators within NRW and partner organizations concerned with balancing the sometimes apparently conflicting objectives of coastal dune management. It is also intended to assist the exploration of four areas of opportunity which have been identified by NRW (2016) relating to coastal zone management, namely:

- addressing coastal squeeze
- supporting coastal habitats
- supporting coastal communities
- future proofing from coastal flooding and sea level rise.

1.2 Approach

The approach adopted in this study has involved the following:

- a review of previous published and unpublished literature
- a review of the physical setting, geomorphological character, function and significance of Welsh dune sites in terms of flood and coastal defence, nature conservation significance, significance as geomorphological systems, economic and/or military importance, recreation importance, and historical / archaeological interest, based on examination of LiDAR data, aerial photographs, ground surveys and archival information
- a review of SMP policy and its underlying intent
- a review of available sand dune management techniques and wider coastal management techniques relevant to sand dunes

Shoreline Management Plans (SMP2s) provide a key source of information to guide decisions about the management of coast. The SMP2 policies for sections of coast containing sand dunes have had various policies applied including the three primary options of Hold the Line, No Active Intervention and Managed Realignment. However, in making decisions for sand dune management it is particularly important to look beyond the preferred policy headline to understand exactly what is intended by the proposed policy and why. If new information comes to light which is relevant to the management of a policy unit then it should be also considered to inform management decisions at a project level (e.g. in relation to dunes).

1.3 Report structure

The report consist of two volumes. Volume 1, the 'Main Report', provides a national overview and summarises the main conclusions of the study. Volume 2 contains individual information summaries for each of the 87 separate dune sites identified.

Following this introduction, Section 2 of this volume identifies the principal Welsh dunes sites, summarises the environmental conditions which influence their development, and assesses their significance in terms of the various functions they perform. Within this section, the report highlights the different nature of sand dunes, emphasising the need to consider them within the overall geomorphological context of the coast. This is developed further in considering how the physical function of a dune system, in general, interacts with the natural ecological value and the way in which management and landuse influences dune behaviour. This section aims to set the overall context that is then applied at a site level in determining critical management objectives. A brief analysis has been provided showing the number of sites where, in particular, Flood and Coastal Erosion Risk Management (FCERM) issues are significant and how this relates to other management drivers.

Section 3 provides a review of SMP policy within Wales. This section includes a brief discussion of how SMP policy has developed and, critically, attempts to draw out

examples of how, in different areas and with respect to specific sites, SMP policy and intent may need to be interpreted.

Section 4 extends the above in considering and reviewing dune categorization. The section sets out a different approach based on functional dune management, developing a framework within which different specific management approaches may be assessed.

All the above sections provide background and context to the assessment of management techniques. Section 5 discusses management techniques and provides a summary of how individual techniques relate to different management drivers. This is followed by Section 6 where more detailed consideration is given to developing a more integrated approach to dune management, considering which management options are likely to provide sustainable solutions at those dune sites which have Medium / High FCERM significance, and / or where Hold the Line (HTL) or Managed Realignment (MR) policies have been proposed for one or more SMP epochs. The overall conclusions of the study are set out in Section 7.

Supplementary information is provided in Appendices A to I. Appendix A provides summary data relating to natural influences on Welsh dune system. Appendix B provides a summary of dune function and SMP2 policy at each site. Appendices C,D,E,F,G and H provide summaries of the relationship between the FCERM importance of each dune system, the SMP2 policy at each site, and the importance of each site for nature conservation, geomorphological features, recreation, economic / military use, and archaeological / historical features. Appendix I provides factsheet summaries for six of the most commonly used dune management techniques applicable at sites of high FCERM significance.

2. Review of Welsh Dune Systems

2.1 Identification and definition of dune systems

As part of this study a full review has been undertaken of dune sites around Wales. Eighty seven separate dune sites have been identified, the locations of which are shown in Figure 1. Six sites have been subdivided as 'a' and 'b' because they contain more than one SMP2 policy unit for which different management policies have been recommended in at least one policy epoch, reflecting differences in physical conditions, shoreline trends, and/ or coastal defence status.

The criteria used to define a coastal dune 'site' in this context include the following:

- it represents an identifiable coastal geomorphological unit consisting predominantly of windblown sand, separated from other areas of windblown sand either by natural physical features (e.g. major headland or river) or by areas of urban development
- in some cases, although active aeolian processes and aeolian landforms may now be absent in an area of windblown sand due to human activities (e.g.

creation of golf courses, levelling for agriculture), the re-establishment of such features and their associated habitats could be achieved through a change in land use and land management.

Areas of former dunes and/ or sand sheets which have been effectively covered by urban and industrial development (i.e. houses, factories, roads) are not included in the list of sites since restoration of a quasi-natural dune landscape is considered impractical in such areas.

Based on the site assessments reported in Volume 2, a summary of the importance of each site in terms of FCERM, nature conservation, geomorphological features, recreation, economic / military use and archaeological and historical features is presented in Table 1. The major conservation designations at each site are summarised in Table 2.

The dune sites identified vary significantly in size, ranging from small areas such as that at Ferryside within the Towy (Afon Tywi) Estuary, through to major dune systems such as those at Kenfig, Pembrey and Morfa Harlech. Similarly, sites vary in their nature from small barrier systems, sometimes covered in scrub and now receiving relatively little sediment supply from the foreshore (e.g. Aberthaw and Aber Dysynni), to large active systems, closely associated and interacting with a wider shoreline system (e.g. Gronant Dunes). At some sites there are narrow zones of dune growth in front of defences (e.g. Swansea Beach) and in other areas the main dune system is isolated from direct interaction with the beach by man-made defences (e.g. Trearddur Bay).

Each dune site has, therefore, distinctive characteristics, in terms of the way in which the dune interacts with the broader coastal system, the manner in which the dune functions both physically and in relation to the demands placed on the dune, with respect to its natural ecological integrity, its function as a coastal defence, the internal use of the dune or the degree of constraint imposed within the dune system itself or by hinterland land use and the levels of the land behind the dune system. A more detailed discussion of how the various factors influences dune systems is provided in the *Sand Dune Processes and Management for Flood and Coastal Defence* research report (Pye et al., 2007). It is not intended to repeat this discussion in the current study but a brief overview is provided below, focusing on the critical drivers for management and the influence these potentially have on the behaviour and natural physical function of the dune system. This aims to aid the understanding of how specific management objectives need to be developed in relation to the underpinning intent to sustain a healthy dune system, and how this is then applied within the context of SMP policy and through the selection of specific dune management techniques.

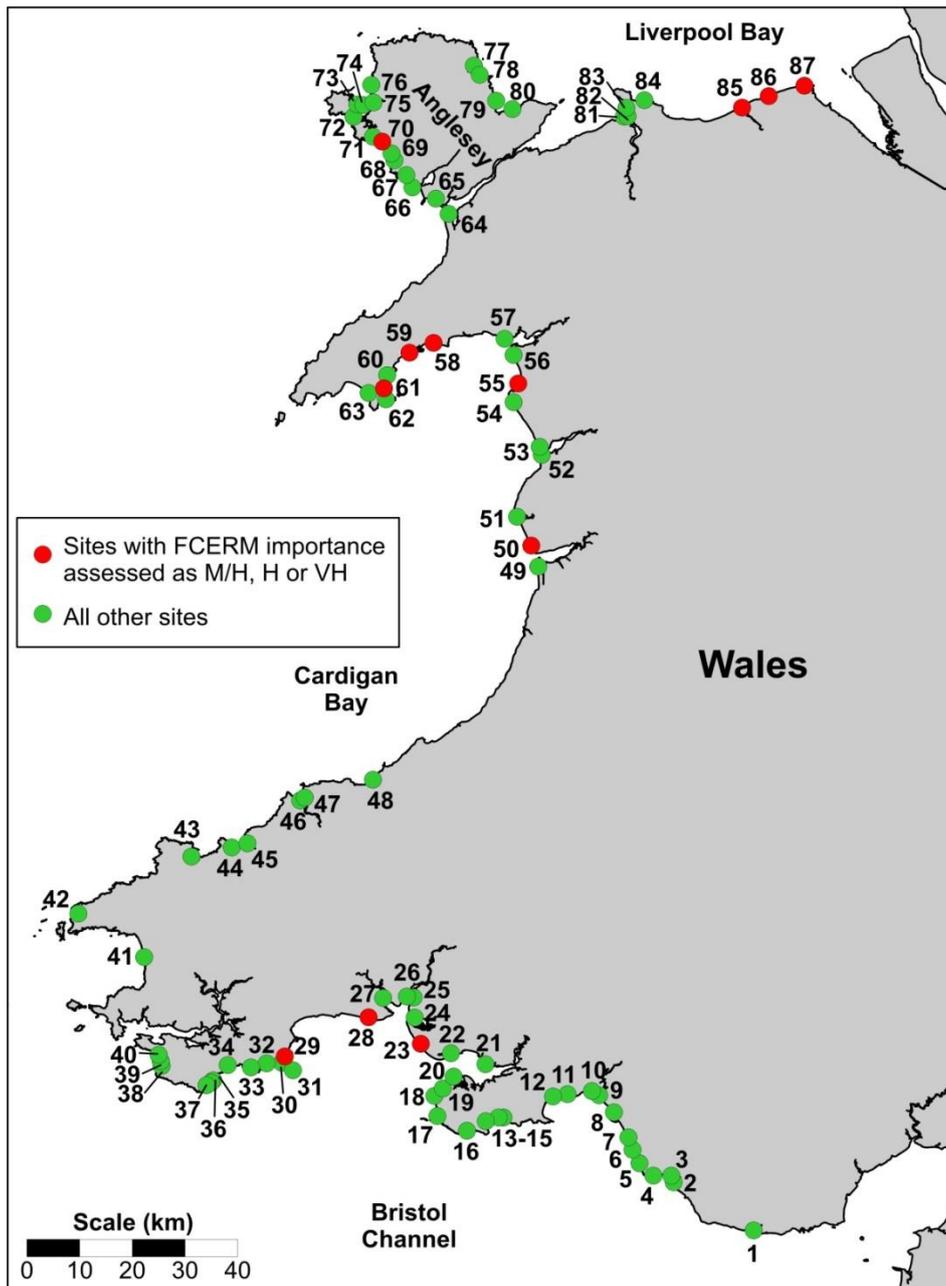


Figure 1. The locations of dune sites referred to in this report

Table 1. List of dune sites importance, classification of their importance, and SMP2 policies: L = Low, M = Medium, H = High, VH = Very High, N = None; HTL = Hold the Line, MR = Managed Realignment, NAI = No Active Intervention

No.	Site Name	Flood and Coastal Erosion Risk Management (FCERM)	Nature Conservation Designation	Geomorphological Features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy: Epoch 1	SMP2 Policy: Epoch 2	SMP2 Policy: Epoch 3
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI
2	Ogmore Dunes	N	L	L	L	L	L	MR	MR	MR
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL
8	Aberavon	N	L	L	L	L	L	HTL	HTL	HTL
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL
13	Pennard Burrows	N	H	VH	M	L	H	NAI	NAI	NAI
14	Penmaen Burrows	N	H	VH	M	L	H	NAI	NAI	NAI
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR
17	Rhossilli Bay South	N	VH	L	L	L	L	NAI	NAI	NAI
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR
19	Delvid Burrows and Hills Burrows	N	L	VH	M	L	M	MR	MR	MR
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR
30	Giltar Point	N	VH	L	L	L	L	MR	MR	MR
31	Priory Bay, Caldey Island	N	L	L	L	L	L	NAI	NAI	NAI
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI
33	Manorbier Bay	N	H	L	M	L	L	NAI	NAI	NAI
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI
36	Stackpole Warren	N	VH	M	M	L/M	H	NAI	NAI	NAI
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR
39	Gupton Burrows	N	M	L	L	L	H	MR	MR	MR
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR
41	Nolton Haven	N	VH	L	L	L	L	HTL	MR	MR
42	The Burrows, Whitesands Bay	N	L	M	L	L	H	HTL	MR	MR
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR
44	Aber Fforest	N	L	L	M	L	L	NAI	NAI	NAI
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI
45b	Newport Bay: Newport Sands North	N	L	L	M	M	L	HTL	MR	NAI

Table 1. continued

No.	Site Name	Flood and Coastal Erosion Risk Management (FCERM)	Nature Conservation Designation	Geomorphological Features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy: Epoch 1	SMP2 Policy: Epoch 2	SMP2 Policy: Epoch 3
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR
48	Traeth Penbryn	N	VH	L	L	L	L	NAI	NAI	NAI
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M	L	L	HTL	MR	MR
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	L	L	L	HTL	HTL	HTL
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI
62	Tywyn yr Wyfa, Abersoch	N	H	L	L	L	L	NAI	NAI	NAI
63	Tai Morfa, Porth Neigwl	L	VH	L	M	L	L	NAI	NAI	NAI
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI
66	Porth Twyn-mawr and Porth Gro	N	H	L	L	L	L	NAI	NAI	NAI
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI
68	Porth Trecastell	L	L	L	M	L	L	NAI	NAI	NAI
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI
75	Tywyn-gywyn	L/M	M	L	M	L	L	MR	MR	MR
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI
79	Benllech Sand	N	L	L	M	L	L	HTL	HTL	MR
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL
85	Kinnel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR

Table 2. Conservation designations of the dune sites: X = part or whole part of the dunes designated; A - designated area is adjacent to the dunes alongshore; B = designated area is adjacent to the dune in front or behind

No.	Site Name	SAC	SPA	Ramsar	SSSI	Biosphere	NNR	LNR	National Park	AONB	Heritage Coast	SINC	ESA	GCR	Wildlife Trust Reserve	RSPB Reserve	National Trust Ownership
1	Aberthaw										X						
2	Ogmore Dunes				X						X						
3	Merthyr-mawr Warren and Newton Burrows	X			X		X				X						
4	Sandy Bay, Porthcawl																
5	Porthcawl to Sker Point																
6	Kenfig Burrows	X			X		X	X									
7	Margam Burrows	B			B		B	B									
8	Aberavon																
9	Baglan Burrows				B												
10	Crymlyn Burrows and Earlswood Golf Club				X												
11	Spontex Dunes, Swansea											X					
12	Swansea Beach and Black Pill Burrows				X					B		X					
13	Pennard Burrows				X					X	X						X
14	Penmaen Burrows				X		B			X	X						X
15	Oxwich and Nicholaston Burrows	B			X		X			X	X			X			X
16	Port-Eynon and Horton Dunes	X			X					X	X				X		B
17	Rhossilli Bay South	X			X					X	X						X
18	Llangennith, Hillend and Broughton Burrows	A	A		B					X	X			X			X
19	Delvid Burrows and Hills Burrows	X	A	A	X		X			X	X			X			
20	Whiteford Burrows	X	X	X	X		X			X	X			X			X
21	Machynys and Llanelli	X	X		X					B							
22	Burry Port	X	X		X					B							
23	Pembrey Burrows	X	X	X	X			X						X			
24	Gwendraeth Estuary North Shore	X			X							X					
25	Ferryside to Morfa Uchaf, River Towy	X			X												A
26	Llansteffan and Ferry Point, River Towy	X			X												A
27	Pentowyn, River Taf	X			X												X
28	Pendine and Laugharne Burrows	X	A		X									X			
29	Tenby Burrows	B			X				X								
30	Giltar Point	X			X				X		X						
31	Priory Bay, Caldey Island	B							X		X						
32	Lydstep Haven	B			X				X		X						A
33	Manorbier Bay	X			X				X		X						B
34	Freshwater East	X			X				X		X						A
35	Barafundle Bay	X	X		X		X		X		X						X
36	Stackpole Warren	X	X		X		X		X		X						X
37	Broad Haven	X	X		X		X		X		X						X
38	Brownslade and Linney Burrows	X	X		X				X		X						
39	Gupton Burrows	X	X		X				X		X						A
40	Broomhill, Kilpaison and Newton Burrows	X	X		X				X		X						X
41	Nolton Haven	X			X				X		X						
42	The Burrows, Whitesands Bay	X	X		X				X		X		X				B
43	The Parrog, Fishguard																
44	Aber Fforest								X		X						
45a	Newport Bay: The Bennet								X				X				
45b	Newport Bay: Newport Sands North				B				X				X				

Table 2. continued

No.	Site Name	SAC	SPA	Ramsar	SSSI	Biosphere	NNR	LNR	National Park	AONB	Heritage Coast	SINC	ESA	GCR	Wildlife Trust Reserve	RSPB Reserve	National Trust Ownership
46	Poppit Sands	X			X				X		X		X				
47	Towyn Warren	X			X												
48	Traeth Penbryn	X			X						X						X
49a	Borth to Ynyslas: Ynyslas South	B		B	X	X	B							X			
49b	Borth to Ynyslas: Ynyslas North	X	B	X	X	X	X							X			
50	Aberdovey to Tywyn	X	A	A	X				X								
51	Aber Dysynni				X												
52	Fairbourne spit	X			X												
53	Barmouth																
54	Morfa Dyffryn	X			X		X		X					X			
55	Llandanwg	X			X				X					X			X
56	Morfa Harlech	X			X		X		X					X			
57	Morfa Bychan	X			X							X	X		X		X
58a	Morfa Abererch to Pwllheli: Abererch East	B			X					X			X				
58b	Morfa Abererch to Pwllheli: Abererch West	B			A					X			X				
58c	Morfa Abererch to Pwllheli: Glan y Don	B								X			X				
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	X			X					X			X				
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	X			X					X			X				
59c	Pwllheli and Traeth Crugan: Traeth Crugan	X			X					X			X				
60	The Warren, Abersoch	A			B					X			X				X
61	Morfa Gors, Abersoch	A			B					X			X				
62	Twyn yr Wylfa, Abersoch	X	X		X					X	X						
63	Tai Morfa, Porth Neigwl	X	X		X					X	X		X				B
64	Morfa Dinlle	X			X			B		X				X			
65	Newborough	X			X		X			X			X	X			
66	Porth Twyn-mawr and Porth Gro				X					X	X		X				
67	Twyn Aberffraw	X			X					X	X		X	X			
68	Porth Trecastell									X							
69	Twyn Fferam and Tywyn Llyn				B					X			X				
70	Twyn Trewan		B		B					A			X				
71	Twyn Bryn-y-Bar, Holy Island		B		B					X							
72	Trearddur Bay, Holy Island									B							
73	Traeth Penrhos, Holy Island									X							
74	Gorsedd-y-penrhyn, Holy Island				X					X							
75	Twyn-gwyn				X					X			X				
76	Twyn-mawr									X			X				
77	Traeth Dulas				X					X			X				
78	Traeth Lligwy				X					X			X				
79	Benllech Sand		B		A					X							
80	Red Wharf Bay	A	B		B					X			X				
81	Conwy Morfa	A	B		A												
82	Deganwy South	B	B		X												
83	Deganwy North and Llandudno West Shore	B	B		B												
84	Llandudno East Shore	B	B		X												
85	Kinmel Dunes		B					X									
86a	Rhyl East		B														
86b	Ffrith Beach, Prestatyn		B														
87	Barkby Beach, Gronant Dunes and Talacre Warren	X	X	X	X			X		B						X	

2.2 Natural influences on dune development and physical function

As identified in previous guidance, the key factors in maintaining a naturally functioning dune system are (a) the supply of sediment to the system, (b) the width of the system and (c) the mobility of sediment within the system, which in turn dependent on wind energy and the vigour of vegetation growth (Pye, 1983; Pye et al. 2007). The sediment supply to a dune system depends on interaction with the wider coastal system in terms of the level of the beach and the processes of sediment transport, erosion and accretion occurring at the beach face. These factors are in turn determined, within a natural system, by tidal range, the wind and wave energy climate, the effectiveness of alongshore currents, and hence are related to the geographical setting of the dune system.

Most of the Welsh coast experiences a mean spring tidal range greater than 4 m (Figure 2), and can therefore be classified as 'macrotidal' according to the scheme proposed by Davies (1972). On the north shore of the Bristol Channel and southern shore of Liverpool Bay the mean spring tidal range exceeds 7 m. Consequently, in many places a wide intertidal zone is exposed at low tide. However, in terms of potential for aeolian sand transport and dune building total beach width is less important than the width of dry backshore (above mean high water spring tide level) exposed to wind action at most states of the tide, and the rate of sediment supply to the backshore from the foreshore and nearshore zones.

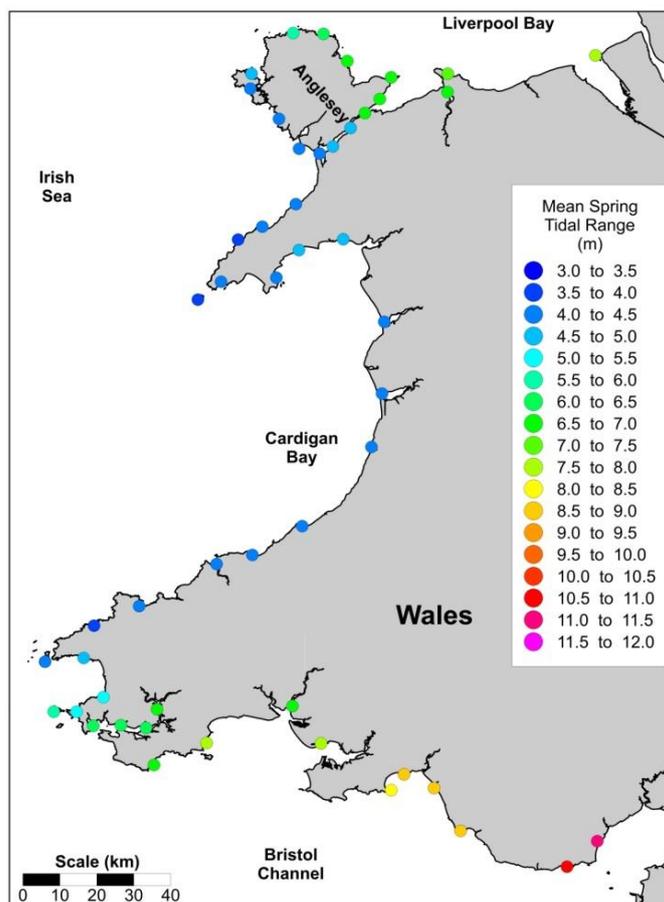


Figure 2. Mean spring tidal range around the coast of Wales (based on data from Admiralty Tide Tables 2017)

The capacity of the wind to move sand from the dry backshore, and to a lesser extent higher parts of the foreshore where the surface sand is able to dry out at low tide, varies considerably with coastal aspect, topographic setting and exposure. Long term measured wind data are available only for a small number of coastal stations in Wales, and the majority of these are not truly representative of conditions at the nearest dune sites. However, the available data do show that stations exposed to southwesterly winds have the highest total wind energy and potential sand-transporting capacity, or drift potential (Figure 3). The resultant wind direction for winds > 11 knots calculated for the closest nearshore model grid points in the Wavenet Hindcast database, managed by Cefas on behalf of the Environment Agency (Figure 4), is broadly southwesterly around most of the Welsh coast, and west-southwesterly to the east of Great Orme's Head (Figure 5). However, as winds approach the coast they are deflected and experience changes in relative speed due to the effects of topography.

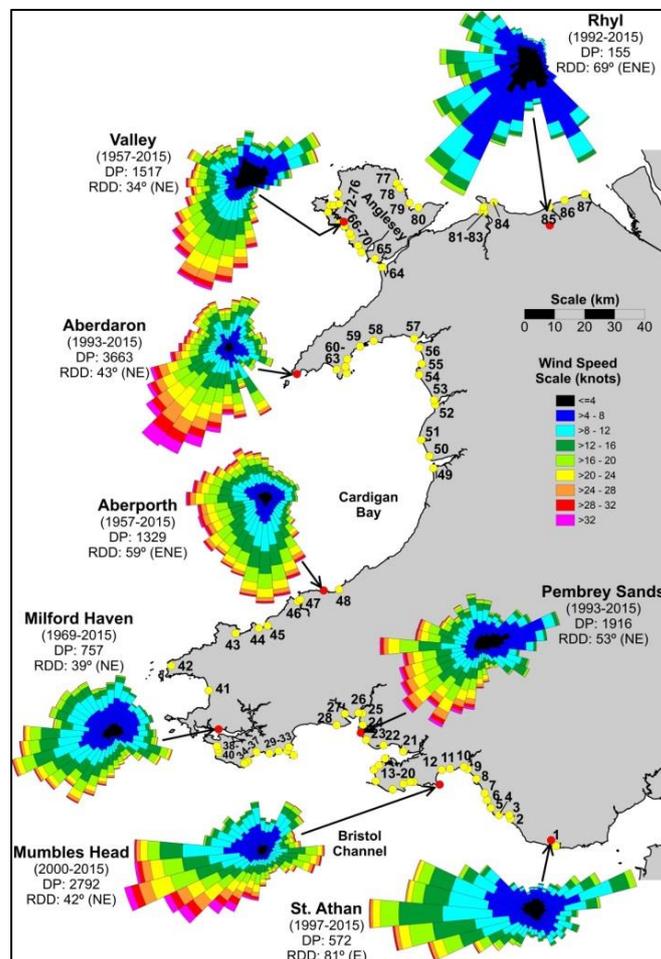


Figure 3. Wind roses based on recorded data at UK Met Office onshore stations. The data are strongly dependent on the topographic setting, aspect, elevation and overall 'exposure' of the individual recording stations and in many cases are not representative of conditions at the nearest dune systems

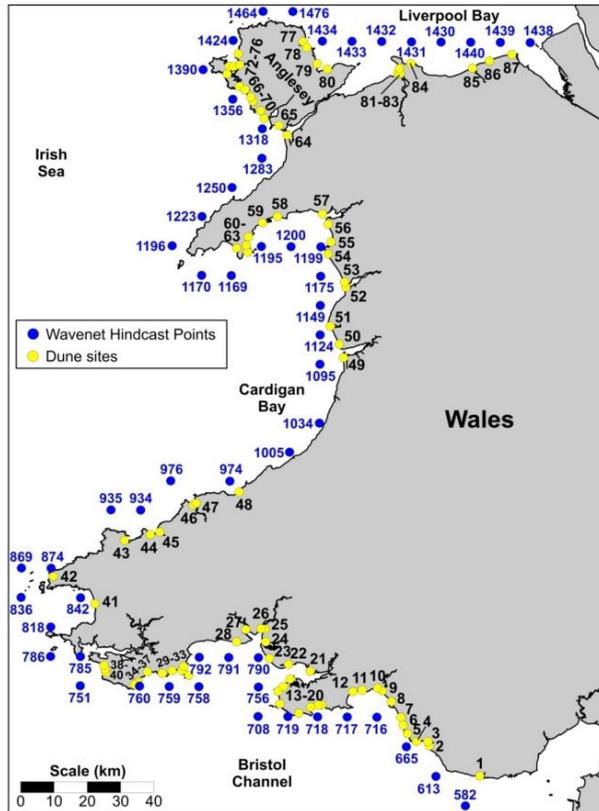


Figure 4. Wavenet hindcast points closest to shore in relation to dune sites.

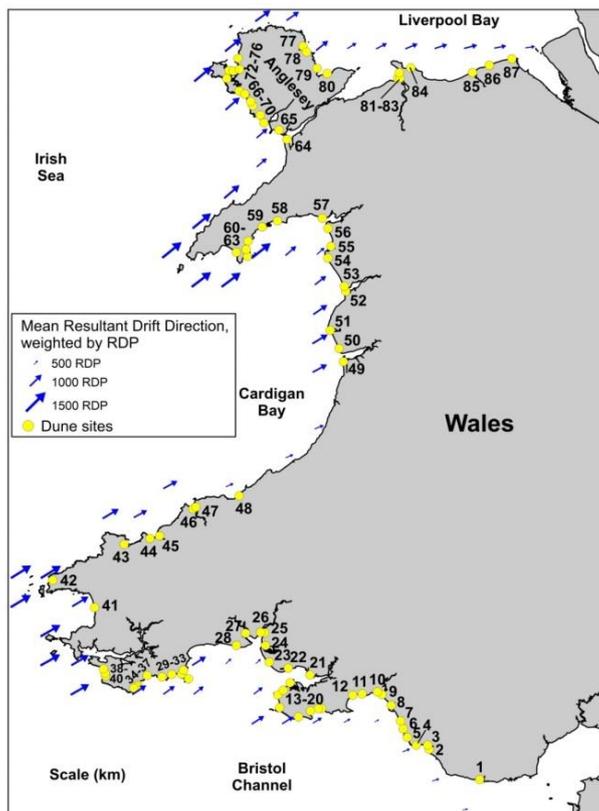


Figure 5. Resultant wind direction and calculated resultant 'drift potential' at the Wavenet hindcast points shown in Figure 4.

In terms of the role played by dune systems as defences against marine flooding, both the maximum crest height and the cross-sectional area of the dune system are important, as are the maximum still water level and the maximum wave energy which are likely to be experienced. The level of the predicted Highest Astronomical Tide (HAT), relative to Ordnance Datum Newlyn (ODN), varies from >7.6 m ODN on the east Glamorgan coast to < 3.0 m ODN around much of Cardigan Bay (Figure 6). Positive storm surges can raise the level of high waters considerably above predicted levels, especially where coastal orientation and topography allow water to 'pile up' close to the shore. The geographical variation in estimated 1 in 200 still water level, based on statistical analysis by McMillan et al. (2011), is shown in Figure 7. Forecast levels approach and exceed 8 ODN in the Severn estuary but are mostly < 4 m ODN around Cardigan Bay. Substraction of the predicted HAT level from the estimate 1 in 200 still water level provides a proxy 'surge magnitude' parameter; values of this parameter exceed 0.8 m in the Severn estuary, the northern part of St Bride's Bay and around Colwyn Bay on the North Wales coast, but are <0.5 along much of the south Pembrokeshire coast and along the north side of the Llyn Peninsula (Figure 8).

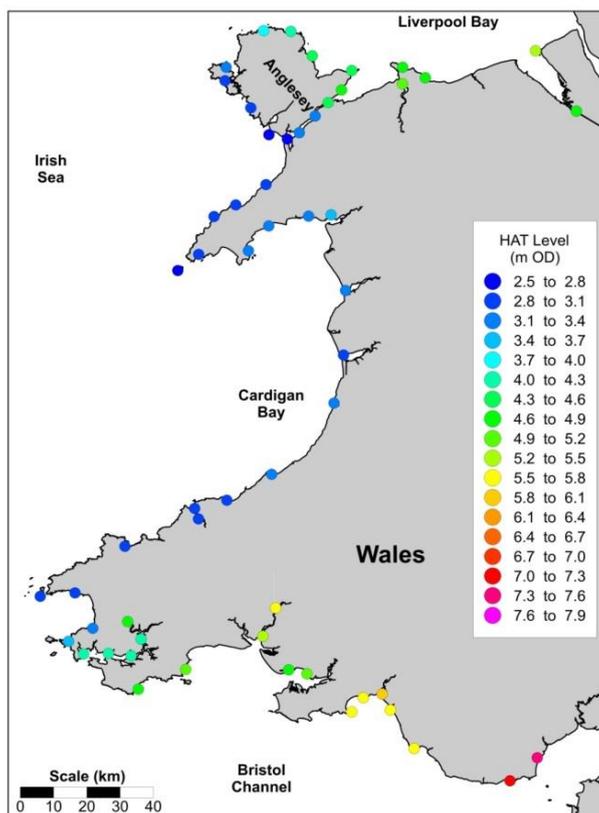


Figure 6. Highest Astronomical Tide levels at Standard and Secondary Ports, relative to Ordnance Datum Newlyn (ODN), around the coast of Wales. Based on data in Admiralty Tide Tables 2017.

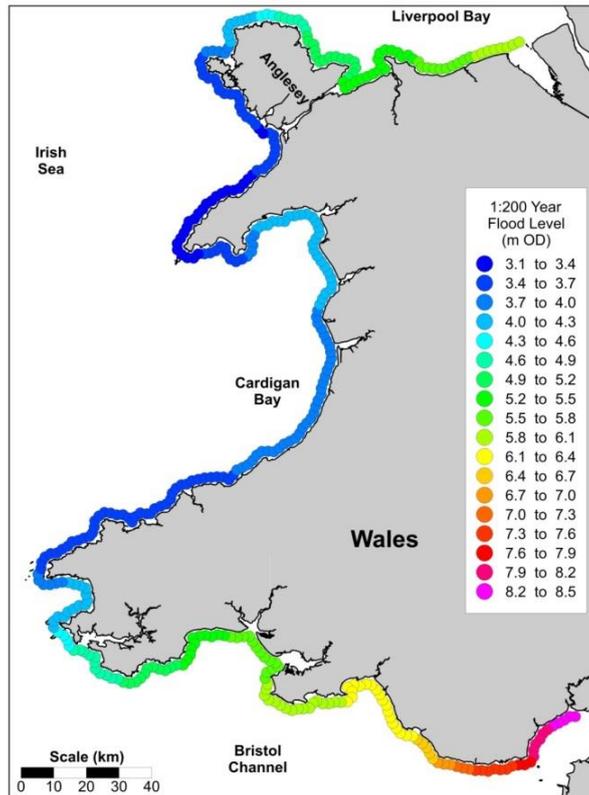


Figure 7. Estimated 1 in 200 year still water levels, relative to ODN, based on statistical analysis by McMillan et al (2011)

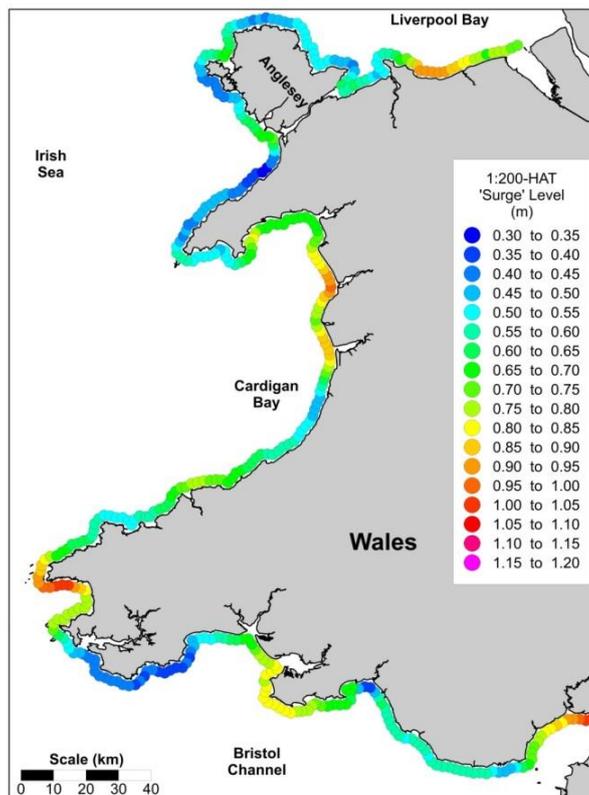


Figure 8. Indicative 'surge magnitude' parameter, calculated as the estimated 1 in 200 year still water level minus the Highest Astronomical Tide level.

Exposure to large, powerful waves increases both the risk of dune overtopping and, in the case of narrow dune systems, or dune breaching. Analysis of the Wavenet Hindcast data indicates that the most energetic waves are experienced off the south-west facing Pembrokeshire coast, followed by the southwest-facing coast of the Gower and southern tip of the Llyn Peninsula (Figure 8). These areas have high exposure to long period swell waves from the Atlantic. Southwesterly waves, locally refracted to approach from a more westerly direction, dominate the coasts of South Wales and West Wales, but on the North Wales coast the mean wave travel direction, weighted by wave power, is from northwest to southeast.

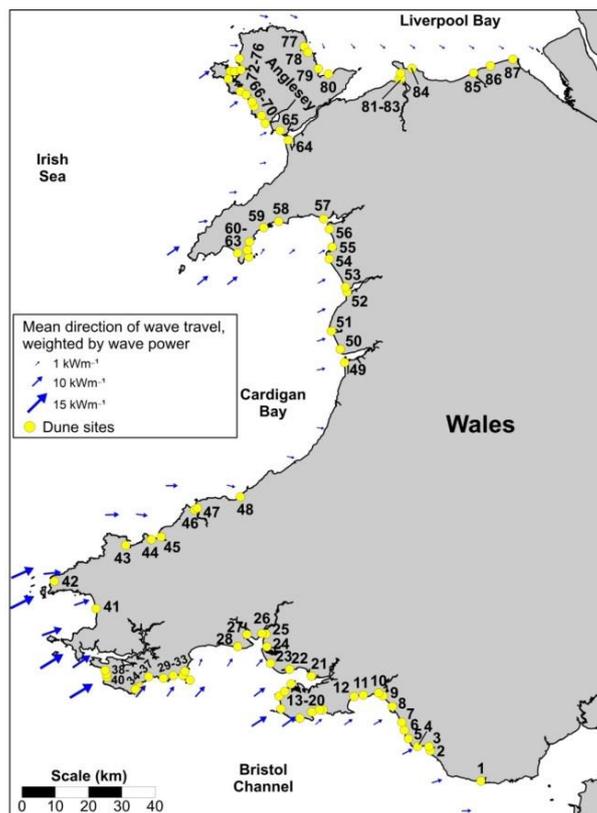


Figure 9. Mean wave direction weighted by wave power at the Wavenet hindcast points shown in Figure 5.

The dominant wind direction (onshore or offshore) and wind strength, linked with sediment availability, determines the effective height of a dune system, its form, and functional width. The principal aspect of the frontal dune ridge with respect to the effective sand transporting wind direction is therefore a major factor which controls the size and morphology of a dune system, and also its potential value as a flood defence. Aspect of the beach / dune system also determines in part the susceptibility to wave attack during storms. Aspect can differ considerably on sections of coast which are characterised by numerous bays and headlands of varying size. This may be seen by comparing Freshwater West and Freshwater East in Pembrokeshire (Figure 10). At Freshwater West exposure to the prevailing south-westerly winds has allowed development of transgressive dunes which have extended up to 1km inland. At Freshwater East, which faces southeast and experiences lower wind energy,

transgressive dunes are much less well-developed and the dune system essentially consist of a shore-parallel composite ridge system.



Figure 10. Comparison of two South Wales dune systems with differing exposure to prevailing south-westerly winds: Freshwater West (left) and Freshwater East (right)

Within the broad geographical context, processes are modified by the local geomorphological setting. Shoreline variation may be influenced locally by control features such as headlands, setting a dune within the context of a bay, or by more fundamental geomorphological change such as in an estuary regime. These dune development processes are then modified by change on a day by day, year by year and decade by decade basis, altering the underlying geomorphology and influencing the dune as a result of geomorphological change (Figure 11). Indeed, the development of a dune system is often closely linked to the geomorphological development of the wider coast in terms of spit formation or forelands, with accretional coastal features allowing dune development (Figure 12).



Figure 11. An example of short term morphological change in a beach - nearshore system impacting on a dune frontage: Aberdovey in 2006 (left) and in 2009 (right)



Figure 12. An example of double prograding spit systems with embryo dune development: Gronant Dunes and Talacre Warren on the North Wales coast

Dune migration inland (transgression) may be constrained by steeply rising land, and internally to the dune system, by changes in vegetation density which influence sediment mobility. At the shoreline there may be significant variation to both the functional width of the foreshore and variation in sediment supply determined by storm events or by longer term pressures for erosion at the dune face. The dune responds to change within that shoreline system, while also interacting with this system, acting often as an important buffer zone, with the potential to both store sediment and release sediment to the shoreline.

In all of the above examples, it is also recognised that the dune system lies, therefore, within a broader coastal system. In outline, therefore, any dune may be seen to sit within a general **shoreline system**, dominated by the main driving forces of waves, tidal flow and varying water levels. These forces drive sediment movement and patterns of erosion and accretion. The dune, itself, acts as a system (the **dune system**) with similar natural driving forces, in particular, the influence of wind and sediment supply and aeolian sediment movement. This dune system is influenced or constrained by the natural hinterland. These basic interactions are captured schematically in Figure 13.

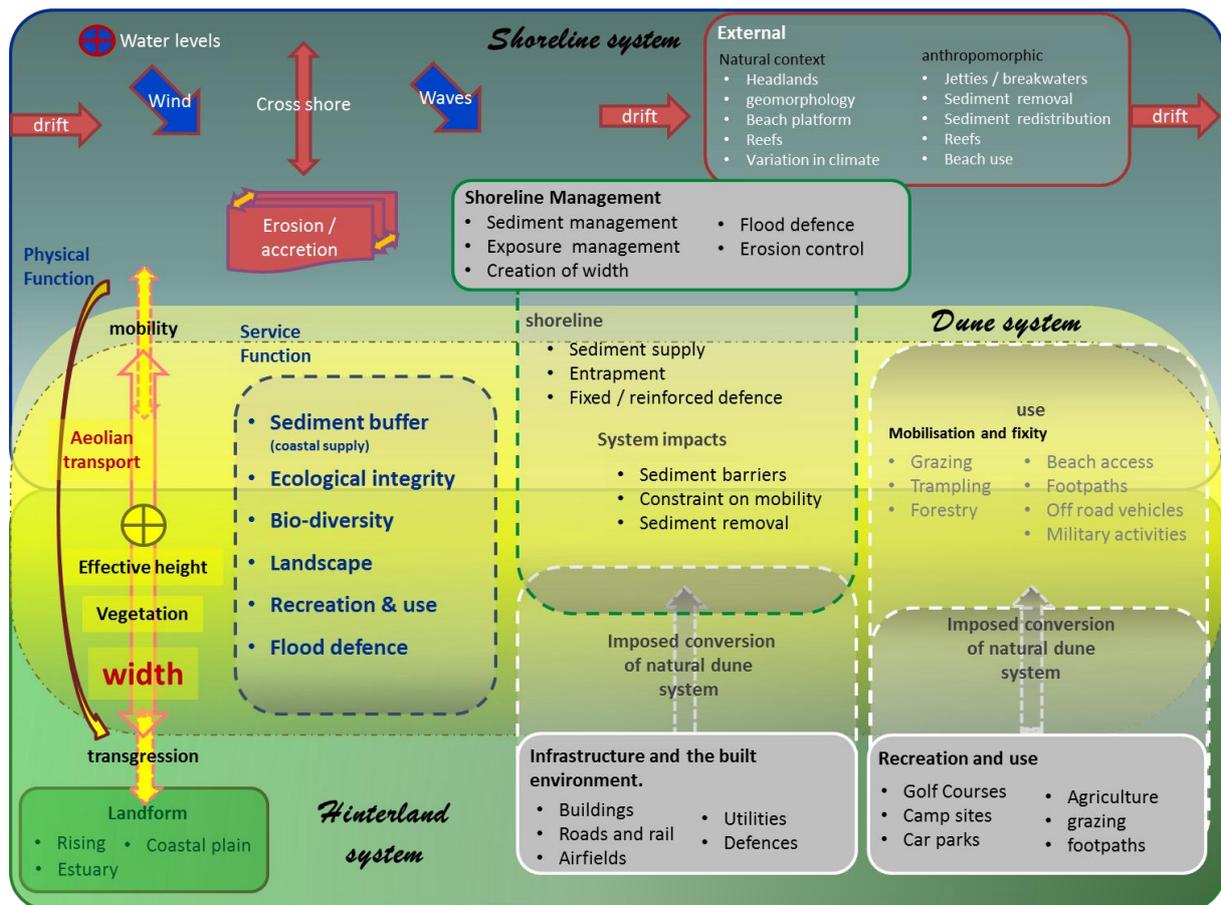


Figure 13. Schematic representation of the functional influences on dune development

The basic structure of the dune or physical function may be further defined in terms of its ability to move, landward or seaward, its height, the vegetation cover and its width. Imposed upon this naturally functioning system are influences of use, development and human intervention. There may be external influences, both natural and man made, affecting at any individual site wave exposure, sediment supply or the geomorphological context. The management at the interface between the shoreline and the dune may be influenced by shoreline management, in terms of defences or dune management and may also be influenced by the use of the beach. Within the dune, management and use influence the natural physical function, in terms of recreation or commercial use. Management and development of the hinterland (in some cases imposing change on or constraining the behaviour of the dune) imposes conversion of the dune to a more static system. These various aspects of the overall coastal system are captured in outline in Figure 13, aiming to highlight both the complexity of dune management but also to bring out the need to consider how different drivers may influence different zones or areas of the complete system. These issues are discussed briefly below.

2.3 Anthropogenic Influences

Within the nearshore area, external to the shoreline and dune system, the human influence is seen more broadly in the way in which interventions act to influence sediment availability and frontal dune exposure. Typically, breakwaters and jetties,

adjacent defences or navigational dredging may influence both the broader sediment movement and supply and, potentially, more local sediment retention. Such activities may be negative or positive in their effect on the beach and frontal dune sediment budget.

Construction of nearshore structures or navigational structures may effectively act to create an area of sediment entrapment which supports dune development. Equally, such structures may restrict longshore sediment movement or actively modify wave exposure drawing sediment away from areas of the adjacent shoreline.

To the rear of the dune (within the hinterland system), infrastructure may constrain the natural transgression of the dune, restricting dune movement or developing into the dune (conversion), actively reducing dune width. Similarly, recreational and commercial use may limit the zone of active dune development along the shoreline or encroach into the existing dune area. Extending within the dune system, different forms of use may reduce or increase the mobility of the dune system, changing vegetation or creating barriers to sediment movement.

At the interface between shoreline and the dune face, intervention management may impose more direct control and influence on the dune system, by:

- restricting the mobility of the front face of the dune through hard defences, preventing erosion and natural transfer of sediment between the beach and the dune
- retaining sediment at the face of the dune, in some cases enhancing the aeolian supply but in other cases restricting such supply
- in some areas defence lengths adjacent to the dune system, or defences constructed in the nearshore zone, may trap sediment, restrict the supply of sediment to the dune system or create weaknesses or discontinuities within the broader shoreline system.

2.4 Dune system function and importance

In developing a strategy for the management of a dune system, all of the above factors have to be considered in relation to the value derived from the dune system in terms of its natural ecological function, its development within the natural landscape and in relation to its use and its function as a coastal defence. In terms of these service functions, consideration has to be given to the interaction between the dune and the beach, or foreshore.

In considering the individual sites identified in this report an assessment has been made of the significance of the dune system in relation to:

- flood and coastal erosion risk management (FCERM)
- nature conservation
- geomorphological features
- recreational use

- the broader economic use of the system, including military use
- historical and
- archaeological interests present within the site.

Particular attention has been given in this study to dune systems in Wales which have FCERM significance; i.e. where the dune systems either act as a physical barrier to marine flooding or otherwise exert a significant influence on flood risk to the hinterland, for example may reducing wave penetration into an estuary. In situations where dunes form a complete physical barrier, the efficiency of the barrier is related to (a) the minimum crest height of the dune, (b) the width of the dune barrier, and (c) the sediment volume of the barrier. In this context it is useful to consider the barrier width and sediment volume (per metre length) at three different levels, namely that of the highest astronomical tide, a selected storm surge still water level (e.g. the estimated 1 in 200 return period level), and the estimated maximum wave run-up level under storm surge conditions (Figure 14).

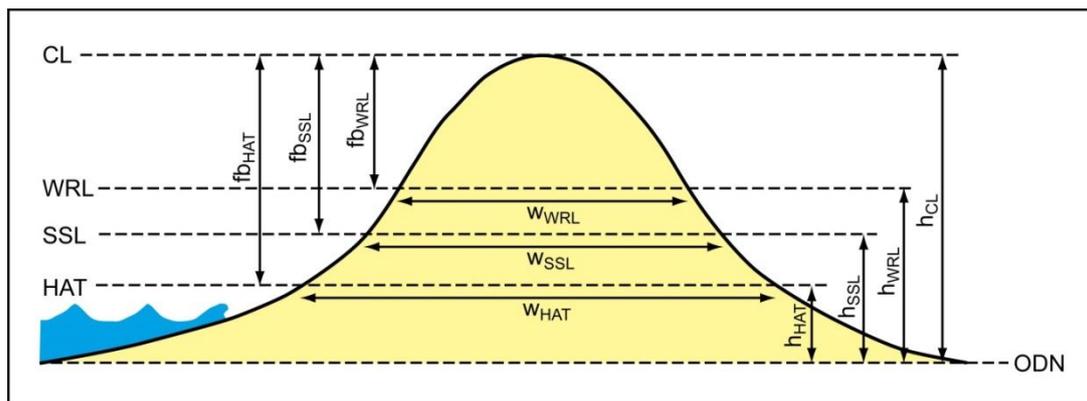


Figure 14. Concept diagram showing three defined levels and widths applicable to a dune barrier. HAT = highest astronomical tide; SSL = storm surge level; WRL = wave run-up level; CL = crest level; h = height above ODN; fb = free-board

Although a high, narrow dune may initially act as an effective barrier to marine overtopping, its effectiveness is likely to be short lived under storm-wave conditions. Observations have demonstrated that exposed frontal dunes on parts of the Welsh coast can experience up to 12 m of erosion during a single severe storm event, and several successive events during a single winter period, such as that of 2013-14, result in 30m or more of erosion. Dune face recession is likely to be greater when the dunes are relatively low, and when the frontal dune sand volume is therefore relatively small. However, if marine processes are effective in removing sand offshore or alongshore during severe storms, even high dunes (crest level >10 m ODN) can experience rapid erosion.

Figure 15 illustrates the general relationship between the standard of protection against marine flooding provided by a dune barrier in relation to its crest level and width. The highest level of protection is provided by a wide dune system which consists of several shore parallel dune ridges, each with a crest level several metres higher than the predicted maximum storm surge wave run-up level.

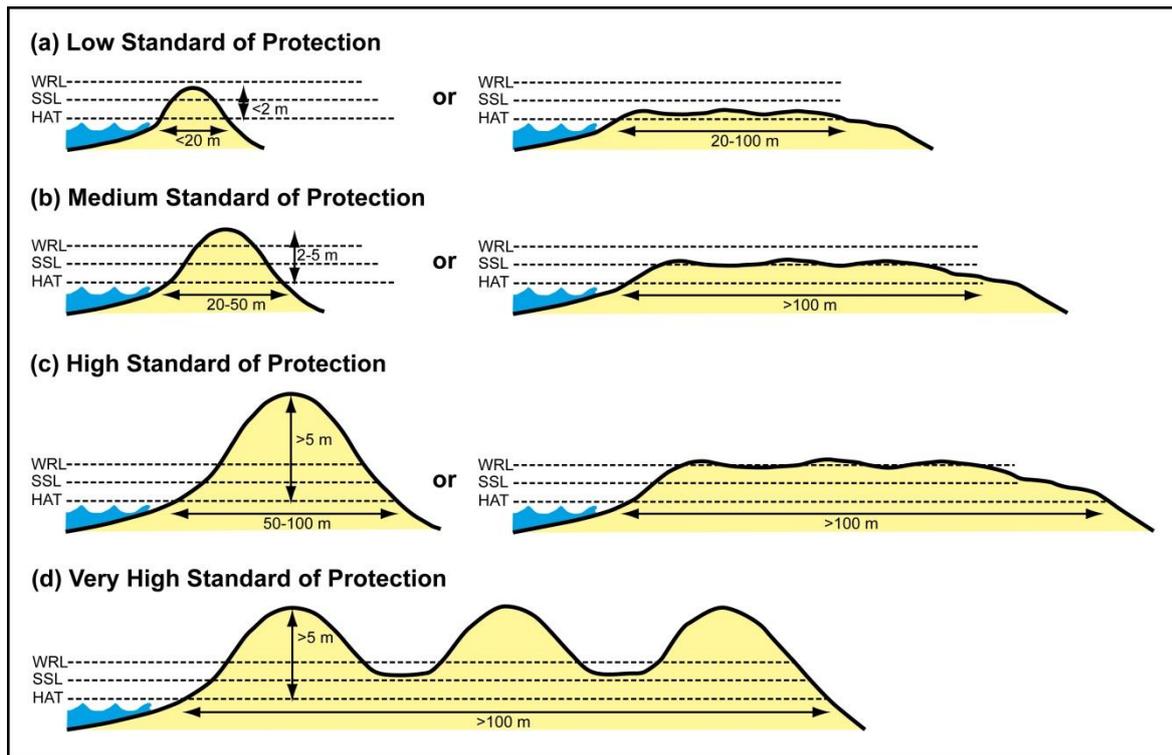


Figure 15. Conceptual diagram illustrating differences in the relative standard of protection against marine flooding provided by a sand dune barrier as a function of crest level and dune system width

Of the 87 Welsh dune sites identified in this study:

- 12 sites (represented by 16 SMP2 policy units) are assessed as having medium/high, high or very high FCERM significance, with the dune either acting directly as a defence or part of a wider defence system (Table 3)
- 42 sites are assessed as having medium/high to very high nature conservation significance, of which 7 sites have medium/high, high or very high FCERM significance
- 19 sites are assessed as having medium/high to very high geomorphological significance in terms of the range and quality of landform features and processes represented, of which 3 sites have medium/high, high or very high FCERM significance
- 17 sites are assessed as having medium /high to very high recreational significance, of which 8 sites have medium/high, high or very high FCERM significance

Table 3. Other functional importance and SMP2 policies at sites judged to be of medium to very high FCERM importance

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	def.system
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	def.system
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	defence
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	def.system
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	def.system
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	defence
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	def.system
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	H	M	L	HTL	HTL	HTL	defence
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	def.system
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	def.system
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	def.system
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	def.system
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	def.system
85	Kinmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	def.system
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	def.system
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	defence

In terms of shoreline management policy, there are 32 sites with a policy of Hold the Line (HTL), of which 15 sites have this policy proposed in all three epochs. Seven of these 32 sites have medium to very high nature conservation importance, three of the seven being assessed as having little or no significance in relation to other classifications (including no direct FCERM benefit). These three sites (Nolton Haven, Aber Dysynni and Llandudno North Shore) are very small in extent. In this context, it should be noted that these dune sites sit within larger SMP policy units, where the SMP policy relates to other aspects of the shoreline. This highlights the need to understand the interplay between SMP policy, the drivers for such policy and how these relate more directly to the nature conservation objectives at the dune sites; this is discussed further in Section 3.

Possibly as significantly, there are 21 sites which are assessed to have low nature conservation value and where there is a HTL policy, with a further 6 sites with low nature conservation value where the SMP2 policies identify the need for some other form of management (i.e. managed realignment). Critically, understanding of the SMP policy intent provides an opportunity to enhance the nature conservation function of these dunes through the assessment of possible techniques which are applicable to delivery of the SMP2 policy. These opportunities need to be considered in relation to the physical functioning of the dune system alongside an understanding of the different uses and services provided by a dune site.

A summary of the characteristics of each of the 87 dune sites, including their functions and SMP2 context, is presented in Appendix B. Table 4 provides a summary of the inter-relation between the principal service function management drivers, while Table 5 provides a more detailed summary of the qualitative importance of each site in terms of each of the six main functions, the SMP2 policies in each epoch. As detailed in the introductory section to Volume 2, each of the qualitative levels of importance assigned to each function has also been assigned a numerical value and the results summed to provide an overall 'significance score' for each site; this is also shown in Table 5. Pembrey Burrows has the highest overall significance score (20.5), compared with a maximum potential score of 24.

Table 4. Comparison of different service function management drivers

Service function		Of which: M/H to VH significance						None, L or L/M significance	
		FCERM	Nature conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	FCERM / Nature conservation	Any Other
	No.								
M to VH nature conservation	49	11	45	17	15	4	10	32/0	13
M to VH FCERM	28	16	16	7	17	4	4	0/11	13
M to VH Recreation	65	14	28	16	21	3	8	40/33	12

Table 5. List of dune sites, ordered by their Overall Significance Score, together with classification of dune site importance, and SMP2 policies: L = Low, M = Medium, H = High, VH = Very High, N = None; HTL = Hold the Line, MR = Managed Realignment, NAI = No Active Intervention

No.	Site Name	Flood and Coastal Erosion Risk Management (FCERM)	Nature Conservation Designation	Geomorphological Features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy: Epoch 1	SMP2 Policy: Epoch 2	SMP2 Policy: Epoch 3	Overall Significance Score
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	20.5
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	19.5
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI	18.0
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI	16.0
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR	15.5
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR	15.0
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI	15.0
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI	15.0
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	15.0
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR	14.5
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	14.5
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI	14.5
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR	14.0
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	14.0
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI	14.0
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR	13.5
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	13.5
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR	13.5
13	Pennard Burrows	N	H	VH	M	L	H	NAI	NAI	NAI	13.0
14	Penmaen Burrows	N	H	VH	M	L	H	NAI	NAI	NAI	13.0
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR	13.0
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	13.0
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	13.0
36	Stackpole Warren	N	VH	M	M	L/M	H	NAI	NAI	NAI	12.5
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI	12.0
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	12.0
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	12.0
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	12.0
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR	11.5
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR	11.5
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI	11.0
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI	11.0
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL	11.0
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR	10.0
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL	10.0
19	Delvid Burrows and Hills Burrows	N	L	VH	M	L	M	MR	MR	MR	10.0
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M	L	L	HTL	MR	MR	10.0
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	10.0
63	Tai Morfa, Porth Neigwl	L	VH	L	M	L	L	NAI	NAI	NAI	10.0
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI	10.0
85	Kinmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	10.0
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL	10.0
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	10.0
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR	9.5
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR	9.5
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI	9.0

Table 5. continued

No.	Site Name	Flood and Coastal Erosion Risk Management (FCERM)	Nature Conservation Designation	Geomorphological Features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy: Epoch 1	SMP2 Policy: Epoch 2	SMP2 Policy: Epoch 3	Overall Significance Score
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	L	L	L	HTL	HTL	HTL	9.0
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	9.0
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR	9.0
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL	8.5
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR	8.5
75	Tywyn-gywyn	L/M	M	L	M	L	L	MR	MR	MR	8.5
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL	8.0
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL	8.0
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR	8.0
17	Rhossilli Bay South	N	VH	L	L	L	L	NAI	NAI	NAI	8.0
30	Giltar Point	N	VH	L	L	L	L	MR	MR	MR	8.0
33	Manorbier Bay	N	H	L	M	L	L	NAI	NAI	NAI	8.0
39	Gupton Burrows	N	M	L	L	L	H	MR	MR	MR	8.0
41	Nolton Haven	N	VH	L	L	L	L	HTL	MR	MR	8.0
42	The Burrows, Whitesands Bay	N	L	M	L	L	H	HTL	MR	MR	8.0
48	Traeth Penbryn	N	VH	L	L	L	L	NAI	NAI	NAI	8.0
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR	8.0
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR	8.0
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI	8.0
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI	8.0
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL	8.0
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR	7.5
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL	7.5
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR	7.5
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL	7.0
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI	7.0
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR	7.0
45b	Newport Bay: Newport Sands North	N	L	L	M	M	L	HTL	MR	NAI	7.0
62	Tywyn yr Wylfa, Abersoch	N	H	L	L	L	L	NAI	NAI	NAI	7.0
66	Porth Twyn-mawr and Porth Gro	N	H	L	L	L	L	NAI	NAI	NAI	7.0
68	Porth Treacastell	L	L	L	M	L	L	NAI	NAI	NAI	7.0
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR	7.0
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR	7.0
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI	7.0
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI	7.0
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI	7.0
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI	6.5
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR	6.5
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI	6.0
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	6.0
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	6.0
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI	6.0
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI	6.0
44	Aber Fforest	N	L	L	M	L	L	NAI	NAI	NAI	6.0
79	Benllech Sand	N	L	L	M	L	L	HTL	HTL	MR	6.0
2	Ogmore Dunes	N	L	L	L	L	L	MR	MR	MR	5.0
8	Aberavon	N	L	L	L	L	L	HTL	HTL	HTL	5.0
31	Priory Bay, Caldey Island	N	L	L	L	L	L	NAI	NAI	NAI	5.0

3. Review of SMP policy in relation to dune management

This section considers the development of the SMP process from SMP1 through to SMP2 and how changing attitudes to management then influence the way in which SMP policy applies to different dune sites.

3.1 SMP1

A complete set of Shoreline Management Plans was first developed in England and Wales during the 1990s. The general approach, which started to take a broader perspective on coastal risk management, aimed to ensure that due consideration was given to the wider and longer term implications of defences and defence management at the shoreline. SMP1, looking over a period of 50 years, tended still to focus on defence structures, considering the economic value of such defences in terms of damages avoided. The first generation SMPs took a high level, broad brush assessment of assets at risk, typically based on a zone extending 1km inland from the shoreline. Importantly, these assessments started to consider the impact that one section of defence might have on the management of adjacent sections of the coast.

Critically, while the SMPs had to consider the impact on other aspects and interests associated with the coastal zone, these impacts tended to be assessed in terms of the constraint such impacts might have on the choices being made for defence or risk management. Ultimately, the SMP1s aimed to identify where there was insufficient justification, or no need, for defence management and where there was justification for continuing defence to area, either by sustaining the existing defence line, retreating that defence line or advancing the defence. These choices were captured in policies of:

- Do Nothing
- Hold the Line
- Retreat the line
- Advance the Line.

With the focus on the approach to defence, the main function was on whether the existing approach could be sustained over a period of fifty years and, if not, what alternatives might then have to be adopted.

3.2 SMP2

The SMP1 approach significantly advanced the understanding of the coast and raised important issues and challenges. However, it was recognised that such an approach did not go far enough, in particular the time scale over which adaptation might be needed was insufficiently well defined, and that change needs both to consider existing issues and to looking forward to where a more sustainable form of management might be achieved in the future. In taking such a different attitude, there was also the need to take a different approach to the assessment of risk, broadening this out to examine how management of flood and erosion risk and management of

defences needed to be considered as part of managing a coastal system. This required greater weight to be given to aspects such as the natural and historic landscape. These issues were addressed in developing the SMP2s during the period between 2005 and 2012.

While the SMP2 approach still sets policy solely with respect to FCERM, the ultimate aim of the SMP2 process has been to move towards a more integrated plan for sustainable management of the shoreline, creating a framework for development of broader coastal zone management. Individual policies for FCERM, therefore, sit within a broader intent of management, attempting to address broader, longer timescale issues.

To enable this, policies were developed over three epochs – short term (nominally 20 years), medium term (nominally 20 to 50 years) and long term (nominally 50 to 100 years plus). In many ways, the long term policy sets the direction of travel, with the short term policy examining the existing issues that need to be addressed, while also the degree of adaptation that may be possible in moving forward to a longer term intent for change. The interaction between this intent and specific policy is captured in the SMP2 Guidance:

*This distinction between the ‘preferred plan’ and ‘policies’ should also be recognised. The ‘plan’ represents the long-term vision, considering the interactions and implications across the whole SMP and identifies the changes required to achieve that. The ‘policies’ are **the means of achieving this plan** at the local level over discrete timescales.*

While the SMP2s retained, to a degree, the concept of “the line”, this line was defined more broadly with less reference to actual defences and greater focus on assets and interests at risk (defined within the SMP2s as features and issues) and the interactions within the coastal system. Again, from the SMP2 Guidance:

In some cases, it is more appropriate to consider the defence line as a zone of defences protecting assets, particularly in those situations where there is a series of structures (such as seawalls) and landforms (such as beaches and dunes) which together provide coastal defence. Adding new components to this series of defences should generally be viewed as improving the defence, rather than moving the shoreline.

In this, the SMP2 Guidance highlighted the importance of existing natural defences (such as sand dunes, saltmarshes and shingle ridges) in delivering effective policies to manage coastal and flood risks. *If these are under threat due to fixed defence structures, then consideration should be given to measures to restore or recreate natural defences.* The SMP2 Guidance also highlighted that, in other cases, measures might need to be taken to maintain the natural standard of defence on shorelines that are increasing (for example, by managing areas of erosion along sand dunes). This clearly relates to concepts discussed earlier in relation to management of a functional system.

Reflecting this, SMP2 policies were defined more widely, such that:

Hold the existing defence line (HTL) by maintaining or changing the standard of protection. This policy covers operations in front of the existing defences (such as beach recharge, building offshore breakwaters) as well as improving the protection provided by the existing defence line. This policy would also cover other actions that involve operations to the back of existing defences (such as building secondary floodwalls) where they form an essential part of maintaining the current coastal defence system.

Similarly from this wider perspective:

Managed realignment (MR) is defined as allowing the shoreline to move **backwards or forwards**, with management to control or limit movement, with the aim of adapting the manner in which the shoreline behaves to allow creation of a more sustainable form. This, in many SMPs, considered the way in which adjacent policies combined to create this new form or behaviour. Equally, this policy has been used to define areas where adaptation in land use is required such that the reliance on defences was reduced.

Advance the existing defence line (AD) by building new defences seaward was limited to those policy units where significant land reclamation was considered.

No active intervention (NAI) was considered to be where there was no justification for investment in coastal defences or operations but was also taken as being where, in combination with other adjacent policies, there was seen as being a need to restore or maintain a naturally functioning shoreline.

3.3 SMP Policy in relation to dune system function

In part this different attitude towards setting SMP policy, taking a more functional and system based approach, starts to explain some of the apparent anomalies identified earlier in comparing SMP2 policy units in relation to the identified dune sites in Wales, their physical context and the varied management drivers.

3.3.1 Context of dune management within SMP2 policy

It has to be recognised that the SMP2s often set policy solely in relation to FCERM and that the geographical boundaries of specific policy units are defined primarily in the context of areas of risk. Of the 87 dunes site identified in this study, 39 are assessed as having little direct association with the overall FCERM function defined by the SMP2 for policy units (see supplementary tables in Appendix A). Clearly, in some of these areas there remains the general function of the dune system in acting as a sediment resource, potentially linking to health of the beach and providing benefit to possible defences within a local sediment system. However, there may also be other factors driving policy beyond FCERM issues. Two such examples are provided at Freshwater East and Delvid and Hills Burrows, within Broughton Bay on the Gower (Figure 16). In both cases there is a policy driven primarily by the intent to maintain the natural function of the dune system, as in:

“Managed realignment to enable the dune system to function naturally, whilst allowing dune management, habitat management or to control recreational pressures, to be undertaken as required” (South Wales SMP2).

At Freshwater East “This policy would not preclude maintenance of the isolated stretch of defences at the western end of the frontage, if alternative funds were available.” - subject to an assessment of potential impact on the natural function of the system.



Figure 16. Examples where SMP Policy has been significantly influenced by consideration of the need to maintain dune function; Freshwater East (left), Delvid and Hills Burrows (right)

It needs to be stressed that in assessing actual management of any dune system there is the need to consider the specific *intent* of the SMP policy. Of the 48 sites which do have a FCERM association, the dune system forms part of an overall “defence system” at 46 sites and specifically performs a “primary defence function” at 4 sites, typically providing the actual level (height) of defence necessary to prevent flooding (NB at Abererch different policy units perform different defence functions). In the case of the 46 “defence system” sites, the dune may provide erosion protection, act as a buffer zone which helps to maintain the health of the beach, or act to reduce wave energy impacting on a ‘hard’ defence behind the dune. Further, dune systems may act more remotely, not specifically acting as part of the local defence but acting to provide influence on the wider system. An example of this is provided by the Abermenai spit adjacent to Newborough Warren, where the dune-capped barrier serves to reduce wave energy at other policy units within the Menai Strait shoreline system.

3.3.2 Example: Small scale dune systems within an estuarine setting

The contrasting roles of dunes acting as part of a defence system and the dune having little direct influence on the defence are evident at Ferryside (Figure 17a & b) and Llansteffan (Figure 17c & d) in the Towy Estuary. These two sites are situated on opposite sides of the same estuarine system, with the dunes influenced both by estuarine processes (notably channel migration) and wave exposure. In both cases the SMP2 policy and longer term intent is to Hold the Line. In the case of Llansteffan,

the dune acts directly to enhance the function of the hard defence line to the rear. There has been a long history of concern, when periodically the dune erodes, exposing sections of defence. The statement within the SMP2 recognises the importance of the dune:

“The policy is to continue to hold the line in order to manage the risk of coastal erosion and flooding to Llansteffan village through maintaining and if required upgrading the existing set back earth embankment, whilst allowing the dunes and intertidal area to function as naturally as possible”.



Figure 17. Changes in dune form and extent at Ferryside (a) and (c) and Lansteffan (b) and (d) between 2006 and 2015

While, clearly, the development of the dune is constrained by the hard defence to the rear, the SMP encourages the need to maintain the natural function of the dune as an integral part of the defence system. Sediment supply to, and removal of sediment from, the dune, influencing the natural function of the dune, is related far more to its context within the estuary system than to any conflict between natural dune and imposed FCERM function.

At Ferryside, the small area of dune provides toe protection to the principal defence (the railway line). Here, however, the interaction is less clearly defined. The natural process of erosion threatens both the railway and the natural function of the dune.

Potentially, the presence of the railway line tends to enhance this process, while the erosion of the dune increases the risk to the railway. The response to these risks might be to extend direct protection to the railway (typically, as in the past, extending and improving the riprap protection along the dune toe), responding to the erosion that also affects the dune. Equally, there is scope to consider how erosion pressure might be modified in a way that provides protection against continued erosion to the railway, while, incidentally, also reducing pressure on the dune face (e.g. by deflecting the estuarine channel away from the area). In effect, under the second approach, there may be the opportunity to influence the general processes (external influence) rather than merely responding at the dune face or railway embankment. In the case of both sites, the SMP policy highlights the issues and overall intent of management. However, the constraints and nature of potential conflicts or joint benefits relating to the different functions of the dune have to be considered at a more local level, within the context of the broader system.

3.3.3 Example: large scale, open coast setting defence system

At a larger scale, a system such as Morfa Harlech (Figure 18) is recognised with the SMP2 to be part of a wider defence system, despite having an SMP2 policy of NAI over all epochs. The SMP2 states that:

“While there is recognised to be a northerly drift of sediment along the Harlech frontage, the main process at work is seen as being the slow setback of the whole nearshore and foreshore profile. This would inevitably expose a greater length of the old cliff headland to the south but this would not imply that maintaining erosion along this cliff is critical to the supply of sediment to the system to the north. With sea level rise the process of roll back will increase. While at present, changes along the frontage are seen very much as an intermittent process of erosion and accretion, there would be anticipated to be a more persistent change to one of retreat. It is very unlikely, over the main section of the dunes that there would be an actual breach in the system through to low lying land behind”.

Flood defence to the area behind is more critically dependent on the potential flood route to the north of the main frontage dune system. The SMP goes on to state:

“The management of the dunes under this scenario is for No Active Intervention. The natural dunes would provide a competent defence to the area behind. To attempt to intervene (at the front face), even over a short length, is likely to start a process where there would be greater and greater need to intervene. This With Present Management approach (i.e. NAI) is seen as being sensible and sustainable in terms of meeting nature conservation values and maintaining defence to the hinterland”.



Figure 18. Morfa Harlech, photograph taken in February 2014 after storm trimming of the frontal dunes

3.3.4 Example: Small scale open coast dune system, primary defence function

In contrast to the Harlech example, the dunes at Deganwy North and Llandudno West Shore, to the east of the Conwy estuary (Figure 19) are seen as being examples where there is more direct interaction between hard defences, control structures and the natural development of the dune system. Until the late 1980s defence to the northern part of the frontage comprised a concrete stepped sea wall with little sand over a stony foreshore. Some minor protection had been provided to the headland to the south but erosion of this headland progressively allowed set back of the shingle ridge and dunes, backed by the North Wales Golf Club, further towards Deganwy. Subsequent to the introduction of the control structures (fishtail groynes) the southern section of the frontage has been stabilised to a degree and local dune growth has developed behind the structures to the north.

The SMP2 states:

“Current management is through control structures and beach management. This is viewed as being a sustainable approach. However, with sea level rise, there would be an increased risk of wave overtopping at West Shore and increased pressure for erosion along the golf course. Consideration will need to be given to adapting the defence in the longer term such that there is opportunity to provide more width for sustainable management of the present defence system. This may mean setting back the formal defence along West Shore, with the potential to encourage beach or dune growth. This approach, however, could be discussed through consultation with a view to starting consultation about the need for longer term change”.



Figure 19. Deganwy North and Llandudno West Shore, showing areas of dune formation around the stem of two fishtail groynes built during the early 1990s

Along this frontage local management of the dunes needs to recognise the longer term policy or intent to create more width within the defence system rather than retreating from the existing line. In many respects, therefore, managed realignment is through change of land use to create space. Dune development becomes part of this process, supported by the retention and management of sediment along the front face.

In different ways, both the Harlech and Llandudno West shore examples provide scope to maintain, or in the case of Llandudno West Shore to enhance, the nature conservation value of the dune system while maintaining the FCERM function. Critically, in the case of Llandudno, the SMP2 policy and intent aim to move away from a very rigid static management approach to a more adaptive model, creating width. In both cases sediment supply and sediment management become critical factors in dune management – in the case of Morfa Harlech through non-intervention and, in the case of Llandudno West Shore, in providing the structure within which sediment is retained.

3.3.5 Example: Interpretation of SMP policy in relation to dune management

The case of Sandy Bay, Porthcawl (Figure 20) offers a slightly different perspective and is briefly discussed below.

The South Wales SMP2 states:

“The vision is to continue to manage the risk of coastal erosion and flooding to Porthcawl, therefore the policy is to hold the line through maintaining and upgrading existing defences, including extending defences over the relict dunes along the eastern shore of Sandy Bay.”

The SMP2 identifies that the Sandy Bay dune frontage is an integral part of the defence system, although effectively recording that the dune itself offers little in terms of flood defence. Despite, therefore, the quite specific reference to extending the defence across the frontage, from a policy perspective this needs further consideration. From a dune management perspective, dune development might be allowed or encouraged to function within this context, potentially acting as a store for sediment supply to the beach. This might then also enhance the ecological function of the dune and the landscape, while still delivering the SMP policy.



Figure 20. Sandy Bay, Porthcawl, in 2006 and 2015; note the tendency to towards increased vegetation cover and dune stabilization

3.4 Summary of SMP review

Importantly, the examples discussed above demonstrate the need to consider the interaction between actual management and SMP policy. The longer term dynamics of the overall shoreline-dune-hinterland system need to be recognised, coupled to a differentiation between underlying policy intent and delivery of SMP policy.

There are potential opportunities that may be developed in actual management in a manner that supports management of the dune system, while still delivering the SMP intent. In the first, policy intent, this has been agreed through consultation with a wide range of stakeholders. In the second, delivery, there is scope to develop opportunities.

4. Review of strategic dune management guidance

4.1 Dune management strategies identified in previous Guidance

The Defra Guidance (Pye et al., 2007) highlighted five alternative strategies for the management of coastal dunes primarily for the purpose of coastal defence:

1. 'do nothing': allow natural processes to take their course, possibly resulting in frontal dune erosion, blowout development and formation of transgressive dunes / sand sheets where the balance of forcing factors and human pressures favours this; allow accretion of new dunes to occur where favoured by forcing factors and sediment supply.
2. 'hold the line', or 'static preservation': undertake engineering works (hard or soft) to maintain the position of the beach-dune interface, and by raising the level and width of the frontal dunes where necessary to ensure they can withstand the impact of a severe storm (e.g. 1 in 200, 1 in 1000 or 1 in 10000 year event)
3. 'dynamic preservation': maintain the general position of the coast but view the frontal dunes as a buffer zone within which limited change is permitted to take place during storms, and within which a degree of natural process instability is encouraged for the benefit of nature conservation
4. 'managed retreat' or 'managed realignment': re-position the dune sea defence and create a second line of defence, inland of the frontal dune, using imported sand, re-profiling or existing sand and/or vegetation planting; alternatively allow or encourage the frontal dunes to roll back in a controlled manner in order to maintain the integrity of the defence; cease maintenance and possibly remove existing artificial defences and dune toe protection
5. 'advance the line', by fence construction and planting of vegetation to seaward of the existing foredune ridge, encouragement of vegetation development in areas of natural potential accretion, by beach nourishment and / or creation of artificial dunes by bulldozing, planting and fencing.

These strategies closely align with the policies developed for SMP1, having been developed at a time when the SMP2 approach to shoreline management was still emerging. In principle these strategies still apply but more at a policy level, reflecting the way in which SMP1 policy for defence management imposed on management of the nature conservation values. With SMP2s now in place, this study takes the opportunity to review and revise the approach by taking a more functional perspective. This is felt to allow:

- better reflection of the breadth of issues associated with dune management and the degree to which different service functions, particularly that of coastal defence, interact with, impose or influence different approaches to overall management of the dune system
- taking account of policy intent and potential impact at a local management level
- greater adaptability to the varied nature of dune systems around Wales (allowing the nature of the dune system to be considered on a more on an individual basis)
- provide a structured framework within which to assess impact on the critical aspects of physical performance of any dune
- provide an informed way in which to assess how specific management techniques relate to that physical function and may then be applicable in any specific location.

This reflects the different ways in which dune systems function naturally, while also recognising the greater variation in how SMP2 policy needs to be viewed, as highlighted in earlier section of the report. While still capturing the essence of the original strategies, this approach aims to provide more clarity as to how different strategies align with different aspects of natural dune function(s). As such, “static preservation”, as a constraint on overall dune function, may be seen as applying to the dune face, involving the need to maintain aeolian sediment supply to allow natural development within the dune system, or equally to the potentially crucial interaction with the beach. It may equally be seen as applying within the dune system, effectively maintaining the crest level, or to the rear of the dune system in providing an essential component of the defence (as in the case of Llansteffan), but still allowing natural variation along the front face of the dune. It may, therefore, be better described purely as a functional constraint, rather than either a dune management strategy or a technique for management.

4.2 A structure for dune functional classification and assessment

The breakwaters at Llandudno West Shore provide an important broader scale control benefiting dune development (“dynamic preservation”), whereas, at the same site, the sea wall acts a constraint (static preservation”). Again, rather than seeing these as strategic aims in managing the natural dune function, the construction and maintenance of the breakwaters provides an important way of managing both flood defence and allowing dune growth at the front face of the defence system, while the sea wall acts as a constraint on system width (acknowledging the longer term SMP2 aim of removing this constraint by adaptive management).

In categorising the function of Welsh dune sites, this study aims to provide a structure by which a better understanding of the issues can be achieved, highlighting the critical aspects of function and identifying constraints. Table 6 highlights the critical aspects of dune behaviour and natural dune development, setting the function of the dune in the broader context including constraints imposed by the wider coastal system. This forms the basis for assessment of the applicability of specific

management techniques based on the need maintain, where possible, the fundamental objectives for dune management.

Table 6. Structure for functional dune management classification and assessment

Zone	Aspect	Criteria / description	Influence / capacity	
Context / External influence				
Broad scale Morphological setting		Open coast	Drift / Swash aligned	
		Bay	Drift / Swash aligned	
		Estuary	Flow dominated	
		Morphological type	type	
		Erosion/ progradation status		
Morphological scale influence (natural or man-made)		Sediment transport	Open / controlled /retained	
		Alignment	Unconstrained /controlled	
Hinterland		Nature Level	Rising / level / lower	
Sediment		Type		
		Supply (movement)	Drift / onshore offshore	
		Supply (adequacy)	Adequate / limited / removed	
Nature Conservation		Significance	VH / H / MH / M / LM / L	
Defence Function		Significance of dune	VH / H / MH / M / LM / L / NA	
		Dune function	Defence / defence system/ not associated	
SMP		Policy	NAI / HTL / MR/ AL by epoch	
		intent	Fixed / adaptive / no intervention	
Recreation		Significance	VH / H / MH / M / LM / L	
Economic / Military		Significance	VH / H / MH / M / LM / L	
Historic		Significance	VH / H / MH / M / LM / L	
Function / management - significance / constraint in relation to Natural Dune function				
Dune face / Beach				
Beach condition		Supply (adequacy)	Adequate / limited / removed	
		Retention	Availability for dune development	
		Beach level	Connectivity between beach and dune	
Mobility		Interaction	Capacity as sediment supply to beach	
		Erosion (ability to adapt)	Aeolian transport (supply in shore)	
			Exposure	
			Reinforced (partial)	
		Protected (isolated)		
		Capacity for foredune growth		
Dune system – active behaviour				
Condition		type		
		Nature Conservation function	Mobile / Fixed	
Sediment		Supply adequacy	Adequate / limited / isolated	
		Mobility	Active / limited / fixed	
Vegetation		Impact on sediment transport	Fixed / mobile	
		Diversity	High / Low	
Use / functional Issues		Recreation	Impact on dune mobility	
		Grazing	Impact on vegetation	
		Conversion	Impact on mobility	
Dune system structure –Width and Elevation				
Structural integrity		resilience	Capacity to survive coastal pressure	
		width	Capacity to adapt to long term trends	
Structural change		elevation	Capacity to resist overtopping	
		Development / land use	Constraint on width	
	Flood defence		Constraint on width and elevation	

5. General applicability of management techniques

5.1 Categories of intervention measures for dune management

Several previous publications have provided detailed descriptions and examples of specific dune management techniques (e.g. Ranwell & Boar, 1979; SNH, 2000; Brooks, 2001; Agate, 2001; Pye et al. 2007; Pye & Tsoar, 2009). No attempt is made to replicate these here, and the reader is referred to these earlier publications for additional detailed information. The following section aims to categorise these techniques in line with their functional application, as discussed earlier in this report.

Management intervention measures can be divided into three broad categories in terms of their geographical application:

- external to the dune system (nearshore)
- beach and dune face
- internal to the dune system

Tables 7, 8 and 9 summarise the main techniques applicable to the nearshore / beach zone external to the dune system, the upper beach and dune face, and to internal parts of the dune system, respectively. The potential longevity of impact associated with the techniques is also highlighted, together with their adaptability, context and dependency, purpose or function, and potential impacts. Some techniques are applicable only in one zone while others can be applied in more than one zone, sometimes as part of an integrated management package.

5.2 Sources of detailed information relating to specific management techniques

Example factsheets for five techniques used most commonly to manage the beach and dune face, and / or internal areas of a dune system, and which are integral to the delivery of a HTL policy in the short to medium term, are provided in Appendix I. Other techniques which can be used to deliver a HTL policy, including measures such as offshore breakwaters and large-scale sand nourishment, external to the dune system (Table 9), are not discussed in detail here and the reader is referred to other publications which contain relevant information. These include the CIRIA Beach Management Manual (Rogers et al, 2010) and two reports which consider the opportunities for beach nourishment in Wales which may deliver multiple benefits (McCue et al. 2010; Winnard et al. 2011).

Table 7. Techniques applicable to management of the zone external to the dune system (nearshore)

Function and impact			Context and dependency				Purpose or function and influence					Potential aspect of impact		
Technique	Longevity	Adaptability	Drift	Swash	Flow	Sediment availability	Morphological control	Sediment supply	Sediment retention	Exposure	Width / alignment	Sediment transport	Sediment supply	Progradation / dune development
Nearshore Breakwaters	L	+	+	+		D	++		+	++	++	-	-	+
Fishtail Groynes	L	+	++	+	+	D	++		++	++	++	--	-	++
Artificial reefs	L	+	+	++		D	+		+	+	+			+
Training bank	L				++		++				++	-		+
Wave dissipaters	M	-	+	+					+	+			-	
Timber breastwork	M	-	+	+					+	+			-	
Major sediment nourishment (sand engine)	M	++	+	+			+	++	++	+	++	++	++	++

Table 8. Techniques applicable to management of the dune face / beach

Technique	Function and impact		Context and dependency					Purpose or function and influence								Potential aspect of impact			
	Longevity	Adaptability	Drift	Swash	Flow	Sediment availability	Beach level	Sediment supply	Beach retention	Connect beach and dune	Reinforcement	Protection	Fore dune dev.	Dune stabilisation	Exposure	Increase width	Sediment transport	Beach scour	Dune development
Headland breakwaters	L	+	+	+	+	D		++	+	+				+	+	-	+	+	+
Rock/gabion bastions	L	+	+	+	+			+		+	+					-	+	+	
Rock revetment	L	-	+	+	+			+			++		+				-	-	-
Impermeable sea walls	L	-	+	+	+			-			++		+				-	-	-
Timber breastwork	M	-	+	+			D	+		+				+				+	
Back beach breastwork	M	-	+	+	+					+			+						-
Wave dissipaters	M	-	+	+			D	+		+				+				+	
Fishtail Groynes	L	+	+	+	+	D		++	+	+				+	+	--	+	+	+
Groynes	M	+	+		+			++	+	+						--	+		+
Toe defence rock	L	-	+	+	+					+								+	+
Toe defence gabions	S	-	+	+	+					+								-	
Toe defence geobags	M	+	+	+	+					+									+
Dune grass planting	S	+		+		D	D	+	+	+		++	+				+	+	+
Chestnut paling fencing	S	+	+	+		D	D	+	+	+		++	+				+	+	-
Brushwood fencing	S	+	+	+		D	D	+	+	+		++	+				+	+	+
Sand engine nourishment	M	+	+	+				++	+	++		+	+				++	+	+
Small beach nourishment	M	+	+	+				++		++		+					+	+	+
Beach drainage	M	+	+	+		D		+	+		+			+			+	+	+
Beach harrowing	S	+	+	+		D	D						-					-	++

Table 9. Techniques applicable to management of the internal dune system

Function and impact			Context and dependency			Purpose or function and influence							Potential aspect of impact				
Technique	Longevity	Adaptability	Sediment availability	Width	Hinterland level	Increase sediment supply	Reduced mobility	Increase mobility	Increased resilience	Limit positional change	Dune stabilisation	Increase dune elevation	Increase defence function	increase width	Sediment transport	Sediment supply	Dune development
Dune grass planting	M	+	D				+		+			+			-		
Dune fencing	M	+	D				+		+		+	+			-	-	
Aero dynamic reprofiling	M	-		D			++			+	++		+		-	-	+
Thatching	M	-					++				+				-	-	
Aeolian trapment (brushwood**)	M	+	D				+					+			-	-	
Back face/internal nourishment	L	+		D		+		+	+			+	+	+	+	+	+
Back face flood defence	L	+		D	D				+	+	+		++	-			
Active zone core	M								++	++			++				+
Buried core	L	+		D					++	++			++				+

6. Selection of dune management approaches and techniques

6.1 Past practice

Much dune management carried out in the past for FCERM purposes has been piece-meal, focusing on the protection of local sections of the dune toe and stabilization of the seaward dune face and / or dune crest, with little thought given to maintaining the natural functioning of the dune system, or the implications for nature conservation or recreational use. From a purely coastal defence perspective, engineers have often viewed a high, wide, topographically uniform and thickly vegetated dune ridge as ideal, and have seen areas of bare sand or topographic variability as potential weaknesses which could threaten the integrity of the defence. In most cases, natural movement of the dune toe, due to alternating storm impact and periods of recovery, has been viewed as something to be minimised or eliminated altogether. To limit this process, placement of rock armour and gravel upper beach berms, or construction of wooden breastwork and similar structures has frequently been undertaken along the dune toe / upper beach interface (Figure 21).



Figure 21. Rock armour and piling revetment at Abererch west, effectively cutting off the sediment transport connection between the beach and the dunes

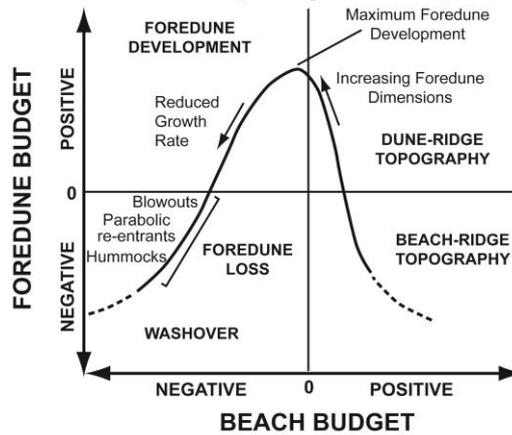
Such measures have often had negative impacts, including cutting off or significantly reducing the sediment transport connectivity between beach and dunes, and sometimes contributing to beach lowering by increasing the degree of wave reflection. At the ends of defended sections of dune toe frontal dune erosion has often been made worse by wave refraction and increased wave run-up around the ends of the structures. The defended sections of dune have become fossilised, with limited supply of new sand from the beach leading to the deterioration of natural marram communities and their replacement with scrub which completely shades out remaining areas of bare and thinly vegetated sand which are required for pioneer and early successional dune species and obligate dune invertebrates to thrive.

6.2 The importance of considering sediment budget as background to technique selection

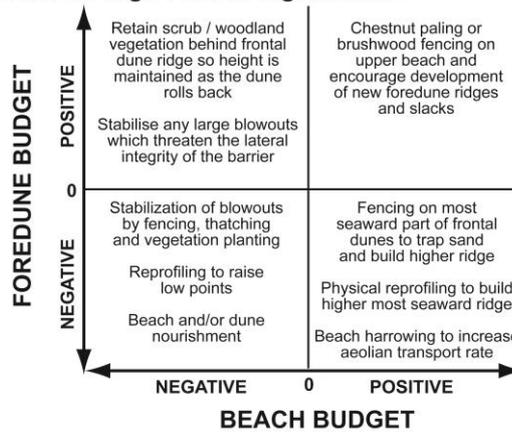
Over the past 15 years there has been increasing recognition that dune management on developed coasts, where some form of 'hold the line' policy might be required to protect human assets, needs to take into account the full range of service functions provided by dune systems, including those associated with nature conservation and recreation (Nordstrom, 2000, 2008; papers in Martinez & Psuty, 2004 and Martinez et al., 2013; Doody, 2013). Wherever possible, the natural dynamic functioning of dune systems should be maintained, and if possible enhanced, to maximise the nature conservation value of the site and to enhance recreational visitor 'appeal'. An integrated approach to dune management is therefore required which takes account of the full range of coastal and flood defence, nature conservation, recreational, geomorphological, historical and archaeological interests which may apply to a particular site.

The development of an appropriate overall dune management strategy, and the selection of intervention techniques, needs to take into account the sediment budget status of the beach and the frontal dunes in any given area (Figure 22).

(a) Beach and dune morphological development



(b) Areas of High FCERM Significance



(c) Areas of Low to Medium FCERM Significance

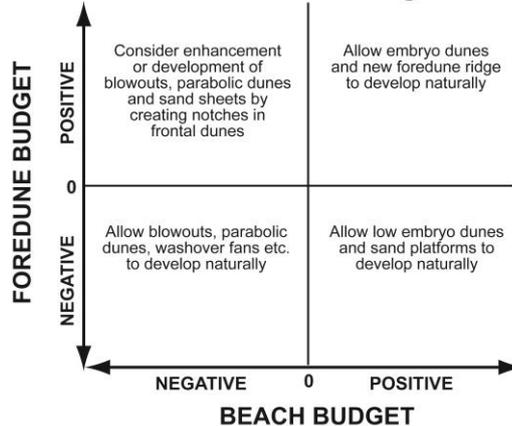


Figure 22. The relationship between beach and dune sediment budget (a), dune management strategy and application of specific intervention measures in situations where dune have high (b) and low to medium (c) FCERM significance. Figure (a) after Psuty (1992)

In areas of low wind energy (i.e. positive beach budget but negative dune budget) where the natural tendency is to develop a beach ridge plain of low windblown sand platform, the rate of aeolian transport may be increased to a degree by beach harrowing, thereby reducing the cohesion of the surface sand, increasing its rate of drying, and reducing the threshold velocity required for aeolian entrainment. In some

circumstances it may be necessary to create an artificially high frontal dune by reprofiling (bulldozing) the backshore sand, followed by fence construction and surface sand stabilization using thatching, surface geotextile or coir matting and/or vegetation planting. Where wind energy is sufficiently high, a high dune ridge can be created by erecting lines of fencing at successively higher levels as the dune grows. The use of gabion walls to achieve this purpose in this type of setting is not recommended.

If the beach sediment budget is negative, beach levels are likely to show a falling trend in the medium to longer term. However, short-term periods of sand accretion may increase beach levels to a point where sand can dry out and be blown by the wind into the frontal dune. This process can be accelerated by beach harrowing and/or physical re-profiling of the upper beach ('beach-scraping') to form a wider / higher frontal dune. However, the forms created are only likely to be temporary and will be removed by storms within a few years. The natural tendency on eroding dune frontages is to form dune cliffs broken at intervals by blowouts which are usually initiated at low points in the dune crest line where windspeeds are accelerated, and/or where footpaths descent to the beach. Appropriate management measures in such situations include the blocking of pathways using brushwood or chestnut paling fencing, stabilization of any blowouts which threaten the integrity of the barrier using thatching and vegetation planting, and raising of the level of low points using imported sand. The rate of dune cliff recession can be slowed to some degree by retaining tall scrub or tree vegetation in the frontal dune area. Although scrub and tree root systems only increase the erosion resistance of dune sand to a small degree the presence of tall, high density vegetation close to the dune cliff edge (even if dead or dying) provides an effective roughness which prevents the dispersal of windblown sand over a wide area landward of the dune cliff, tending to maintain dune height and reducing the rate of 'roll-back'. Long-term negative beach sediment budget can only be addressed through beach nourishment, with or without associated structures to reduce wave and current action.

Where dunes have low to medium FCERM significance, the aim should be to keep intervention measures to a minimum and to allow the dune system to evolve as naturally as possible. Frequently, however, it will be necessary to employ measures to control the development of scrub, and manage visitor access, to meet nature conservation and recreational use objectives. In situations where there are concerns that the dune system has become over-stabilized, it may be appropriate to undertake interventions such as creation of notches in the frontal dunes to enhance wind flow and sand transport into the hind-dune area, without any implications in terms of increased flood risk. Such interventions are likely to have the greatest chance of success in situations where there is some sand supply to the beach but the overall beach sediment budget is neutral to negative, due largely to the local wind energy being high enough to transport all the available sand into the frontal dune system (i.e. there is a positive frontal dune sediment budget). Where both the beach and frontal sediment budget are negative, artificial notches may persist and enlarge due to wind erosion of the sides and base, but inland spread of mobile sand will be less extensive than in situations where additional sand is available from the beach.

In situations where dunes have high FCERM significance it will generally be inappropriate to create notches in the frontal dunes unless the dune system is very

wide. In situations where the beach sediment budget is positive, i.e. there is a natural tendency for coastal progradation, there is likely to be an opportunity to increase the width of the dune defence by erecting chestnut paling or brushwood fencing at the dune toe or on the upper beach to trap sand and develop a wider frontal dune, or a separate new dune ridge. Under most circumstances vegetation will establish naturally on the newly accreted sand, but the process can be accelerated either by seeding or planting. The development of new embryo dunes and foredune ridges may be prevented by excessive human pressure (trampling by pedestrians or passage of vehicles. This can easily be controlled by placing rows of posts on the upper beach to exclude cars, or by the erection of sand fencing on the upper beach to regulate pedestrian movements and to trap sand (e.g. at Morfa Bychan, Figure 23).



Figure 23. Row of posts erected on the upper beach at Morfa Bychan to exclude cars and encourage the growth of embryo dunes

In areas where the current beach sediment budget is currently negative, resulting in a fall in average beach levels, frontal dune erosion will inevitably occur. Erosion of the dunes may also be made worse by high visitor pressure. If no counter measures are taken, the dune front will become cliffed, making it difficult for sand to be blown up the dune face and into the hind dune area, although sand may continue to pass through low points in the dune ridge. As the dune ridge is eroded, there is likely to be a reduction in both its crest height and width, reducing its value as flood defence (Figure 24a). The development of blowouts introduces additional points of weakness which increase the risk both of overtopping and breach and make the delivery of a HTL policy much more difficult.

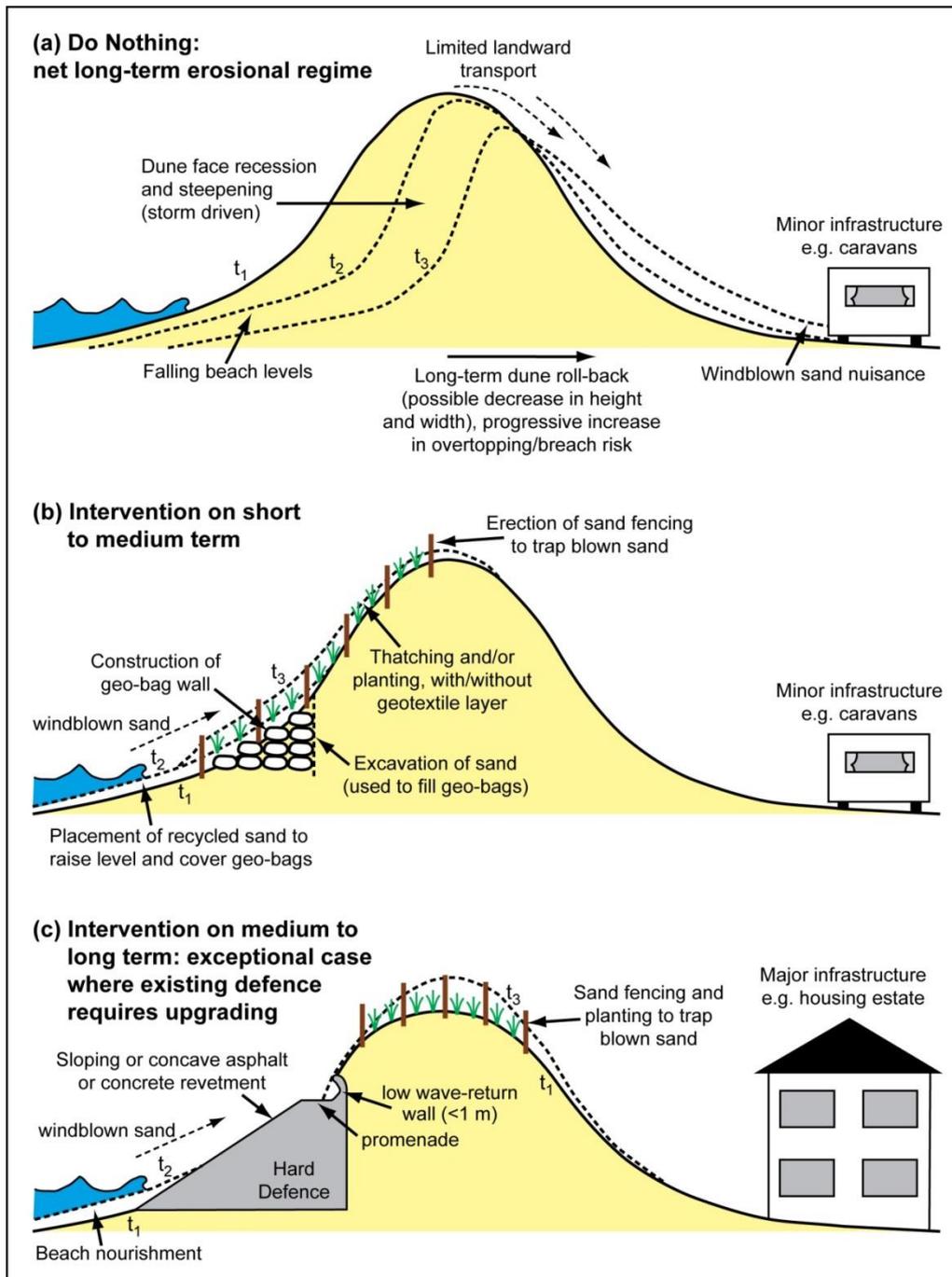


Figure 24. Schematic representation of three management options for an eroding dune frontage: (a) 'Do nothing', allowing the dune face to recede, with associated reduction in height, width and flood protection; (b) 'soft' engineering intervention involving placement of sediment-filled geotextile containers, upper beach nourishment, sand fencing, thatching and vegetation planting; (c) 'hard' engineering intervention involving construction of a sloping revetment with low wave return which allows continued sediment transport connectivity between the beach and dunes

In such circumstances, measures are required to control the recession of the dune toe and to maintain the integrity of the coastal defence (or the element of the overall coastal defence system provided by the dune system). If assets of only modest importance / value are present immediately behind the dune ridge, or high value assets are located some distance away, possibly protected by some other defence

system component such as a road or railway line, a major hard coastal defence scheme (sea wall, offshore breakwaters, major rock revetment) is unlikely to be justified on economic grounds, and in any case may be considered undesirable from an environmental point of view. An assessment of long-term shoreline change trends in the area may have led to the conclusion in the SMP process that the only long term solution is managed realignment, but in the short to medium term a policy of HTL may have been proposed while a long term strategy is developed. In such situations, which relate to dune sites such as Abererch and Morfa Gors Abersoch, rock armour or steel bulkheads have often been used in the past to stabilise locations of high concern (Figures 21 and 25).



Figure 25. Rock armour and groynes used to protect the dune frontage at the southern end of Morfa Gors, Abersoch

However, a more sustainable and environmentally acceptable solution would be to use a combination of 'soft' and 'firm' intervention methods. These might include the construction of a buried geobag wall following excavation and/ or re-grading of part of the cliffed frontal dune, followed by its burial and reinforcement of the upper beach using recycled sediment from a local source (e.g. the down-drift end of a beach system where the sediment budget is positive, or from harbour dredging arisings). Trapping and retention of the placed sand and additional sand blown from the beach can be achieved by erection of sand fencing, accompanied by vegetation planting and possible thatching (with brushwood or geotextile), on the seaward slope covering the sand-filled geotextile containers, and on the crest of the original dune ridge, as necessary (Figure 24b). Such measures would give the dune defence additional width, as well as resistance to wave attack. Maintenance, in the form of further periodic sediment cycling, is likely to be necessary, but the requirement for regular replacement of sand fencing is likely to diminish as natural vegetation gets better established. If and when the HTL policy is replaced by one of NAI or MR, it would be a much simpler and cheaper? matter to remove the residual geotextile bags and fencing than it would to remove large amounts of rock armour, steel or plastic

bulkheads, and groynes (e.g. as exist along the southern half of Morfa Gors Abersoch and at Abererch).

In situations where high value assets exist behind a dune system, a HTL policy is likely to have been recommended in all three SMP epochs (e.g. at Rhyl - Prestatyn on the North Wales coast). Such shorelines have usually been defended using seawalls and other hard engineering techniques for many years, and the dune system only acts as one component of a wider coastal defence system. With the exception of golf courses, the wider functional benefits of dunes in such situations have often been ignored, and the design of the hard defences has often resulted in the dune being largely or wholly cut off from the source of aeolian sand supply on the beach. This not only has a detrimental impact on the ecology of the dunes but also prevents the dunes from increasing in height / width and thereby providing a more effective component of the overall coastal defence system. If the sediment supply to the upper beach from the nearshore zone is large, new dunes may form in front of the sea wall (e.g. at Barmouth), but where there is little or no contemporary sediment supply to the upper beach this cannot occur and wave reflection from the hard defences may in fact lead to beach lowering.

Any hard defence system is likely to have a negative impact on the ecological integrity of a dune system, and the design of any hard defence scheme now judged to be necessary for the protection of important assets should take into account the desirability of allowing windblown sand to pass from the beach, across the defence, into a dune system behind. Where the assets of interest lie some distance away from the defence (i.e. accommodation space exists), the inland transfer of sand across the defence should be encouraged, since this will both maintain (to a degree) the ecological interest of the dune system and enhance the flood defence value of the dune component of the coastal defence system. A sloping or curving revetment, built of concrete or asphalt and with a maximum angle of 30° to seaward of a promenade, will permit the un-interrupted flow of windblown sand from the beach into the dunes behind the promenade (Figure 24c). It may be necessary to incorporate a low wave return wall into the design at the landward side of the promenade, but this will not act as a significant barrier to windblown sand movement if the height does not exceed about 1 m (e.g. Figure 26). If the promenade is sufficiently wide (4m or greater), it may be permissible to allow a small windblown sand ramp to form and remain on the windward side of the wave return wall. However, safety considerations associated with the use of the promenade need to be taken into account when deciding how to manage any local sand build-up.



Figure 26. Gently sloping revetment and low wave return wall at Frith Beach, Prestatyn, which allows blown sand from the beach to reach the dunes

6.3 The decision making process

Figure 27 shows a 'decision tree' which relates the principal SMP2 policies (Advance the Defence, Hold the Line, No Active Intervention and Managed Realignment) to the most appropriate / feasible dune management intervention options. Figure 28 shows a similar decision tree relating only to situations where dunes have high or very high FCERM significance and the SMP2 policy is 'Hold the Line'. The latter also takes account of whether the existing dune defence offers a very high, high, medium or low standard of risk protection, based on its morphological attributes (crest height, freeboard, width, sediment volume). The selection of intervention techniques (fencing, thatching, planting, geobags, re-profiling beach and/ or dune nourishment etc) depends essentially on whether there is a need to increase the height and /or width of the dune system, and the degree to which sand and dune form mobility can be permitted at any particular location. The latter aspect, in turn, will be dependent on the nature of any assets present behind the frontal dunes.

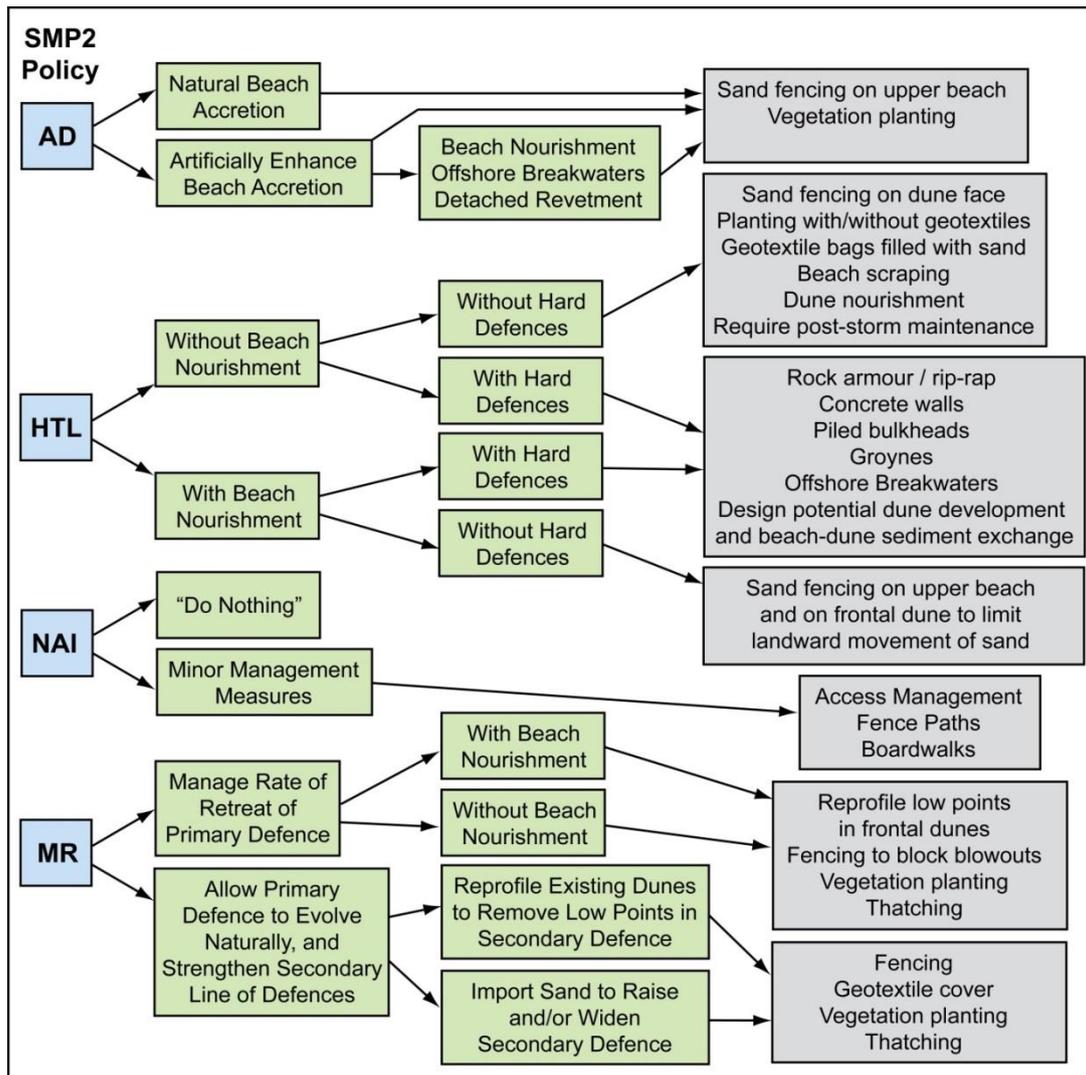


Figure 27. Decision tree relating SMP2 policy and dune management intervention options

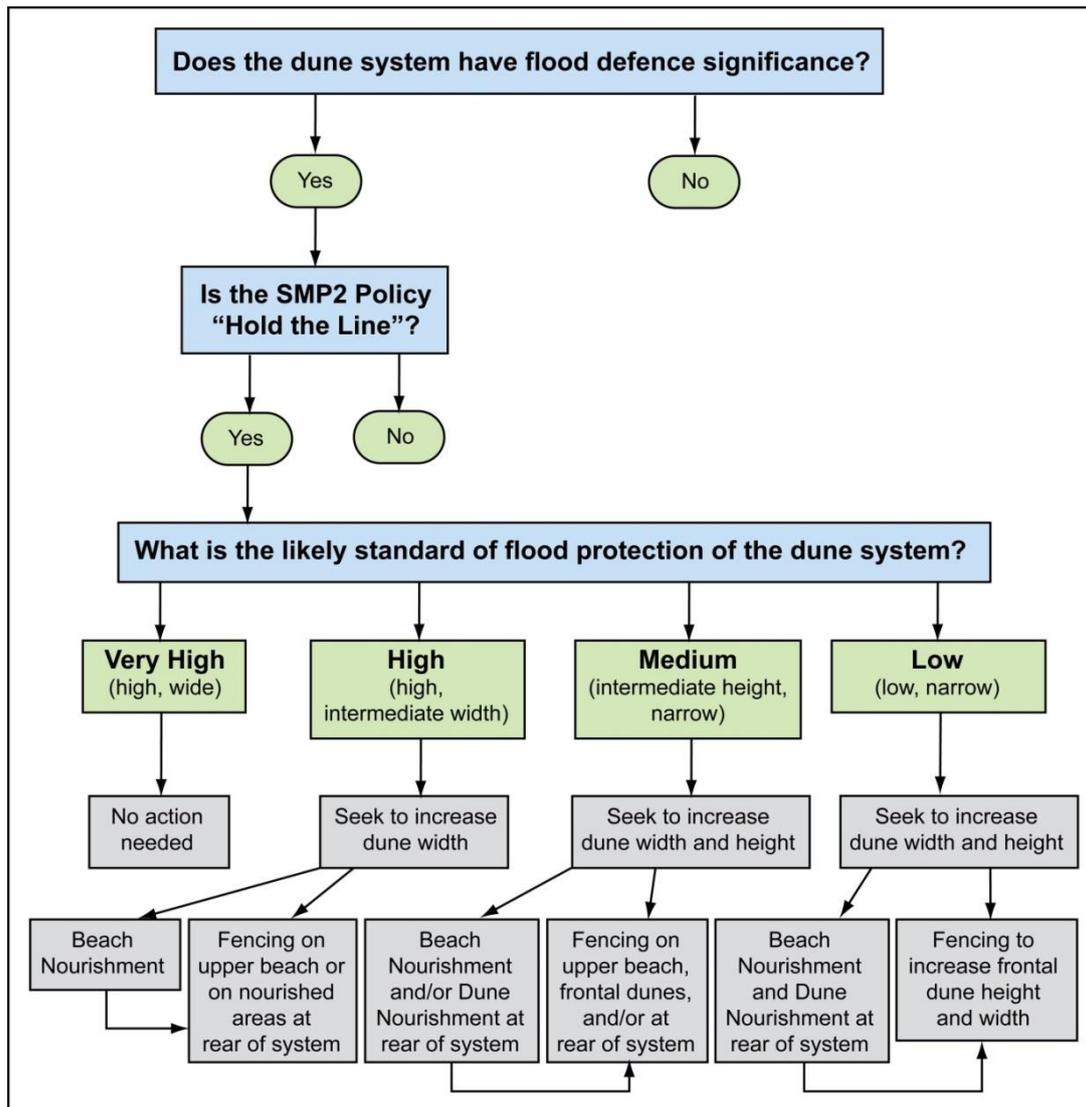


Figure 28. Decision tree relating FCERM significance and dune management intervention options

7. Conclusions and recommendations

A total of 87 sand dune sites has been identified in Wales, represented by 94 SMP2 policy units. Of these, 39 sites (39 policy units) do not perform a FCERM function. Twelve sites (16 policy units) are judged to have Medium / High, High or Very High FCERM significance. Of these, 5 sites (8 policy units) have an SMP2 shoreline management policy of Hold the Line (HTL) in Epoch 1, and 5 sites (4 policy units) have a HTL policy in Epochs 2 and 3. The sites of particular importance from a FCERM and SMP2 HTL policy point of view are Morfa Abererch to Pwllheli, Pwllheli and Traeth Crugan, Morfa Gors (Abersoch), Kinmel Dunes, and Ffrith Beach (Prestatyn). There are also a number of other sites where SMP2 policy in Epoch 1 and subsequent epochs is MR, and there remains a requirement to managed the dunes to deliver the policy while at the same time avoiding imminent risk to life, residential property and strategically important assets; these sites include the northern section of Pembrey Burrows (MOD Air Weapons Range), Pendine and

Laugharne Burrows (MOD / NATO missile testing range), Tenby Burrows (golf course, railway line), Aberdovey to Towyn (golf course, railway line), Llandanwg (building of historical importance, Arthro estuary and surrounding properties), and Barkby Beach to Talacre Warren (housing, caravan parks, golf course, sewage works).

In addition, Trwyn Trewan (RAF Valley / Anglesey Airport) and the Abererch East policy unit are considered to be of Medium / High FCERM significance in terms of risk to important assets. Although the SMP2 management policy for these areas is No Active Intervention in all three epochs, some dune protection measures are currently in place at Trwyn Trewan and additional dune management measures should be considered at both sites.

Historically, implementation of HTL policies along dune frontages has often involved the construction of hard defences, including sea walls, rock revetments, groynes, timber breastwork and employment of beach reinforcement using natural gravel or quarried rock. All of these interventions have negative environmental impacts and should be avoided wherever possible.

Less environmentally intrusive solutions, involving 'soft' and/ or 'firm' engineering methods such as sand-filled geotextile bag revetments, beach and frontal dune nourishment using recycled beach sediment or material dredged from local harbours, sand fencing, thatching and vegetation planting, should be used where practicable to maintain the natural sediment exchange processes between beaches and dunes, and to provide benefits for nature conservation, recreation and other interests.

In instances where hard defences already exist, and are due to be replaced or upgraded, or where short lengths of new hard defence need to be constructed, the design process should take into account dune creation and/ or maintenance in order to deliver multiple benefits. An example includes the provision of a gently sloping seaward revetment to a sea wall, backed by a relatively low wave return wall, which allows the free movement of blown sand across the structure to feed the dunes behind. In such cases the dunes should be seen as an important component of the overall coastal defence system, an one which can deliver additional benefits (e.g. for nature conservation and recreation). A second example is provided by the choice of a defence system employing detached breakwaters or shore-attached fishtail groynes which encourage the accumulation of beach sand and formation of areas of dunes in their lee.

It is recommended that, for each dune system in Wales which has medium, high or very high FCERM significance, a detailed study should be undertaken to quantify the morphological characteristics and erosion / accretion status of the dunes, including identification and any weak points and areas / assets in the hinterland which are at risk from marine flooding. A dune management plan should be developed, where none exists, which takes account of the FCERM requirements and the significance of the site, together with future aspirations, in terms of other aspects of interest (conservation of natural habitats, species, geomorphological features, sites of archaeological and historical interest, recreation, economic and military use), within the context of the *intent* of SMP2 policy. This assessment should include, at an early stage, a detailed assessment of the geomorphological setting, the operative physical

processes, sedimentological characteristics, sediment budget and environmental risks applicable to the site. Based on this information, the options for future dune management can be evaluated, a strategy developed, and appropriate intervention techniques specified.

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APPENDIX A

NATURAL INFLUENCES ON DUNE SYSTEMS AROUND THE COAST OF WALES

Table A1. HAT and 1 in 200 year extreme water levels

No.	Site Name	Highest Astronomical Tide Level (m OD)	1:200 year storm surge level (m OD)	Surge parameter (1:200 year level minus HAT, m)	Surge parameter multiplied by the mean wave power	Surge parameter plus mean significant wave height
1	Aberthaw	6.70	7.33 ± 0.4	0.63	2.26	1.47
2	Ogmore Dunes	5.80	6.42 ± 0.3	0.62	2.95	1.56
3	Merthyr-mawr Warren and Newton Burrows	5.80	6.36 ± 0.3	0.56	2.67	1.50
4	Sandy Bay, Porthcawl	5.70	6.31 ± 0.3	0.61	2.90	1.55
5	Porthcawl to Sker Point	5.70	6.26 ± 0.3	0.56	2.67	1.50
6	Kenfig Burrows	5.65	6.22 ± 0.3	0.57	2.18	1.41
7	Margam Burrows	5.65	6.21 ± 0.3	0.56	2.14	1.40
8	Aberavon	5.60	6.18 ± 0.3	0.58	2.22	1.42
9	Baglan Burrows	5.80	6.17 ± 0.3	0.37	1.41	1.21
10	Crymlyn Burrows and Earlswood Golf Club	5.80	6.17 ± 0.3	0.37	1.41	1.21
11	Spontex Dunes, Swansea	5.50	6.15 ± 0.3	0.65	2.48	1.50
12	Swansea Beach and Black Pill Burrows	5.50	6.15 ± 0.3	0.65	2.48	1.50
13	Pennard Burrows	5.30	6.02 ± 0.3	0.72	2.10	1.49
14	Penmaen Burrows	5.30	6.02 ± 0.3	0.72	2.10	1.49
15	Oxwich and Nicholaston Burrows	5.30	6.00 ± 0.3	0.70	2.04	1.47
16	Port-Eynon and Horton Dunes	5.15	5.95 ± 0.3	0.80	6.55	2.02
17	Rhossilli Bay South	5.00	5.82 ± 0.3	0.82	7.35	2.11
18	Llangennith, Hillend and Broughton Burrows	5.00	5.79 ± 0.3	0.79	5.07	1.86
19	Delvid Burrows and Hills Burrows	4.90	5.75 ± 0.3	0.85	5.46	1.92
20	Whiteford Burrows	4.90	5.73 ± 0.3	0.83	5.33	1.90
21	Machynys and Llanelli	5.14	5.73 ± 0.3 est	0.59	0.59	1.09
22	Burry Port	4.90	5.73 ± 0.3 est	0.83	0.83	1.33
23	Pembrey Burrows	4.90	5.69 ± 0.3	0.79	2.83	1.60
24	Gwendraeth Estuary North Shore	5.00	5.58 ± 0.4 est	0.58	0.58	1.08
25	Ferryside to Morfa Uchaf, River Towy	5.30	5.58 ± 0.4 est	0.28	0.28	0.78
26	Llansteffan and Ferry Point, River Towy	5.30	5.58 ± 0.4 est	0.28	0.28	0.78
27	Pentowyn, River Taf	5.30	5.58 ± 0.4 est	0.28	0.28	0.78
28	Pendine and Laugharne Burrows	4.90	5.56 ± 0.4	0.66	2.28	1.46
29	Tenby Burrows	4.90	5.30 ± 0.2	0.40	0.97	1.09
30	Giltar Point	4.85	5.27 ± 0.2	0.42	1.02	1.11
31	Priory Bay, Caldey Island	4.85	5.27 ± 0.2	0.42	0.42	0.92
32	Lydstep Haven	4.80	5.19 ± 0.2	0.39	2.09	1.39
33	Manorbier Bay	4.70	5.06 ± 0.2	0.36	1.93	1.36
34	Freshwater East	4.65	5.06 ± 0.2	0.41	2.97	1.54
35	Barafundle Bay	4.60	4.99 ± 0.2	0.39	2.83	1.52
36	Stackpole Warren	4.60	4.99 ± 0.2	0.39	2.83	1.52
37	Broad Haven	4.55	4.96 ± 0.2	0.41	2.97	1.54
38	Brownslade and Linney Burrows	4.35	4.78 ± 0.2	0.43	6.29	2.02
39	Gupton Burrows	4.35	4.78 ± 0.2	0.43	6.29	2.02
40	Broomhill, Kilpaison and Newton Burrows	4.35	4.78 ± 0.2	0.43	6.29	2.02
41	Nolton Haven	3.30	4.08 ± 0.2	0.78	6.08	1.90
42	The Burrows, Whitesands Bay	2.80	3.68 ± 0.2	0.88	11.62	2.47
43	The Parrog, Fishguard	3.06	3.58 ± 0.2	0.52	3.26	1.65
44	Aber Fforest	3.00	3.59 ± 0.2	0.59	2.91	1.59
45a	Newport Bay: The Bennet	3.00	3.59 ± 0.2	0.59	2.91	1.59
45b	Newport Bay: Newport Sands North	3.00	3.59 ± 0.2	0.59	2.91	1.59

Table A1. continued

No.	Site Name	Highest Astronomical Tide Level (m OD)	1:200 year storm surge level (m OD)	Surge parameter (1:200 year level minus HAT, m)	Surge parameter multiplied by the mean wave power	Surge parameter plus mean significant wave height
46	Poppit Sands	2.86	3.60 ± 0.2	0.74	3.80	1.79
47	Towyn Warren	2.86	3.60 ± 0.2	0.74	3.80	1.79
48	Traeth Penbryn	3.00	3.68 ± 0.2	0.68	3.50	1.73
49a	Borth to Ynyslas: Ynyslas South	3.06	3.94 ± 0.2	0.88	2.65	1.67
49b	Borth to Ynyslas: Ynyslas North	3.06	3.94 ± 0.2	0.88	2.65	1.67
50	Aberdovey to Tywyn	3.06	3.93 ± 0.2	0.87	2.62	1.66
51	Aber Dysynni	3.15	3.91 ± 0.2	0.76	2.46	1.57
52	Fairbourne spit	3.26	4.22 ± 0.2	0.96	2.88	1.73
53	Barmouth	3.26	4.22 ± 0.2	0.96	2.88	1.73
54	Morfa Dyffryn	3.30	4.14 ± 0.2	0.84	1.71	1.48
55	Llandanwg	3.36	4.09 ± 0.2	0.73	1.49	1.37
56	Morfa Harlech	3.40	4.08 ± 0.2	0.68	1.39	1.32
57	Morfa Bychan	3.40	4.07 ± 0.2	0.67	1.37	1.31
58a	Morfa Abererch to Pwllheli: Abererch East	3.36	4.05 ± 0.2	0.69	1.45	1.36
58b	Morfa Abererch to Pwllheli: Abererch West	3.36	4.05 ± 0.2	0.69	1.45	1.36
58c	Morfa Abererch to Pwllheli: Glan y Don	3.36	4.05 ± 0.2	0.69	1.45	1.36
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	3.36	4.03 ± 0.2	0.67	1.17	1.30
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	3.36	4.03 ± 0.2	0.67	1.17	1.30
59c	Pwllheli and Traeth Crugan: Traeth Crugan	3.36	4.03 ± 0.2	0.67	1.17	1.30
60	The Warren, Abersoch	3.16	3.97 ± 0.2	0.81	1.42	1.44
61	Morfa Gors, Abersoch	3.16	3.91 ± 0.2	0.75	1.31	1.38
62	Tywyn yr Wylfa, Abersoch	3.10	3.74 ± 0.3	0.64	3.65	1.70
63	Tai Morfa, Porth Neigwl	3.00	3.52 ± 0.3	0.52	2.97	1.58
64	Morfa Dinlle	2.70	3.41 ± 0.2	0.71	1.59	1.40
65	Newborough	2.70	3.41 ± 0.2	0.71	1.59	1.40
66	Porth Twyn-mawr and Porth Gro	2.75	3.40 ± 0.2	0.65	1.46	1.34
67	Tywyn Aberffraw	2.80	3.40 ± 0.2	0.60	1.34	1.29
68	Porth Trecastell	2.90	3.41 ± 0.2	0.51	1.99	1.41
69	Tywyn Fferam and Tywyn Llyn	2.90	3.41 ± 0.2	0.51	1.99	1.41
70	Tywyn Trewan	2.95	3.41 ± 0.2	0.46	1.80	1.36
71	Tywyn Bryn-y-Bar, Holy Island	2.95	3.41 ± 0.2	0.46	1.80	1.36
72	Trearddur Bay, Holy Island	3.00	3.42 ± 0.2	0.42	1.64	1.32
73	Traeth Penrhos, Holy Island	3.25	3.93 ± 0.2	0.68	1.77	1.47
74	Gorsedd-y-penrhyn, Holy Island	3.25	3.93 ± 0.2	0.68	1.77	1.47
75	Tywyn-gywyn	3.25	3.93 ± 0.2	0.68	1.77	1.47
76	Tywyn-mawr	3.25	3.93 ± 0.2	0.68	1.77	1.47
77	Traeth Dulas	4.40	4.96 ± 0.2	0.56	0.57	1.09
78	Traeth Ligwy	4.45	4.96 ± 0.2	0.51	0.52	1.04
79	Benllech Sand	4.50	5.01 ± 0.2	0.51	0.52	1.04
80	Red Wharf Bay	4.50	5.03 ± 0.2	0.53	0.54	1.06
81	Conwy Morfa	4.80	5.30 ± 0.2	0.50	0.80	1.15
82	Deganwy South	4.80	5.30 ± 0.2	0.50	0.80	1.15
83	Deganwy North and Llandudno West Shore	4.80	5.30 ± 0.2	0.50	0.80	1.15
84	Llandudno East Shore	4.75	5.41 ± 0.2	0.66	1.04	1.30
85	Kinmel Dunes	4.90	5.71 ± 0.2	0.81	1.16	1.41
86a	Rhyl East	5.05	5.80 ± 0.2	0.75	1.07	1.35
86b	Ffrith Beach, Prestatyn	5.05	5.80 ± 0.2	0.75	1.07	1.35
87	Barkby Beach, Gronant Dunes and Talacre Warren	5.15	5.91 ± 0.2	0.76	0.98	1.32

Table A2. List of dune sites and closest offshore Wavenet Hindcast point

No.	Site Name	Hindcast Point Number	Latitude (degrees)	Longitude (degrees)	OSGB36 Easting	OSGB36 Northing	Distance offshore (km)
1	Aberthaw	582	51.306	-3.476	297213	157344	9.3
2	Ogmore Dunes	665	51.463	-3.736	279505	175255	2.5
3	Merthyr-mawr Warren and Newton Burrows	665	51.463	-3.736	279505	175255	2.5
4	Sandy Bay, Porthcawl	665	51.463	-3.736	279505	175255	2.5
5	Porthcawl to Sker Point	665	51.463	-3.736	279505	175255	2.5
6	Kenfig Burrows	716	51.542	-3.867	270629	184219	6.6
7	Margam Burrows	716	51.542	-3.867	270629	184219	6.6
8	Aberavon	716	51.542	-3.867	270629	184219	6.6
9	Baglan Burrows	716	51.542	-3.867	270629	184219	6.6
10	Crymlyn Burrows and Earlswood Golf Club	716	51.542	-3.867	270629	184219	6.6
11	Spontex Dunes, Swansea	717	51.540	-3.995	261748	184276	2.7
12	Swansea Beach and Black Pill Burrows	717	51.540	-3.995	261748	184276	2.7
13	Pennard Burrows	718	51.539	-4.124	252798	184339	1.7
14	Penmaen Burrows	718	51.539	-4.124	252798	184339	1.7
15	Oxwich and Nicholaston Burrows	718	51.539	-4.124	252798	184339	1.7
16	Port-Eynon and Horton Dunes	719	51.537	-4.252	243915	184393	1.1
17	Rhossilli Bay South	708	51.535	-4.381	234962	184454	5.9
18	Llangennith, Hillend and Broughton Burrows	756	51.615	-4.384	235044	193345	4.9
19	Delvid Burrows and Hills Burrows	756	51.615	-4.384	235044	193345	4.9
20	Whiteford Burrows	756	51.615	-4.384	235044	193345	4.9
21	Machynys and Llanelli	756	51.615	-4.384	235044	193345	4.9
22	Burry Port	756	51.615	-4.384	235044	193345	4.9
23	Pembrey Burrows	790	51.695	-4.388	235058	202250	2.2
24	Gwendraeth Estuary North Shore	790	51.695	-4.388	235058	202250	2.2
25	Ferryside to Morfa Uchaf, River Towy	790	51.695	-4.388	235058	202250	2.2
26	Llansteffan and Ferry Point, River Towy	790	51.695	-4.388	235058	202250	2.2
27	Pentowyn, River Taf	790	51.695	-4.388	235058	202250	2.2
28	Pendine and Laugharne Burrows	791	51.693	-4.517	226136	202316	5.1
29	Tenby Burrows	792	51.690	-4.645	217281	202373	2.5
30	Giltar Point	792	51.690	-4.645	217281	202373	2.5
31	Priory Bay, Caldey Island	792	51.690	-4.645	217281	202373	2.5
32	Lydstep Haven	759	51.608	-4.770	208295	193532	3.2
33	Manorbier Bay	759	51.608	-4.770	208295	193532	3.2
34	Freshwater East	760	51.605	-4.899	199353	193589	1.0
35	Barafundle Bay	760	51.605	-4.899	199353	193589	1.0
36	Stackpole Warren	760	51.605	-4.899	199353	193589	1.0
37	Broad Haven	760	51.605	-4.899	199353	193589	1.0
38	Brownslade and Linney Burrows	751	51.600	-5.156	181534	193704	7.0
39	Gupton Burrows	751	51.600	-5.156	181534	193704	7.0
40	Broomhill, Kilpaison and Newton Burrows	751	51.600	-5.156	181534	193704	7.0
41	Nolton Haven	842	51.840	-5.171	181655	220410	3.5
42	The Burrows, Whitesands Bay	869	51.913	-5.435	163860	229428	8.5
43	The Parrog, Fishguard	935	52.082	-5.055	190778	247053	6.1
44	Aber Fforest	934	52.085	-4.925	199696	246997	5.9
45a	Newport Bay: The Bennet	934	52.085	-4.925	199696	246997	5.9
45b	Newport Bay: Newport Sands North	934	52.085	-4.925	199696	246997	5.9

Table A2. continued

No.	Site Name	Hindcast Point Number	Latitude (degrees)	Longitude (degrees)	OSGB36 Easting	OSGB36 Northing	Distance offshore (km)
46	Poppit Sands	976	52.168	-4.799	208682	255841	7.2
47	Towyn Warren	976	52.168	-4.799	208682	255841	7.2
48	Traeth Penbryn	974	52.172	-4.539	226478	255721	4.3
49a	Borth to Ynyslas: Ynyslas South	1095	52.498	-4.159	253542	291133	7.1
49b	Borth to Ynyslas: Ynyslas North	1095	52.498	-4.159	253542	291133	7.1
50	Aberdovey to Tywyn	1095	52.498	-4.159	253542	291133	7.1
51	Aber Dysynni	1124	52.578	-4.162	253605	300036	4.1
52	Fairbourne spit	1175	52.738	-4.168	253733	317832	5.4
53	Barmouth	1175	52.738	-4.168	253733	317832	5.4
54	Morfa Dyffryn	1199	52.818	-4.171	253800	326735	1.4
55	Llandanwg	1199	52.818	-4.171	253800	326735	1.4
56	Morfa Harlech	1199	52.818	-4.171	253800	326735	1.4
57	Morfa Bychan	1199	52.818	-4.171	253800	326735	1.4
58a	Morfa Abererch to Pwllheli: Abererch East	1200	52.816	-4.304	244831	326803	8.8
58b	Morfa Abererch to Pwllheli: Abererch West	1200	52.816	-4.304	244831	326803	8.8
58c	Morfa Abererch to Pwllheli: Glan y Don	1200	52.816	-4.304	244831	326803	8.8
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	1195	52.814	-4.436	235929	326863	4.8
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	1195	52.814	-4.436	235929	326863	4.8
59c	Pwllheli and Traeth Crugan: Traeth Crugan	1195	52.814	-4.436	235929	326863	4.8
60	The Warren, Abersoch	1195	52.814	-4.436	235929	326863	4.8
61	Morfa Gors, Abersoch	1195	52.814	-4.436	235929	326863	4.8
62	Tywyn yr Wylfa, Abersoch	1169	52.732	-4.565	226911	318024	5.9
63	Tai Morfa, Porth Neigwl	1169	52.732	-4.565	226911	318024	5.9
64	Morfa Dinlle	1318	53.134	-4.450	236201	362472	3.1
65	Newborough	1318	53.134	-4.450	236201	362472	3.1
66	Porth Twyn-mawr and Porth Gro	1318	53.134	-4.450	236201	362472	3.1
67	Tywyn Aberffraw	1318	53.134	-4.450	236201	362472	3.1
68	Porth Trecastell	1356	53.212	-4.587	227351	371436	4.7
69	Tywyn Fferam and Tywyn Llyn	1356	53.212	-4.587	227351	371436	4.7
70	Tywyn Trewan	1356	53.212	-4.587	227351	371436	4.7
71	Tywyn Bryn-y-Bar, Holy Island	1356	53.212	-4.587	227351	371436	4.7
72	Trearddur Bay, Holy Island	1356	53.212	-4.587	227351	371436	4.7
73	Traeth Penrhos, Holy Island	1424	53.372	-4.595	227463	389250	2.4
74	Gorsedd-y-penrhyn, Holy Island	1424	53.372	-4.595	227463	389250	2.4
75	Tywyn-gywyn	1424	53.372	-4.595	227463	389250	2.4
76	Tywyn-mawr	1424	53.372	-4.595	227463	389250	2.4
77	Traeth Dulas	1434	53.378	-4.193	254224	389054	4.3
78	Traeth Ligwy	1434	53.378	-4.193	254224	389054	4.3
79	Benllech Sand	1434	53.378	-4.193	254224	389054	4.3
80	Red Wharf Bay	1434	53.378	-4.193	254224	389054	4.3
81	Conwy Morfa	1432	53.382	-3.925	272059	388917	5.6
82	Deganwy South	1432	53.382	-3.925	272059	388917	5.6
83	Deganwy North and Llandudno West Shore	1432	53.382	-3.925	272059	388917	5.6
84	Llandudno East Shore	1431	53.383	-3.790	281042	388851	6.2
85	Kinmel Dunes	1440	53.386	-3.523	298806	388728	7.0
86a	Rhyl East	1440	53.386	-3.523	298806	388728	7.0
86b	Ffrith Beach, Prestatyn	1440	53.386	-3.523	298806	388728	7.0
87	Barkby Beach, Gronant Dunes and Talacre Warren	1439	53.387	-3.389	307719	388657	4.1

Table A3. Modelled wind parameters for offshore hindcast points closest to each dune site, averaged for the period of record (1980-2016 inclusive)

No.	Site Name	Wind speed (knots)	Wind direction (degrees)	Resultant Drift Direction (RDD, degrees)	Drift Potential (DP, vector units)	Resultant Drift Potential (RDP, vector units)	RDP/DP ratio
1	Aberthaw	11.36	255.8	79.8	1016	558	0.55
2	Ogmore Dunes	11.80	248.9	68.0	1201	694	0.58
3	Merthyr-mawr Warren and Newton Burrows	11.80	248.9	68.0	1201	694	0.58
4	Sandy Bay, Porthcawl	11.80	248.9	68.0	1201	694	0.58
5	Porthcawl to Sker Point	11.80	248.9	68.0	1201	694	0.58
6	Kenfig Burrows	10.99	244.8	62.8	927	548	0.59
7	Margam Burrows	10.99	244.8	62.8	927	548	0.59
8	Aberavon	10.99	244.8	62.8	927	548	0.59
9	Baglan Burrows	10.99	244.8	62.8	927	548	0.59
10	Crymlyn Burrows and Earlswood Golf Club	10.99	244.8	62.8	927	548	0.59
11	Spontex Dunes, Swansea	11.70	243.7	60.5	1178	669	0.57
12	Swansea Beach and Black Pill Burrows	11.70	243.7	60.5	1178	669	0.57
13	Pennard Burrows	12.52	243.4	58.5	1509	828	0.55
14	Penmaen Burrows	12.52	243.4	58.5	1509	828	0.55
15	Oxwich and Nicholaston Burrows	12.52	243.4	58.5	1509	828	0.55
16	Port-Eynon and Horton Dunes	13.22	243.8	57.9	1819	975	0.54
17	Rhossilli Bay South	13.65	243.5	56.7	2040	1053	0.52
18	Llangennith, Hillend and Broughton Burrows	12.75	241.1	52.0	1589	868	0.55
19	Delvid Burrows and Hills Burrows	12.75	241.1	52.0	1589	868	0.55
20	Whiteford Burrows	12.75	241.1	52.0	1589	868	0.55
21	Machynys and Llanelli	12.75	241.1	52.0	1589	868	0.55
22	Burry Port	12.75	241.1	52.0	1589	868	0.55
23	Pembrey Burrows	11.60	237.6	46.6	1103	636	0.58
24	Gwendraeth Estuary North Shore	11.60	237.6	46.6	1103	636	0.58
25	Ferryside to Morfa Uchaf, River Towy	11.60	237.6	46.6	1103	636	0.58
26	Llansteffan and Ferry Point, River Towy	11.60	237.6	46.6	1103	636	0.58
27	Pentowyn, River Taf	11.60	237.6	46.6	1103	636	0.58
28	Pendine and Laugharne Burrows	11.84	237.0	45.4	1193	669	0.56
29	Tenby Burrows	14.00	243.3	57.3	2212	1128	0.51
30	Giltar Point	14.00	243.3	57.3	2212	1128	0.51
31	Priory Bay, Caldey Island	14.00	243.3	57.3	2212	1128	0.51
32	Lydstep Haven	13.52	241.7	53.8	1948	1011	0.52
33	Manorbier Bay	13.52	241.7	53.8	1948	1011	0.52
34	Freshwater East	14.10	243.4	56.4	2252	1145	0.51
35	Barafundle Bay	14.10	243.4	56.4	2252	1145	0.51
36	Stackpole Warren	14.10	243.4	56.4	2252	1145	0.51
37	Broad Haven	14.10	243.4	56.4	2252	1145	0.51
38	Brownslade and Linney Burrows	15.19	245.8	60.0	2929	1386	0.47
39	Gupton Burrows	15.19	245.8	60.0	2929	1386	0.47
40	Broomhill, Kilpaison and Newton Burrows	15.19	245.8	60.0	2929	1386	0.47
41	Nolton Haven	14.45	242.8	58.6	2482	1265	0.51
42	The Burrows, Whitesands Bay	15.46	242.6	57.8	3145	1519	0.48
43	The Parrog, Fishguard	14.38	240.4	58.9	2426	1254	0.52
44	Aber Fforest	13.71	241.3	61.1	2017	1065	0.53
45a	Newport Bay: The Bennet	13.71	241.3	61.1	2017	1065	0.53
45b	Newport Bay: Newport Sands North	13.71	241.3	61.1	2017	1065	0.53

Table A3. continued

No.	Site Name	Wind speed (knots)	Wind direction (degrees)	Resultant Drift Direction (RDD, degrees)	Drift Potential (DP, vector units)	Resultant Drift Potential (RDP, vector units)	RDP/DP ratio
46	Poppit Sands	13.79	240.5	61.4	2127	1106	0.52
47	Towyn Warren	13.79	240.5	61.4	2127	1106	0.52
48	Traeth Penbryn	12.32	241.7	66.7	1380	714	0.52
49a	Borth to Ynyslas: Ynyslas South	12.91	237.2	61.6	1932	1127	0.58
49b	Borth to Ynyslas: Ynyslas North	12.91	237.2	61.6	1932	1127	0.58
50	Aberdovey to Tywyn	12.91	237.2	61.6	1932	1127	0.58
51	Aber Dysynni	13.01	235.8	58.9	2018	1203	0.60
52	Fairbourne spit	12.18	231.7	51.8	1592	1026	0.64
53	Barmouth	12.18	231.7	51.8	1592	1026	0.64
54	Morfa Dyffryn	11.34	228.9	48.0	1193	805	0.68
55	Llandanwg	11.34	228.9	48.0	1193	805	0.68
56	Morfa Harlech	11.34	228.9	48.0	1193	805	0.68
57	Morfa Bychan	11.34	228.9	48.0	1193	805	0.68
58a	Morfa Abererch to Pwllheli: Abererch East	12.38	230.5	48.4	1604	1018	0.63
58b	Morfa Abererch to Pwllheli: Abererch West	12.38	230.5	48.4	1604	1018	0.63
58c	Morfa Abererch to Pwllheli: Glan y Don	12.38	230.5	48.4	1604	1018	0.63
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	14.84	234.5	51.4	2872	1536	0.53
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	14.84	234.5	51.4	2872	1536	0.53
59c	Pwllheli and Traeth Crugan: Traeth Crugan	14.84	234.5	51.4	2872	1536	0.53
60	The Warren, Abersoch	14.84	234.5	51.4	2872	1536	0.53
61	Morfa Gors, Abersoch	14.84	234.5	51.4	2872	1536	0.53
62	Tywyn yr Wylfa, Abersoch	14.68	235.4	53.0	2805	1517	0.54
63	Tai Morfa, Porth Neigwl	14.68	235.4	53.0	2805	1517	0.54
64	Morfa Dinlle	12.64	230.1	48.5	1656	1025	0.62
65	Newborough	12.64	230.1	48.5	1656	1025	0.62
66	Porth Twyn-mawr and Porth Gro	12.64	230.1	48.5	1656	1025	0.62
67	Tywyn Aberffraw	12.64	230.1	48.5	1656	1025	0.62
68	Porth Trecastell	13.58	230.3	48.4	2118	1259	0.59
69	Tywyn Fferam and Tywyn Llyn	13.58	230.3	48.4	2118	1259	0.59
70	Tywyn Trewan	13.58	230.3	48.4	2118	1259	0.59
71	Tywyn Bryn-y-Bar, Holy Island	13.58	230.3	48.4	2118	1259	0.59
72	Trearddur Bay, Holy Island	13.58	230.3	48.4	2118	1259	0.59
73	Traeth Penrhos, Holy Island	14.15	230.5	50.9	2343	1339	0.57
74	Gorsedd-y-penrhyn, Holy Island	14.15	230.5	50.9	2343	1339	0.57
75	Tywyn-gwyn	14.15	230.5	50.9	2343	1339	0.57
76	Tywyn-mawr	14.15	230.5	50.9	2343	1339	0.57
77	Traeth Dulas	13.29	230.0	51.2	1871	1088	0.58
78	Traeth Ligwy	13.29	230.0	51.2	1871	1088	0.58
79	Benllech Sand	13.29	230.0	51.2	1871	1088	0.58
80	Red Wharf Bay	13.29	230.0	51.2	1871	1088	0.58
81	Conwy Morfa	12.88	234.7	62.5	1732	907	0.52
82	Deganwy South	12.88	234.7	62.5	1732	907	0.52
83	Deganwy North and Llandudno West Shore	12.88	234.7	62.5	1732	907	0.52
84	Llandudno East Shore	13.00	237.3	67.4	1848	973	0.53
85	Kinmel Dunes	12.76	241.0	75.8	1792	980	0.55
86a	Rhyl East	12.76	241.0	75.8	1792	980	0.55
86b	Ffrith Beach, Prestatyn	12.76	241.0	75.8	1792	980	0.55
87	Barkby Beach, Gronant Dunes and Talacre Warren	12.40	241.9	78.8	1611	909	0.56

Table A4. Wave parameters for offshore hindcast points closest to each dune site, averaged for the period of record (1980-2016 inclusive)

No.	Site Name	Significant wave height, Hs (m)	Zero up-crossing period, Tz (sec)	Peak wave period, Tp (sec)	Energy period, Te (sec)	Wave power (kW m ⁻¹)	Wave direction (degrees)	Wave direction scaled for wave power (degrees)
1	Aberthaw	0.84	4.56	7.81	6.86	3.59	269.6	268.3
2	Ogmore Dunes	0.94	4.75	8.16	6.98	4.76	244.0	243.0
3	Merthyr-mawr Warren and Newton Burrows	0.94	4.75	8.16	6.98	4.76	244.0	243.0
4	Sandy Bay, Porthcawl	0.94	4.75	8.16	6.98	4.76	244.0	243.0
5	Porthcawl to Sker Point	0.94	4.75	8.16	6.98	4.76	244.0	243.0
6	Kenfig Burrows	0.84	4.59	8.04	6.84	3.82	240.2	239.1
7	Margam Burrows	0.84	4.59	8.04	6.84	3.82	240.2	239.1
8	Aberavon	0.84	4.59	8.04	6.84	3.82	240.2	239.1
9	Baglan Burrows	0.84	4.59	8.04	6.84	3.82	240.2	239.1
10	Crymlyn Burrows and Earlswood Golf Club	0.84	4.59	8.04	6.84	3.82	240.2	239.1
11	Spontex Dunes, Swansea	0.85	4.43	7.76	6.66	3.81	236.6	234.9
12	Swansea Beach and Black Pill Burrows	0.85	4.43	7.76	6.66	3.81	236.6	234.9
13	Pennard Burrows	0.77	4.20	7.23	6.34	2.92	232.2	228.1
14	Penmaen Burrows	0.77	4.20	7.23	6.34	2.92	232.2	228.1
15	Oxwich and Nicholaston Burrows	0.77	4.20	7.23	6.34	2.92	232.2	228.1
16	Port-Eynon and Horton Dunes	1.22	4.86	8.17	7.01	8.19	237.6	234.2
17	Rhossilli Bay South	1.29	4.75	7.97	6.89	8.96	240.8	237.2
18	Llangennith, Hillend and Broughton Burrows	1.07	4.61	7.96	6.84	6.42	235.8	232.2
19	Delvid Burrows and Hills Burrows	1.07	4.61	7.96	6.84	6.42	235.8	232.2
20	Whiteford Burrows	1.07	4.61	7.96	6.84	6.42	235.8	232.2
21	Machynys and Llanelli	1.07	4.61	7.96	6.84	<1.00	235.8	232.2
22	Burry Port	1.07	4.61	7.96	6.84	<1.00	235.8	232.2
23	Pembrey Burrows	0.81	4.30	7.62	6.61	3.58	224.3	220.7
24	Gwendraeth Estuary North Shore	0.81	4.30	7.62	6.61	<1.00	224.3	220.7
25	Ferryside to Morfa Uchaf, River Towy	0.81	4.30	7.62	6.61	<1.00	224.3	220.7
26	Llansteffan and Ferry Point, River Towy	0.81	4.30	7.62	6.61	<1.00	224.3	220.7
27	Pentowyn, River Taf	0.81	4.30	7.62	6.61	<1.00	224.3	220.7
28	Pendine and Laugharne Burrows	0.80	4.15	7.35	6.46	3.46	216.0	211.8
29	Tenby Burrows	0.69	3.95	6.74	6.21	2.43	205.9	200.2
30	Giltar Point	0.69	3.95	6.74	6.21	2.43	205.9	200.2
31	Priory Bay, Caldey Island	0.69	3.95	6.74	6.21	<1.00	205.9	200.2
32	Lydstep Haven	1.00	4.31	7.42	6.53	5.35	221.1	214.8
33	Manorbier Bay	1.00	4.31	7.42	6.53	5.35	221.1	214.8
34	Freshwater East	1.13	4.60	7.94	6.85	7.25	225.0	219.1
35	Barafundle Bay	1.13	4.60	7.94	6.85	7.25	225.0	219.1
36	Stackpole Warren	1.13	4.60	7.94	6.85	7.25	225.0	219.1
37	Broad Haven	1.13	4.60	7.94	6.85	7.25	225.0	219.1
38	Brownslade and Linney Burrows	1.59	5.00	8.31	7.18	14.62	242.8	238.7
39	Gupton Burrows	1.59	5.00	8.31	7.18	14.62	242.8	238.7
40	Broomhill, Kilpaison and Newton Burrows	1.59	5.00	8.31	7.18	14.62	242.8	238.7
41	Nolton Haven	1.12	4.95	8.23	7.31	7.80	252.8	251.0
42	The Burrows, Whitesands Bay	1.59	4.76	7.62	6.71	13.20	252.7	245.6
43	The Parrog, Fishguard	1.13	4.31	7.11	6.33	6.27	271.5	268.6
44	Aber Fforest	1.00	4.17	7.04	6.27	4.93	279.3	277.9
45a	Newport Bay: The Bennet	1.00	4.17	7.04	6.27	4.93	279.3	277.9
45b	Newport Bay: Newport Sands North	1.00	4.17	7.04	6.27	4.93	279.3	277.9

Table A4. continued

No.	Site Name	Significant wave height, Hs (m)	Zero up-crossing period, Tz (sec)	Peak wave period, Tp (sec)	Energy period, Te (sec)	Wave power (kW m ⁻¹)	Wave direction (degrees)	Wave direction scaled for wave power (degrees)
46	Poppit Sands	1.05	4.07	6.73	6.01	5.14	272.0	269.4
47	Towyn Warren	1.05	4.07	6.73	6.01	5.14	272.0	269.4
48	Traeth Penbryn	1.05	4.07	6.73	6.01	5.14	272.0	269.4
49a	Borth to Ynyslas: Ynyslas South	0.79	3.75	5.98	5.59	3.01	260.5	258.9
49b	Borth to Ynyslas: Ynyslas North	0.79	3.75	5.98	5.59	3.01	260.5	258.9
50	Aberdovey to Tywyn	0.79	3.75	5.98	5.59	3.01	260.5	258.9
51	Aber Dysynni	0.81	3.81	6.02	5.64	3.24	253.8	251.7
52	Fairbourne spit	0.77	3.88	6.04	5.68	3.00	243.6	240.9
53	Barmouth	0.77	3.88	6.04	5.68	3.00	243.6	240.9
54	Morfa Dyffryn	0.64	3.77	5.83	5.52	2.04	242.3	240.1
55	Llandanwg	0.64	3.77	5.83	5.52	2.04	242.3	240.1
56	Morfa Harlech	0.64	3.77	5.83	5.52	2.04	242.3	240.1
57	Morfa Bychan	0.64	3.77	5.83	5.52	2.04	242.3	240.1
58a	Morfa Abererch to Pwllheli: Abererch East	0.67	3.63	5.53	5.31	2.10	234.7	230.5
58b	Morfa Abererch to Pwllheli: Abererch West	0.67	3.63	5.53	5.31	2.10	234.7	230.5
58c	Morfa Abererch to Pwllheli: Glan y Don	0.67	3.63	5.53	5.31	2.10	234.7	230.5
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	0.63	3.51	5.19	5.11	1.75	218.4	211.5
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	0.63	3.51	5.19	5.11	1.75	218.4	211.5
59c	Pwllheli and Traeth Crugan: Traeth Crugan	0.63	3.51	5.19	5.11	1.75	218.4	211.5
60	The Warren, Abersoch	0.63	3.51	5.19	5.11	1.75	218.4	211.5
61	Morfa Gors, Abersoch	0.63	3.51	5.19	5.11	1.75	218.4	211.5
62	Tywyn yr Wylfa, Abersoch	1.06	3.97	6.05	5.70	5.71	234.8	231.4
63	Tai Morfa, Porth Neigwl	1.06	3.97	6.05	5.70	5.71	234.8	231.4
64	Morfa Dinlle	0.69	3.52	5.53	5.18	2.24	247.7	245.1
65	Newborough	0.69	3.52	5.53	5.18	2.24	247.7	245.1
66	Porth Twyn-mawr and Porth Gro	0.69	3.52	5.53	5.18	2.24	247.7	245.1
67	Tywyn Aberffraw	0.69	3.52	5.53	5.18	2.24	247.7	245.1
68	Porth Trecastell	0.90	3.73	5.73	5.33	3.91	236.8	232.7
69	Tywyn Fferam and Tywyn Llyn	0.90	3.73	5.73	5.33	3.91	236.8	232.7
70	Tywyn Trewan	0.90	3.73	5.73	5.33	3.91	236.8	232.7
71	Tywyn Bryn-y-Bar, Holy Island	0.90	3.73	5.73	5.33	3.91	236.8	232.7
72	Trearddur Bay, Holy Island	0.90	3.73	5.73	5.33	3.91	236.8	232.7
73	Traeth Penrhos, Holy Island	0.79	3.35	5.22	4.76	2.60	272.4	272.2
74	Gorsedd-y-penrhyn, Holy Island	0.79	3.35	5.22	4.76	2.60	272.4	272.2
75	Tywyn-gwyn	0.79	3.35	5.22	4.76	2.60	272.4	272.2
76	Tywyn-mawr	0.79	3.35	5.22	4.76	2.60	272.4	272.2
77	Traeth Dulas	0.53	2.66	3.52	3.55	1.02	319.7	338.4
78	Traeth Ligwy	0.53	2.66	3.52	3.55	1.02	319.7	338.4
79	Benllech Sand	0.53	2.66	3.52	3.55	1.02	319.7	338.4
80	Red Wharf Bay	0.53	2.66	3.52	3.55	1.02	319.7	338.4
81	Conwy Morfa	0.65	2.79	3.77	3.74	1.60	303.8	307.2
82	Deganwy South	0.65	2.79	3.77	3.74	1.60	303.8	307.2
83	Deganwy North and Llandudno West Shore	0.65	2.79	3.77	3.74	1.60	303.8	307.2
84	Llandudno East Shore	0.64	2.78	3.76	3.71	1.58	305.0	307.0
85	Kinmel Dunes	0.60	2.73	3.66	3.62	1.43	301.5	302.9
86a	Rhyl East	0.60	2.73	3.66	3.62	1.43	301.5	302.9
86b	Ffrith Beach, Prestatyn	0.60	2.73	3.66	3.62	1.43	301.5	302.9
87	Barkby Beach, Gronant Dunes and Talacre Warren	0.56	2.71	3.60	3.58	1.29	301.3	304.1

Table A5. Summary of sediment particle size characteristics of dune sediment samples collected at each dune site. Analysis techniques used were laser diffraction (LD) and dry sieving (DS).

No.	Site Name	Number of samples, N	Technique (LD or DS)	Average mean particle size (µm)	Range in mean particle size (µm)
1	Aberthaw	0			
2	Ogmore Dunes	0			
3	Merthyr-mawr Warren and Newton Burrows	11	LD	265	206-347
4	Sandy Bay, Porthcawl	1	LD	199	
5	Porthcawl to Sker Point	0			
6	Kenfig Burrows	15	LD	362	227-675
7	Margam Burrows	5	LD	242	234-256
8	Aberavon	3	LD	259	257-260
9	Baglan Burrows	10	LD	261	232-291
10	Crymlyn Burrows and Earlswood Golf Club	9	LD	270	242-301
11	Spontex Dunes, Swansea	0	LD		
12	Swansea Beach and Black Pill Burrows	5	LD	280	225-300
13	Pennard Burrows	9	LD	290	251-319
14	Penmaen Burrows	7	LD	281	270-292
15	Oxwich and Nicholaston Burrows	9	LD	252	234-309
16	Port-Eynon and Horton Dunes	5	LD	309	257-368
17	Rhossilli Bay South	0			
18	Llangennith, Hillend and Broughton Burrows	12	LD	246	197-293
19	Delvid Burrows and Hills Burrows	5	LD	237	231-244
20	Whiteford Burrows	11	LD	238	211-282
21	Machynys and Llanelli	3	DS	300	187-369
22	Burry Port	2	LD	192	187-197
23	Pembrey Burrows	21	LD	178	150-225
24	Gwendraeth Estuary North Shore	1	DS	166	
25	Ferryside to Morfa Uchaf, River Towy	1	LD	166	
26	Llansteffan and Ferry Point, River Towy	1	LD	168	
27	Pentowyn, River Taf	0			
28	Pendine and Laugharne Burrows	17	LD	182	171-201
29	Tenby Burrows	7	LD	253	227-296
30	Giltar Point	0			
31	Priory Bay, Caldey Island	0			
32	Lydstep Haven	3	LD	225	215-236
33	Manorbier Bay	5	LD	392	308-574
34	Freshwater East	9	LD	313	253-368
35	Barafundle Bay	4	LD	329	316-354
36	Stackpole Warren	6	LD	306	257-362
37	Broad Haven	5	LD	352	333-380
38	Brownslade and Linney Burrows	21	LD	408	278-531
39	Gupton Burrows	1	LD	382	
40	Broomhill, Kilpaison and Newton Burrows	7	LD	282	252-298
41	Nolton Haven	0			
42	The Burrows, Whitesands Bay	7	LD	254	224-295
43	The Parrog, Fishguard	0			
44	Aber Fforest	0			
45	Newport Bay	8	LD	204	183-232

Table A5. continued

No.	Site Name	Number of samples, N	Technique (LD or DS)	Average mean particle size (µm)	Range in mean particle size (µm)
46	Poppit Sands	4	LD	186	172-199
47	Towyn Warren	3	LD	210	200-224
48	Traeth Penbryn	0			
49	Borth to Ynyslas	7	LD	210	193-235
50	Aberdovey to Tywyn	8	LD	254	227-312
51	Aber Dysynni	0			
52	Fairbourne spit	4	LD	214	203-233
53	Barmouth	4	LD	220	205-231
54	Morfa Dyffryn	15	LD	238	210-283
55	Llandanwg	0			
56	Morfa Harlech	17	LD	206	172-246
57	Morfa Bychan	12	LD	175	159-196
58	Morfa Abererch to Pwllheli	13	LD	373	202-476
59	Pwllheli and Traeth Crugan	12	LD	438	387-513
60	The Warren, Abersoch	8	LD	261	236-302
61	Morfa Gors, Abersoch	6	LD	256	240-272
62	Tywyn yr Wylfa, Abersoch	0			
63	Tai Morfa, Porth Neigwl	8	LD	323	274-420
64	Morfa Dinlle	18	LD	225	173-311
65	Newborough	58	LD	215	175-332
66	Porth Twyn-mawr and Porth Gro	9	LD	402	183-492
67	Tywyn Aberffraw	16	LD	191	171-229
68	Porth Trecastell	0			
69	Tywyn Fferam and Tywyn Llyn	6	LD	401	257-583
70	Tywyn Trewan	14	LD	254	167-437
71	Tywyn Bryn-y-Bar, Holy Island	0			
72	Trearddur Bay, Holy Island	5	DS	305	265-350
73	Traeth Penrhos, Holy Island	1	DS	202	
74	Gorsedd-y-penrhyn, Holy Island	0			
75	Tywyn-gywyn	9	LD	238	186-378
76	Tywyn-mawr	7	LD	248	220-304
77	Traeth Dulas	5	LD	435	322-616
78	Traeth Lligwy	6	LD	323	297-379
79	Benllech Sand	0			
80	Red Wharf Bay	9	LD	247	194-356
81	Conwy Morfa	8	LD	273	257-296
82	Deganwy South	0			
83	Deganwy North and Llandudno West Shore	9	LD	256	225-334
84	Llandudno East Shore	0			
85	Kinmel Dunes	10	LD	287	279-305
86	Rhyl East and Ffrith Beach, Prestatyn	7	LD	291	278-312
87	Barkby Beach, Gronant Dunes and Talacre Warren	21	LD	309	248-357

Table A6. Summary of calcium carbonate and silica content of dune sediment samples collected at each dune site

No.	Site Name	Number of samples, N	Average CaCO ₃ content (%)	Range of CaCO ₃ content (%)	Average SiO ₂ content (%)	Range of SiO ₂ content (%)
1	Aberthaw	0				
2	Ogmore Dunes	0				
3	Merthyr-mawr Warren and Newton Burrows	3	6.2	4.27-8.62	87.7	84.7-90.0
4	Sandy Bay, Porthcawl	0				
5	Porthcawl to Sker Point	0				
6	Kenfig Burrows	5	4.9	3.44-6.55	89.0	88.0-94.6
7	Margam Burrows	3	4.8	4.03-5.41	89.3	89.1-89.7
8	Aberavon	0				
9	Baglan Burrows	4	5.9	4.21-7.16	88.7	86.2-91.4
10	Crymlyn Burrows and Earlswood Golf Club	3	5.9	5.69-6.34	87.4	86.3-88.4
11	Spontex Dunes, Swansea	0				
12	Swansea Beach and Black Pill Burrows	3	6.6	6.01-6.94	87.9	87.2-89.0
13	Pennard Burrows	4	2.9	0.52-6.76	90.4	85.0-93.8
14	Penmaen Burrows	3	4.4	2.75-7.35	90.1	86.4-92.4
15	Oxwich and Nicholaston Burrows	4	9.5	8.51-10.35	86.6	83.1-92.3
16	Port-Eynon and Horton Dunes	5	7.0	5.59-8.53	87.0	86.0-88.8
17	Rhossilli Bay South	0				
18	Llangennith, Hillend and Broughton Burrows	5	9.3	7.25-11.60	82.1	78.7-84.9
19	Delvid Burrows and Hills Burrows	3	9.9	9.44-10.71	80.1	79.2-81.3
20	Whiteford Burrows	5	7.6	5.50-9.30	86.6	84.4-89.7
21	Machynys and Llanelli	0				
22	Burry Port	0				
23	Pembrey Burrows	6	9.6	7.05-11.10	82.7	81.2-85.7
24	Gwendraeth Estuary North Shore	0				
25	Ferryside to Morfa Uchaf, River Towy	0				
26	Llansteffan and Ferry Point, River Towy	0				
27	Pentowyn, River Taf	0				
28	Pendine and Laugharne Burrows	5	8.7	7.57-10.94	83.9	80.4-86.7
29	Tenby Burrows	3	10.7	9.03-11.78	84.2	82.3-87.9
30	Giltar Point	0				
31	Priory Bay, Caldey Island	0				
32	Lydstep Haven	3	18.3	15.62-22.27	77.0	72.8-79.8
33	Manorbier Bay	3	14.6	12.14-17.51	74.1	69.8-76.5
34	Freshwater East	4	20.4	13.97-24.43	73.1	67.0-80.7
35	Barafundle Bay	3	27.5	21.69-32.72	67.7	62.9-73.4
36	Stackpole Warren	3	16.3	14.65-17.97	78.5	78.2-79.0
37	Broad Haven	3	20.0	17.08-22.93	74.9	71.8-77.8
38	Brownslade and Linney Burrows	7	16.9	11.60-21.79	76.6	70.2-82.7
39	Gupton Burrows	0				
40	Broomhill, Kilpaison and Newton Burrows	3	20.0	18.90-20.61	74.8	74.0-75.7
41	Nolton Haven	0				
42	The Burrows, Whitesands Bay	3	7.5	6.26-8.21	81.5	81.2-81.7
43	The Parrog, Fishguard	0				
44	Aber Fforest	0				
45	Newport Bay	3	1.8	0.66-2.45	87.6	85.6-89.1

Table A6. continued

No.	Site Name	Number of samples, N	Average CaCO ₃ content (%)	Range of CaCO ₃ content (%)	Average SiO ₂ content (%)	Range of SiO ₂ content (%)
46	Poppit Sands	3	2.2	1.73-2.48	90.0	89.3-90.5
47	Towyn Warren	3	1.5	1.21-1.89	88.2	87.5-89.2
48	Traeth Penbryn	0				
49	Borth to Ynyslas	3	3.0	2.59-3.27	89.2	87.7-90.3
50	Aberdovey to Tywyn	3	1.8	1.53-2.09	94.8	94.5-94.9
51	Aber Dysynni	0				
52	Fairbourne spit	0				
53	Barmouth	3	1.6	0.91-2.37	93.5	92.4-94.7
54	Morfa Dyffryn	4	2.1	1.66-2.66	93.4	92.8-94.2
55	Llandanwg	0				
56	Morfa Harlech	5	2.4	1.98-3.03	91.6	90.4-92.5
57	Morfa Bychan	3	1.1	0.55-1.55	92.1	90.9-93.3
58	Morfa Abererch to Pwllheli	3	0.6	0.27-0.91	93.8	92.0-96.2
59	Pwllheli and Traeth Crugan	3	0.8	0.57-0.98	94.2	93.3-94.8
60	The Warren, Abersoch	3	3.3	3.05-3.44	89.9	89.0-90.7
61	Morfa Gors, Abersoch	3	4.3	2.91-5.94	89.6	86.8-91.3
62	Tywyn yr Wylfa, Abersoch	0				
63	Tai Morfa, Porth Neigwl	3	1.5	0.29-2.21	92.6	92.1-93.2
64	Morfa Dinlle	5	2.5	2.00-3.00	91.6	90.3-92.6
65	Newborough	11	3.3	2.21-5.52	90.3	88.1-92.9
66	Porth Twyn-mawr and Porth Gro	4	4.0	2.00-5.76	87.9	74.8-93.9
67	Tywyn Aberffraw	4	3.7	3.32-4.55	90.8	89.1-91.6
68	Porth Trecastell	0				
69	Tywyn Fferam and Tywyn Llyn	3	3.5	2.82-4.78	90.5	89.0-92.7
70	Tywyn Trewan	4	3.5	2.46-4.12	90.6	88.9-92.2
71	Tywyn Bryn-y-Bar, Holy Island	0				
72	Trearddur Bay, Holy Island	0				
73	Traeth Penrhos, Holy Island	0				
74	Gorsedd-y-penrhyn, Holy Island	0				
75	Tywyn-gywyn	4	1.2	0.48-2.02	91.3	85.0-94.0
76	Tywyn-mawr	3	7.7	4.84-11.15	87.2	82.6-90.4
77	Traeth Dulas	3	3.4	1.04-4.62	88.4	86.0-93.4
78	Traeth Lligwy	3	2.8	2.12-3.77	93.5	91.9-94.9
79	Benllech Sand	0				
80	Red Wharf Bay	3	6.2	1.02-1.27	87.7	85.6-91.8
81	Conwy Morfa	3	1.2	1.02-1.27	94.5	93.4-96.5
82	Deganwy South	0				
83	Deganwy North and Llandudno West Shore	3	2.9	1.89-4.27	90.5	88.4-91.8
84	Llandudno East Shore	0				
85	Kinmel Dunes	3	6.6	5.96-7.50	86.5	85.4-87.2
86	Rhyl East and Ffrith Beach, Prestatyn	3	4.5	4.14-4.84	89.2	87.6-90.5
87	Barkby Beach, Gronant Dunes and Talacre Warren	5	5.5	4.71-7.03	86.1	80.2-88.4

APPENDIX B

SUPPLEMENTARY TABLES RELATING TO DUNE SITE FUNCTION AND SMP2 POLICY

Table B1. Dune sites where the SMP2 policy is HTL in all three epochs

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL	not assoc.
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL	def.system
8	Aberavon	NA	L	L	L	L	L	HTL	HTL	HTL	def.system
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL	def.system
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL	def.system
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL	def.system
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL	def.system
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	H	M	L	HTL	HTL	HTL	defence
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	def.system
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL	def.system
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL	def.system
85	Kinmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	def.system
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL	def.system
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	def.system

Table B2. Dune sites where the SMP2 policy is HTL in the first two epochs

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR	not assoc.
79	Benllech Sand	NA	L	L	M	L	L	HTL	HTL	MR	def.system
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR	defence
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR	def.system
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR	def.system

Table B3. Dune sites where the SMP2 policy is HTL in the first epoch only

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR	def.system
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI	not assoc.
41	Nolton Haven	NA	VH	L	L	L	L	HTL	MR	MR	def.system
42	The Burrows, Whitesands Bay	NA	L	M	L	L	H	HTL	MR	MR	def.system
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR	def.system
45b	Newport Bay: Newport Sands North	NA	L	L	M	M	L	HTL	MR	NAI	not assoc.
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M/H	L	L	HTL	MR	MR	def.system
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR	def.system
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	def.system
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	def.system
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	def.system
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR	def.system
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	def.system

Table B4. Dune sites where the SMP2 policy is MR in all three epochs

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
2	Ogmore Dunes	NA	L	L	L	L	L	MR	MR	MR	not assoc.
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR	not assoc.
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR	not assoc.
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR	def.system
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR	def.system
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR	not assoc.
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR	not assoc.
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR	not assoc.
19	Delvid Burrows and Hills Burrows	NA	L	VH	M	L	M	MR	MR	MR	not assoc.
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR	not assoc.
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	def.system
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	def.system
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	defence
30	Giltar Point	NA	VH	L	L	L	L	MR	MR	MR	not assoc.
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR	not assoc.
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR	not assoc.
39	Gupton Burrows	NA	M	L	L	L	H	MR	MR	MR	not assoc.
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR	def.system
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	def.system
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	def.system
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR	def.system
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR	not assoc.
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR	def.system
75	Tywyn-gywyn	L/M	M	L	M	L	L	MR	MR	MR	not assoc.
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	defence

Table B5. Dune sites where the SMP2 policy is MR in the first two epochs

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI	def.system
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI	def.system
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI	not assoc.

Table B6. Dune sites where the SMP2 policy is MR in the first epoch only

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI	def.system

Table B7. Dune sites where the SMP2 policy is NAI in all three epochs

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI	not assoc.
13	Pennard Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
14	Penmaen Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
17	Rhossilli Bay South	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI	def.system
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
31	Priory Bay, Caldey Island	NA	L	L	L	L	L	NAI	NAI	NAI	not assoc.
33	Manorbier Bay	NA	H	L	M	L	L	NAI	NAI	NAI	not assoc.
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI	not assoc.
36	Stackpole Warren	NA	VH	M	M	L/M	H	NAI	NAI	NAI	not assoc.
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI	def.system
44	Aber Fforest	NA	L	L	M	L	L	NAI	NAI	NAI	not assoc.
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI	def.system
48	Traeth Penbryn	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI	def.system
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI	def.system
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	defence
62	Tywyn yr Wylfa, Abersoch	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
63	Tai Morfa, Porth Neigwl	L	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI	def.system
66	Porth Twyn-mawr and Porth Gro	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI	not assoc.
68	Porth Trecastell	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	def.system
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI	def.system
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI	not assoc.
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI	def.system

Table B8. Dune sites where the SMP2 policy is NAI in the first two epochs or first epoch only

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR	def.system

APPENDIX C
DUNE SITES ORDERED BY FLOOD AND COASTAL
EROSION RISK MANAGEMENT IMPORTANCE

Table C.1 Dune sites where the FCERM importance is considered to be medium/high, high or very high

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	def.system
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	def.system
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	defence
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	def.system
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	def.system
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	defence
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	def.system
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	H	M	L	HTL	HTL	HTL	defence
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	def.system
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	def.system
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	def.system
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	def.system
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	def.system
85	Kinmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	def.system
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	def.system
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	defence

Table C2. Dune sites where the FCERM importance is considered to be low/medium or medium

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR	not assoc.
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL	def.system
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR	def.system
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR	def.system
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL	def.system
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL	def.system
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR	not assoc.
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR	not assoc.
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL	def.system
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR	def.system
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR	not assoc.
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR	def.system
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR	not assoc.
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M/H	L	L	HTL	MR	MR	def.system
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI	def.system
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI	def.system
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL	def.system
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI	def.system
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI	def.system
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR	def.system
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI	def.system
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI	def.system
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL	def.system
75	Tywyn-gywyn	L/M	M	L	M	L	L	MR	MR	MR	not assoc.
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR	defence
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR	def.system
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR	def.system
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL	def.system

Table C3. Dune sites where the FCERM importance is considered to be low

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL	not assoc.
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI	not assoc.
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR	not assoc.
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR	not assoc.
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR	not assoc.
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI	def.system
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI	not assoc.
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI	not assoc.
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI	def.system
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR	not assoc.
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR	def.system
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR	def.system
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI	def.system
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR	def.system
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR	def.system
63	Tai Morfa, Porth Neigwl	L	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI	not assoc.
68	Porth Tre Castell	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI	not assoc.
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR	not assoc.
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR	def.system
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI	def.system
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI	not assoc.
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI	def.system
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL	def.system

Table C4. Dune sites considered to be of no FCERM importance

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
2	Ogmore Dunes	NA	L	L	L	L	L	MR	MR	MR	not assoc.
8	Aberavon	NA	L	L	L	L	L	HTL	HTL	HTL	def.system
13	Pennard Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
14	Penmaen Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
17	Rhossilli Bay South	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
19	Delvid Burrows and Hills Burrows	NA	L	VH	M	L	M	MR	MR	MR	not assoc.
30	Giltar Point	NA	VH	L	L	L	L	MR	MR	MR	not assoc.
31	Priory Bay, Caldey Island	NA	L	L	L	L	L	NAI	NAI	NAI	not assoc.
33	Manorbier Bay	NA	H	L	M	L	L	NAI	NAI	NAI	not assoc.
36	Stackpole Warren	NA	VH	M	M	L/M	H	NAI	NAI	NAI	not assoc.
39	Gupton Burrows	NA	M	L	L	L	H	MR	MR	MR	not assoc.
41	Nolton Haven	NA	VH	L	L	L	L	HTL	MR	MR	def.system
42	The Burrows, Whitesands Bay	NA	L	M	L	L	H	HTL	MR	MR	def.system
44	Aber Fforest	NA	L	L	M	L	L	NAI	NAI	NAI	not assoc.
45b	Newport Bay: Newport Sands North	NA	L	L	M	M	L	HTL	MR	NAI	not assoc.
48	Traeth Penbryn	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
62	Tywyn yr Wylfa, Abersoch	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
66	Porth Twyn-mawr and Porth Gro	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
79	Benllech Sand	NA	L	L	M	L	L	HTL	HTL	MR	def.system

APPENDIX D

SMP2 POLICY AND DUNE DEFENCE FUNCTION AT SITES OF HIGH/VERY HIGH, LOW/MEDIUM, AND LOW NATURE CONSERVATION IMPORTANCE

Table D1. Dune sites where the nature conservation importance is high or very high

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR	not assoc.
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR	not assoc.
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR	def.system
13	Pennard Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
14	Penmaen Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR	not assoc.
17	Rhossilli Bay South	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR	not assoc.
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	def.system
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	def.system
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	defence
30	Giltar Point	NA	VH	L	L	L	L	MR	MR	MR	not assoc.
33	Manorbier Bay	NA	H	L	M	L	L	NAI	NAI	NAI	not assoc.
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI	not assoc.
36	Stackpole Warren	NA	VH	M	M	L/M	H	NAI	NAI	NAI	not assoc.
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI	def.system
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR	not assoc.
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR	def.system
41	Nolton Haven	NA	VH	L	L	L	L	HTL	MR	MR	def.system
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR	def.system
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR	not assoc.
48	Traeth Penbryn	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M/H	L	L	HTL	MR	MR	def.system
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI	def.system
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	def.system
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR	def.system
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI	def.system
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL	def.system
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI	def.system
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	def.system
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI	def.system
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR	def.system
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	def.system
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	def.system
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	def.system
62	Tywyn yr Wylfa, Abersoch	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
63	Tai Morfa, Porth Neigwl	L	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI	def.system
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI	def.system
66	Porth Twyn-mawr and Porth Gro	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI	not assoc.
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI	def.system
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI	not assoc.
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL	def.system
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	defence

Table D2. Dune sites where the nature conservation importance is low/medium or medium

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR	def.system
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL	def.system
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL	def.system
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR	not assoc.
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR	not assoc.
39	Gupton Burrows	NA	M	L	L	L	H	MR	MR	MR	not assoc.
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	defence
75	Tywyn-gywyn	L/M	M	L	M	L	L	MR	MR	MR	not assoc.
85	Kinmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	def.system

Table D3. Dune sites where the nature conservation importance is low

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
2	Ogmore Dunes	NA	L	L	L	L	L	MR	MR	MR	not assoc.
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL	not assoc.
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI	not assoc.
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL	def.system
8	Aberavon	NA	L	L	L	L	L	HTL	HTL	HTL	def.system
19	Delvid Burrows and Hills Burrows	NA	L	VH	M	L	M	MR	MR	MR	not assoc.
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL	def.system
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR	def.system
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI	def.system
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
31	Priory Bay, Caldey Island	NA	L	L	L	L	L	NAI	NAI	NAI	not assoc.
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI	not assoc.
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR	not assoc.
42	The Burrows, Whitesands Bay	NA	L	M	L	L	H	HTL	MR	MR	def.system
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR	def.system
44	Aber Fforest	NA	L	L	M	L	L	NAI	NAI	NAI	not assoc.
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI	def.system
45b	Newport Bay: Nowport Sands North	NA	L	L	M	M	L	HTL	MR	NAI	not assoc.
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	def.system
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	H	M	L	HTL	HTL	HTL	defence
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR	def.system
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	def.system
68	Porth Tre Castell	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI	not assoc.
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	def.system
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR	not assoc.
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL	def.system
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR	def.system
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
79	Benllech Sand	NA	L	L	M	L	L	HTL	HTL	MR	def.system
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI	def.system
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR	defence
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR	def.system
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR	def.system
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL	def.system
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	def.system

APPENDIX E

SMP2 POLICY AND DUNE DEFENCE FUNCTION AT SITES OF HIGH/ VERY HIGH, MEDIUM AND LOW GEOMORPHOLOGICAL IMPORTANCE

Table E1. Dune sites where the geomorphological importance is high or very high

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR	not assoc.
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR	not assoc.
13	Pennard Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
14	Penmaen Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR	not assoc.
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR	not assoc.
19	Delvid Burrows and Hills Burrows	NA	L	VH	M	L	M	MR	MR	MR	not assoc.
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR	not assoc.
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	def.system
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	def.system
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR	not assoc.
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR	def.system
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI	def.system
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI	def.system
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI	def.system
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI	def.system
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI	def.system
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI	not assoc.
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	defence

Table E2. Dune sites where the geomorphological importance is medium

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR	def.system
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR	def.system
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	defence
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR	not assoc.
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI	not assoc.
36	Stackpole Warren	NA	VH	M	M	L/M	H	NAI	NAI	NAI	not assoc.
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI	def.system
42	The Burrows, Whitesands Bay	NA	L	M	L	L	H	HTL	MR	MR	def.system
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI	def.system
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR	def.system
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	def.system
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR	def.system
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	defence
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI	not assoc.
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	def.system
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR	defence

Table E3. Dune sites where the geomorphological importance is low

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
2	Ogmore Dunes	NA	L	L	L	L	L	MR	MR	MR	not assoc.
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL	not assoc.
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI	not assoc.
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL	def.system
8	Aberavon	NA	L	L	L	L	L	HTL	HTL	HTL	def.system
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL	def.system
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL	def.system
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR	not assoc.
17	Rhossilli Bay South	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL	def.system
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR	def.system
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI	def.system
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
30	Giltar Point	NA	VH	L	L	L	L	MR	MR	MR	not assoc.
31	Priory Bay, Caldey Island	NA	L	L	L	L	L	NAI	NAI	NAI	not assoc.
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI	not assoc.
33	Manorbier Bay	NA	H	L	M	L	L	NAI	NAI	NAI	not assoc.
39	Gupton Burrows	NA	M	L	L	L	H	MR	MR	MR	not assoc.
41	Nolton Haven	NA	VH	L	L	L	L	HTL	MR	MR	def.system
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR	def.system
44	Aber Fforest	NA	L	L	M	L	L	NAI	NAI	NAI	not assoc.
45b	Newport Bay: Nowport Sands North	NA	L	L	M	M	L	HTL	MR	NAI	not assoc.
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR	not assoc.
48	Traeth Penbryn	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M/H	L	L	HTL	MR	MR	def.system
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR	def.system
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI	def.system
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL	def.system
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	def.system
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	def.system
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	H	M	L	HTL	HTL	HTL	defence
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	def.system
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	def.system
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	def.system
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR	def.system
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	def.system
62	Tywyn yr Wylfa, Abersoch	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
63	Tai Morfa, Porth Neigwl	L	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
66	Porth Twyn-mawr and Porth Gro	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
68	Porth Treacastell	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR	not assoc.
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL	def.system
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR	def.system
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
75	Tywyn-gwyn	L/M	M	L	M	L	L	MR	MR	MR	not assoc.
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI	def.system
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI	not assoc.
79	Benllech Sand	NA	L	L	M	L	L	HTL	HTL	MR	def.system
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI	def.system
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR	def.system
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR	def.system
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL	def.system
85	Kimmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	def.system
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL	def.system
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	def.system

APPENDIX F

SMP2 POLICY AND DUNE DEFENCE FUNCTION AT SITES OF HIGH OR MEDIUM/ HIGH, MEDIUM/ LOW AND LOW RECREATION IMPORTANCE

Table F1. Dune sites where the recreation importance is medium/high or high

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL	def.system
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	def.system
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	defence
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR	def.system
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M/H	L	L	HTL	MR	MR	def.system
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI	def.system
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	def.system
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI	def.system
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL	def.system
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI	def.system
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI	def.system
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR	def.system
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	def.system
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	H	M	L	HTL	HTL	HTL	defence
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	def.system
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	def.system
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI	not assoc.
85	Kinmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	def.system
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL	def.system
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	def.system
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	defence

Table F2. Dune sites where the recreation importance is low/medium or medium

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR	not assoc.
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL	not assoc.
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR	not assoc.
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR	def.system
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR	def.system
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL	def.system
13	Pennard Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
14	Penmaen Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR	not assoc.
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR	not assoc.
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR	not assoc.
19	Delvid Burrows and Hills Burrows	NA	L	VH	M	L	M	MR	MR	MR	not assoc.
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR	not assoc.
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL	def.system
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR	def.system
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI	def.system
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	def.system
33	Manorbier Bay	NA	H	L	M	L	L	NAI	NAI	NAI	not assoc.
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR	not assoc.
36	Stackpole Warren	NA	VH	M	M	L/M	H	NAI	NAI	NAI	not assoc.
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI	def.system
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR	def.system
44	Aber Fforest	NA	L	L	M	L	L	NAI	NAI	NAI	not assoc.
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI	def.system
45b	Newport Bay: Nowport Sands North	NA	L	L	M	M	L	HTL	MR	NAI	not assoc.
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR	def.system
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR	not assoc.
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	def.system
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	defence
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR	def.system
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	def.system
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI	def.system
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI	not assoc.
68	Porth Tre Castell	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI	not assoc.
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	def.system
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR	not assoc.
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL	def.system
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR	def.system
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
75	Tywyn-gywyn	L/M	M	L	M	L	L	MR	MR	MR	not assoc.
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
79	Benllech Sand	NA	L	L	M	L	L	HTL	HTL	MR	def.system
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI	def.system
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR	defence
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR	def.system

Table F3. Dune sites where the recreation importance is low

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
2	Ogmore Dunes	NA	L	L	L	L	L	MR	MR	MR	not assoc.
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI	not assoc.
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL	def.system
8	Aberavon	NA	L	L	L	L	L	HTL	HTL	HTL	def.system
17	Rhossilli Bay South	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
30	Giltar Point	NA	VH	L	L	L	L	MR	MR	MR	not assoc.
31	Priory Bay, Caldey Island	NA	L	L	L	L	L	NAI	NAI	NAI	not assoc.
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI	not assoc.
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI	not assoc.
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR	not assoc.
39	Gupton Burrows	NA	M	L	L	L	H	MR	MR	MR	not assoc.
41	Nolton Haven	NA	VH	L	L	L	L	HTL	MR	MR	def.system
42	The Burrows, Whitesands Bay	NA	L	M	L	L	H	HTL	MR	MR	def.system
48	Traeth Penbryn	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR	def.system
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	def.system
62	Tywyn yr Wylfa, Abersoch	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
63	Tai Morfa, Porth Neigwl	L	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI	def.system
66	Porth Twyn-mawr and Porth Gro	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI	def.system
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR	def.system
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL	def.system

APPENDIX G

SMP2 POLICY AND DUNE DEFENCE FUNCTION AT SITES OF HIGH/ VERY HIGH, LOW/ MEDIUM OR MEDIUM, AND LOW ECONOMIC OR MILITARY IMPORTANCE

Table G1. Dune sites where the economic or military importance is high or very high

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	def.system
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	def.system
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR	not assoc.
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI	def.system
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	def.system

Table G2. Dune sites where the economic or military importance is low/medium or medium

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI	not assoc.
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR	not assoc.
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL	def.system
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	defence
36	Stackpole Warren	NA	VH	M	M	L/M	H	NAI	NAI	NAI	not assoc.
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR	def.system
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI	def.system
45b	Newport Bay: Newport Sands North	NA	L	L	M	M	L	HTL	MR	NAI	not assoc.
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	def.system
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI	def.system
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR	def.system
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	def.system
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	H	M	L	HTL	HTL	HTL	defence
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	def.system
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	def.system
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR	def.system
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	def.system
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI	def.system
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI	def.system
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI	not assoc.
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL	def.system
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	defence

Table G3. Dune sites where the economic or military importance is low

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
2	Ogmore Dunes	NA	L	L	L	L	L	MR	MR	MR	not assoc.
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR	not assoc.
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL	not assoc.
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR	not assoc.
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL	def.system
8	Aberavon	NA	L	L	L	L	L	HTL	HTL	HTL	def.system
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR	def.system
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR	def.system
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL	def.system
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL	def.system
13	Pennard Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
14	Penmaen Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR	not assoc.
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR	not assoc.
17	Rhossilli Bay South	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
19	Delvid Burrows and Hills Burrows	NA	L	VH	M	L	M	MR	MR	MR	not assoc.
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR	not assoc.
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR	def.system
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI	def.system
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
30	Giltar Point	NA	VH	L	L	L	L	MR	MR	MR	not assoc.
31	Priory Bay, Caldey Island	NA	L	L	L	L	L	NAI	NAI	NAI	not assoc.
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI	not assoc.
33	Manorbier Bay	NA	H	L	M	L	L	NAI	NAI	NAI	not assoc.
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR	not assoc.
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI	not assoc.
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI	def.system
39	Gupton Burrows	NA	M	L	L	L	H	MR	MR	MR	not assoc.
41	Nolton Haven	NA	VH	L	L	L	L	HTL	MR	MR	def.system
42	The Burrows, Whitesands Bay	NA	L	M	L	L	H	HTL	MR	MR	def.system
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR	def.system
44	Aber Fforest	NA	L	L	M	L	L	NAI	NAI	NAI	not assoc.
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR	def.system
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR	not assoc.
48	Traeth Penbryn	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M/H	L	L	HTL	MR	MR	def.system
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI	def.system
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR	def.system
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI	def.system
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL	def.system
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	def.system
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	defence
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	def.system
62	Tywyn yr Wylfa, Abersoch	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
63	Tai Morfa, Porth Neigwl	L	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
66	Porth Twyn-mawr and Porth Gro	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
68	Porth Trecastell	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI	not assoc.
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR	not assoc.
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL	def.system
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR	def.system
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
75	Tywyn-gywyn	L/M	M	L	M	L	L	MR	MR	MR	not assoc.
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI	def.system
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI	not assoc.
79	Benllech Sand	NA	L	L	M	L	L	HTL	HTL	MR	def.system
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI	def.system
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR	defence
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR	def.system
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR	def.system
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL	def.system
85	Kimmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	def.system
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	def.system

APPENDIX H

SMP2 POLICY AND DUNE DEFENCE FUNCTION AT SITES OF HIGH, MEDIUM AND LOW HISTORICAL OR ARCHAEOLOGICAL IMPORTANCE

Table H1. Dune sites where the historical or archaeological importance is high

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
3	Merthyr-mawr Warren and Newton Burrows	M	VH	H	M	L	H	MR	MR	MR	not assoc.
6	Kenfig Burrows	L	VH	H	M	L	H	MR	MR	MR	not assoc.
13	Pennard Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
14	Penmaen Burrows	NA	H	VH	M	L	H	NAI	NAI	NAI	not assoc.
23	Pembrey Burrows	M/H	VH	VH	H	VH	H	MR	MR	MR	def.system
28	Pendine and Laugharne Burrows	H	VH	VH	L/M	VH	H	MR	MR	MR	def.system
36	Stackpole Warren	NA	VH	M	M	L/M	H	NAI	NAI	NAI	not assoc.
39	Gupton Burrows	NA	M	L	L	L	H	MR	MR	MR	not assoc.
40	Broomhill, Kilpaison and Newton Burrows	L	VH	H	H	L/M	H	NAI	MR	MR	def.system
42	The Burrows, Whitesands Bay	NA	L	M	L	L	H	HTL	MR	MR	def.system
55	Llandanwg	M/H	VH	L	M	L	H	MR	MR	MR	def.system

Table H2. Dune sites where the historical or archaeological importance is low/medium or medium

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
7	Margam Burrows	M	L	L	L	L	M	HTL	HTL	HTL	def.system
12	Swansea Beach and Black Pill Burrows	M	L/M	L	M/H	L	M	HTL	HTL	HTL	def.system
15	Oxwich and Nicholaston Burrows	L/M	H	VH	M	L	M	MR	MR	MR	not assoc.
18	Llangennith, Hillend and Broughton Burrows	L	L/M	H	M	M	M	MR	MR	MR	not assoc.
19	Delvid Burrows and Hills Burrows	NA	L	VH	M	L	M	MR	MR	MR	not assoc.
20	Whiteford Burrows	L/M	VH	VH	M	L	M	MR	MR	MR	not assoc.
29	Tenby Burrows	M/H	H	M	H	M	L/M	MR	MR	MR	defence
35	Barafundle Bay	L	VH	M	L	L	M	NAI	NAI	NAI	not assoc.
54	Morfa Dyffryn	M	VH	VH	H	H	M	NAI	NAI	NAI	def.system
64	Morfa Dinlle	L/M	VH	VH	L	M	M	MR	MR	NAI	def.system
65	Newborough	M	VH	VH	M	M	M	NAI	NAI	NAI	def.system
67	Tywyn Aberffraw	L	VH	VH	M	L/M	L/M	NAI	NAI	NAI	not assoc.

Table H3. Dune sites where the historical or archaeological importance is low

No.	Site Name	FCERM	Nature Conservation	Geomorphological features	Recreation	Economic / Military	Historical / Archaeological	SMP2 Policy			Defence Function
								Epoch 1	Epoch 2	Epoch 3	
1	Aberthaw	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
2	Ogmore Dunes	NA	L	L	L	L	L	MR	MR	MR	not assoc.
4	Sandy Bay, Porthcawl	L	L	L	M	L	L	HTL	HTL	HTL	not assoc.
5	Porthcawl to Sker Point	L	L	L	L	L/M	L	NAI	NAI	NAI	not assoc.
8	Aberavon	NA	L	L	L	L	L	HTL	HTL	HTL	def.system
9	Baglan Burrows	M	L/M	M	M	L	L	MR	MR	MR	def.system
10	Crymlyn Burrows and Earlswood Golf Club	L/M	H	M	L/M	L	L	MR	MR	MR	def.system
11	Spontex Dunes, Swansea	L/M	L/M	L	M	L	L	HTL	HTL	HTL	def.system
16	Port-Eynon and Horton Dunes	L	M	L	M	L	L	MR	MR	MR	not assoc.
17	Rhossili Bay South	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
21	Machynys and Llanelli	L/M	L	L	M	M	L	HTL	HTL	HTL	def.system
22	Burry Port	L/M	L	L	M	L	L	HTL	MR	MR	def.system
24	Gwendraeth Estuary North Shore	L	L	L	M	L	L	NAI	NAI	NAI	def.system
25	Ferryside to Morfa Uchaf, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
26	Llansteffan and Ferry Point, River Towy	L	L	L	L	L	L	HTL	HTL	HTL	def.system
27	Pentowyn, River Taf	L	L	L	L	L	L	NAI	NAI	NAI	not assoc.
30	Giltar Point	NA	VH	L	L	L	L	MR	MR	MR	not assoc.
31	Priory Bay, Caldey Island	NA	L	L	L	L	L	NAI	NAI	NAI	not assoc.
32	Lydstep Haven	L	L	L	L	L	L	HTL	NAI	NAI	not assoc.
33	Manorbier Bay	NA	H	L	M	L	L	NAI	NAI	NAI	not assoc.
34	Freshwater East	L/M	L	M	M	L	L	MR	MR	MR	not assoc.
37	Broad Haven	L	VH	M	M	L	L	NAI	NAI	NAI	def.system
38	Brownslade and Linney Burrows	L	VH	H	L	H	L	MR	MR	MR	not assoc.
41	Nolton Haven	NA	VH	L	L	L	L	HTL	MR	MR	def.system
43	The Parrog, Fishguard	L	L	L	M	L	L	HTL	MR	MR	def.system
44	Aber Forest	NA	L	L	M	L	L	NAI	NAI	NAI	not assoc.
45a	Newport Bay: The Bennet	L	L	M	M	M	L	NAI	NAI	NAI	def.system
45b	Newport Bay: Newport Sands North	NA	L	L	M	M	L	HTL	MR	NAI	not assoc.
46	Poppit Sands	L/M	VH	M	M	L	L	MR	MR	MR	def.system
47	Towyn Warren	L/M	H	L	M	L	L	HTL	HTL	MR	not assoc.
48	Traeth Penbryn	NA	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
49a	Borth to Ynyslas: Ynyslas South	M	H	L	M/H	L	L	HTL	MR	MR	def.system
49b	Borth to Ynyslas: Ynyslas North	M	VH	VH	H	L	L	MR	NAI	NAI	def.system
50	Aberdovey to Tywyn	M/H	VH	M	H	M	L	MR	MR	MR	def.system
51	Aber Dysynni	L	H	L	L	L	L	HTL	MR	MR	def.system
52	Fairbourne spit	M	VH	L	H	L	L	MR	MR	NAI	def.system
53	Barmouth	M	H	L	H	L	L	HTL	HTL	HTL	def.system
56	Morfa Harlech	L/M	VH	VH	H	L/M	L	NAI	NAI	NAI	def.system
57	Morfa Bychan	L/M	VH	M	H	M	L	MR	MR	MR	def.system
58a	Morfa Abererch to Pwllheli: Abererch East	VH	M	M	M	L	L	NAI	NAI	NAI	defence
58b	Morfa Abererch to Pwllheli: Abererch West	VH	L	L	H	M	L	HTL	MR	MR	def.system
58c	Morfa Abererch to Pwllheli: Glan y Don	VH	L	L	H	M	L	HTL	HTL	HTL	defence
59a	Pwllheli and Traeth Crugan: Pwllheli South Beach	H	H	L	H	M	L	HTL	HTL	HTL	def.system
59b	Pwllheli and Traeth Crugan: Pwllheli Golf Club	H	H	L	H	M	L	HTL	MR	MR	def.system
59c	Pwllheli and Traeth Crugan: Traeth Crugan	H	H	L	L	L	L	HTL	MR	MR	def.system
60	The Warren, Abersoch	L	L	L	M	M	L	HTL	MR	MR	def.system
61	Morfa Gors, Abersoch	M/H	L	L	M	L/M	L	HTL	MR	NAI	def.system
62	Tywyn yr Wylfa, Abersoch	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
63	Tai Morfa, Porth Neigwl	L	VH	L	L	L	L	NAI	NAI	NAI	not assoc.
66	Porth Twyn-mawr and Porth Gro	NA	H	L	L	L	L	NAI	NAI	NAI	not assoc.
68	Porth Treacstell	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
69	Tywyn Fferam and Tywyn Llyn	L	L	M	M	L	L	MR	MR	NAI	not assoc.
70	Tywyn Trewan	M/H	L	M	M	VH	L	NAI	NAI	NAI	def.system
71	Tywyn Bryn-y-Bar, Holy Island	L	L	L	M	L	L	MR	MR	MR	not assoc.
72	Trearddur Bay, Holy Island	L/M	L	L	M	L	L	HTL	HTL	HTL	def.system
73	Traeth Penrhos, Holy Island	L	L	L	M	L	L	MR	MR	MR	def.system
74	Gorsedd-y-penrhyn, Holy Island	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
75	Tywyn-gywyn	L/M	M	L	M	L	L	MR	MR	MR	not assoc.
76	Tywyn-mawr	L	L	L	M	L	L	NAI	NAI	NAI	not assoc.
77	Traeth Dulas	L	H	L	L	L	L	NAI	NAI	NAI	def.system
78	Traeth Lligwy	L	H	L	H	L	L	NAI	NAI	NAI	not assoc.
79	Benllech Sand	NA	L	L	M	L	L	HTL	HTL	MR	def.system
80	Red Wharf Bay	L	L	L	M	L	L	NAI	NAI	NAI	def.system
81	Conwy Morfa	M	L	M	M	L	L	HTL	HTL	MR	defence
82	Deganwy South	L/M	L	L	L	L	L	HTL	HTL	MR	def.system
83	Deganwy North and Llandudno West Shore	L/M	L	L	M	L	L	HTL	HTL	MR	def.system
84	Llandudno East Shore	L	H	L	L	L	L	HTL	HTL	HTL	def.system
85	Kinmel Dunes	M/H	L/M	L	H	L	L	HTL	HTL	HTL	def.system
86a	Rhyl East	M	L	L	H	M	L	HTL	HTL	HTL	def.system
86b	Ffrith Beach, Prestatyn	H	L	L	H	L	L	HTL	HTL	HTL	def.system
87	Barkby Beach, Gronant Dunes and Talacre Warren	H	H	H	H	M	L	MR	MR	MR	defence

APPENDIX I

SELECTED DUNE MANAGEMENT TECHNIQUE
FACTSHEETS

Dune Management Technique Factsheet No. 1

Technique: Dune fencing

Function and purpose

Semi-permeable fences are used to slow wind velocities and encourage the deposition of windblown sand both behind and in front of the fence, and to restrict access to areas of damaged dune vegetation; used to control surface wind erosion, to encourage dune growth, and to slow / stop migrating dunes.

Appropriate locations

Above the limit of normal wave run up on beaches and frontal dunes with a potential supply of windblown sand (sandy beaches), beaches with a gravel upper beach and sandy mid/lower beach, within dune areas), and where the dune toe is stable or prograding; unsuitable on eroding shores unless other form of wave dissipation or protection is provided as fencing alone cannot resist wave stresses and may snap or collapse due to scour under storm conditions. Can be used in inland areas within blowouts and on mobile dune slopes / crests to slow the rate of movement.

Methods

The effectiveness in trapping sand depends on the void to solid ratio of the fence: the optimum being 40% to 50% porosity and a lateral spacing between fencing elements of about 30 - 40 mm. Many different material types can be used to form the fence, the simplest and cheapest being a line of brushwood faggots or rows of old Christmas trees. Plastic mesh and chestnut pale fencing requires fixing to vertical support posts. Wooden posts are more environmentally friendly than plastic or metal posts since they are biodegradable and do not introduce contaminants to the environment. Especially when erected on back-beach areas, straining posts of sufficient thickness and length must be used to ensure rigidity under conditions of high wind stress and wave scour.

Effectiveness

Fences built of 1.2 or 1.5 m high chestnut palings, with 3 strand wire and 50% porosity, supported by 10 cm diameter vertical wood posts at 2 m spacing and 15 to 20 cm straining posts at 10 m spacing, buried to a depth of at least 1 m below the sand surface, provide the best performance. Less quality pale fencing can be used in less exposed locations and/or where a major objective is to limit the ingress of people. Pale fencing is typically supplied as 10 m or 30 m long rolls. Plastic mesh, webbing or flimsy brushwood fences have very limited durability and long term effectiveness. Rows of old Christmas trees can be effective in trapping sand provided they are not subject to scour and wind movement.

Benefits

Low environmental impact on natural systems; low cost; encourages growth of new dune vegetation; provides cover for a range of invertebrates and birds.

Potential problems

Depending on fencing type, regular maintenance is required to repair natural damage and the effects of vandalism (including fire); fencing needs moving in areas of rapid sand deposition and/ or erosion; likely to require replacing c, every 5 years. Broken /

decayed fence posts and connecting wires may pose a safety hazard. The brittle stumps of broken Christmas trees can also pose a safety hazard to both people and animals; Christmas trees which are washed or blown into the sea can pose problems for fisherman, leisure craft and bathers.

Cost

Relatively low capital cost (typically £500 to £2500 per 100m length depending on the nature / quality of the fencing material and the number / size of straining posts.

Key references

Agate, E. (2001) Fencing: A Practical Handbook. British Trust for Conservation Volunteers, Wallingford, Edition 2, 141pp.

Brooks, A. (2001) Sand Dunes: A Practical Handbook. British Trust for Conservation Volunteers, Wallingford, Edition 2, 109pp.

SNH (2000) A Guide to Managing Coastal Erosion in Beach / Dune Systems. Scottish Natural Heritage, Perth. Available at: <http://www.snh.org.uk/publications/online/heritagemanagement/erosion/1.shtml>

Recent Welsh example

Swansea Beach: use of fencing to trap sand and build new dunes on the upper beach, seaward of the sea wall near the Civic Centre



Dune Management Technique Factsheet No. 2

Technique: Dune Thatching

Function and purpose

Thatching of bare or partially bare surface is undertaken where it is considered necessary to slow or stop the rate of wind erosion; e.g. to slow or stop blowout and to control migrating dunes which might compromise the integrity of a dune which serves as a coastal defence. The presence of the thatch reduces the shear stress at the sand surface and the greater stability allows a biological surface crust to form, further stabilizing the sand. Seed germination and successful establishment of plant seedlings is also encouraged.

Appropriate locations

Above the limit of normal wave run up on frontal dunes and within inland dune areas where infrastructure may be threatened by mobile sand (e.g. adjacent to car parks and roads).

Methods

The simplest method of thatching is to place brushwood on the sand surface, with or without low fences to divide the thatched area into sub-compartments, thereby creating a chequerboard effect. Straw can also be laid or ploughed into the surface, with or without the use of brushwood and rows of faggots. Other methods can also be used to create a surface mulch, including spraying of sand/ mud mixtures (sometimes containing seed), or a biodegradable polymeric material. Distributed gravel may also be placed on the sand surface to create an armoured layer and increase the wind drag; this may occur naturally if harbour dredge arisings are used to infill blowouts or other low points in the dunes, to strengthen the dune front.

Effectiveness

Thatching can be a very effective method of stabilizing a mobile sand surface, provided the brushwood used is sufficiently large / heavy to prevent wind movement.

Benefits

Low environmental impact on natural systems; low cost; encourages growth of new dune vegetation; provides cover for a range of invertebrates and birds.

Potential problems

Lightweight thatching material (e.g. straw, mulched bark, small grade brushwood) may be blown away). Larger brushwood may be set on fire (arson) or removed for barbecues. If the density of brushwood is too low the thatching may not be fully effective

Cost

Relatively low (typically £200 to £1500 per 100m² depending on the nature and source of material used in the thatching, and whether or not fencing or other methods are also employed).

Key references

Brooks, A. (2001) Sand Dunes: A Practical Handbook. British Trust for Conservation Volunteers, Wallingford, Edition 2, 109pp.

SNH (2000) A Guide to Managing Coastal Erosion in Beach / Dune Systems. Scottish Natural Heritage, Perth. Available at: <http://www.snh.org.uk/publications/online/heritagemanagement/erosion/1.shtml>

Recent Welsh example

Aberdyfi: use of brushwood to stabilise the surface of sand and shingle dredged from Aberdyfi harbour used to infill low points on the frontal dunes and to create dune width.



Dune Management Technique Factsheet No. 3

Technique: Brushwood fences to control sandblow and blowout development

Function and purpose

Rows of cut brushwood can be used to create windbreaks and control sandblow both at locations within the frontal dune sand in hind dune areas. Erection of brushwood fences on the upper beach can also be used to trap sand and encourage the growth of new lines of embryo dunes. The prime objectives is to create increased drag on the wind, reduce wind scour and surface sand erosion, and to encourage the deposition of windblown sand.

Appropriate locations

Above the limit of normal wave run up at any location within a dune system where there is a requirement to reduce local wind velocities, reduce or prevent wind erosion, or to trap sand and build new dunes. This may be applicable at vulnerable locations which have a SMP2 policy of NAI, HTL or MR. More extensive erection of lines of brushwood or discarded Christmas trees may be appropriate in areas where the upper beach shows a natural tendency for sand accretion, where there is a requirement to prevent sand incursion inland, and / or in rare situations where a policy of AD is identified. This may include locations where sand beach nourishment has been undertaken, or where the beach sediment budget is naturally positive. The use of fencing in such situations may be considered as compatible with a strategy of 'working with nature'.

Methods

It is best practice to attach brushwood cuttings to lines of wire stretched between wooden posts in order to prevent them being blow away. Multiple lines of fencing may be required, for example, within large blowouts or on the slopes of mobile dunes, but a single line may suffice in other situations.

Effectiveness

Brushwood fences can provide highly effective windbreaks and trap significant quantities of sand in situations where sand is available for transport. In situations of low wind transport, they can be effective in reducing wind erosion and acting as barriers to pedestrian access. However, in areas of very high wind exposure scouring may underline the fence or results in direct physical damage, including stripping of smaller branches and needles.

Benefits

Low environmental impact on natural systems; relatively low cost; reduces wind erosion, encourages accumulation of sand including growth of embryo dunes

Potential problems

Brushwood cuttings can sometimes become brittle with age. Stems may snap creating sharp edges which pose a potential hazard to people and animals. However, these problems are generally less serious with brushwood cuttings or brushings than with discarded Christmas trees whose broken stems can sometimes form highly dangerous 'spears'; for this reason, use of the latter is not recommended.

If planted on the upper beach or lower dune face within the reach of storm waves, lines of brushwood (or old Christmas trees) can be lost out to sea where they may become trapped in fishing nets or pose a hazard to recreational water uses. Strong winds may detach individual branches (or entire Christmas trees) and blow them inland where they may cause injury to people or damage to infrastructure. The condition of the fences and all fixings requires regular checking. Any potentially hazardous objects should be removed.

Cost

Relatively low (typically £0 to £1000 per 100m² depending on whether materials are freely available and whether volunteer labour is employed).

Key references

Brooks, A. (2001) Sand Dunes: A Practical Handbook. British Trust for Conservation Volunteers, Wallingford, Edition 2, 109pp.

SNH (2000) A Guide to Managing Coastal Erosion in Beach / Dune Systems. Scottish Natural Heritage, Perth. Available at: <http://www.snh.org.uk/publications/online/heritagemanagement/erosion/1.shtml>

Welsh example

Newborough Forest: Brushwood fence lines were established along the back beach in the 1950s to build a new foredune ridge which provided shelter against wind, salt spray and blown sand abrasion for newly planted forest behind.

Dune Management Technique Factsheet No. 4

Technique: Dune Vegetation Planting

Function and purpose

Vegetation may be planted both to stabilize a sand surface, thereby reducing windblown sand hazard or the likelihood of blowout enlargement, and/ or to encourage the vertical and/or lateral growth of a dune.

Appropriate locations

Above the limit of normal wave run up at any location within a dune system where there is a requirement to stabilize the sand surface (e.g. adjacent to infrastructure such as car parks and roads); it should not be undertaken where such stabilization is unnecessary since areas of bare / thinly vegetated and mobile sand are of high importance for biodiversity reasons (essential for the survival of several dune specialist invertebrate and plant species). Planting is unlikely to be successful on eroding dune frontages where upper beach levels are often low or narrow, and where there is periodic but relatively frequent exposure to storm waves.

Methods

Vegetation planting is most effectively undertaken within fenced compartments which will reduce the trampling pressure from visitors. At low elevations along the seaward margin of the dune toe, planting of salt-tolerant species such as lyme grass (*Leymus arenarius*) most likely to be successful. At higher elevation where there is less exposure to salt but potentially high levels of windblown sand accumulation where marram grass (*Ammophila arenaria*) is more effective. Plants may be obtained either by pulling from natural populations in nearby areas (with consent if within a SSSI) or sourced as pot-grown nursery juveniles. Wherever possible, locally source native variants should be used. In areas subject to strong winds the establishment of the young plants is assisted by covering the surface with a layer of geotextile prior to planting. Marram and other plant seeds can also be sown by spraying onto the sand surface as part of a fertilizer / mulch mixture. In areas where there is a need also to create wind break or sand trap (e.g. along the seaward edge of a promenade or road, planting of shrub species can also be considered. Salt cedar (*Tamarix gallica* and/or *Tamarix africana*) has been quite widely used, although care needs to be taken to avoid invasive development. Planting of sea buckthorn (*Hippophae rhamnoides*) is now considered inappropriate due to its highly invasive habit.

Effectiveness

Where environmental conditions are favourable, planted grass vegetation can become well established and effectively stabilize the sand surface within two to three years. However, its success depends heavily on the degree of trampling pressure and other disturbance, and on nutrient availability (ideally from freshly deposited sand).

Benefits

Low environmental impact on natural systems; relatively low cost; encourages growth of new embryo dunes and foredunes; provides cover for a range of invertebrates.

Potential problems

Plantings may fail due to drought, nutrient deficiency, wind scour which exposes the roots, and over trampling by human visitors or livestock. In some circumstances vegetation may develop too quickly or too extensively, resulting in loss of mobile sand habitats.

Cost

Relatively low (typically £100 to £1500 per 100m² depending on whether volunteer labour is employed, fencing and/ or thatching used, whether dunes need to be re-profiled before planting, and the source of plants used (pot grown or naturally sourced transplants).

Key references

Brooks, A. (2001) Sand Dunes: A Practical Handbook. British Trust for Conservation Volunteers, Wallingford, Edition 2, 109pp.

SNH (2000) A Guide to Managing Coastal Erosion in Beach / Dune Systems. Scottish Natural Heritage, Perth. Available at: <http://www.snh.org.uk/publications/online/heritagemanagement/erosion/1.shtml>

Recent Welsh example

Talacre Warren: marram transplants on imported sand used to fill a low point in the second dune ridge; a layer of geotextile was used to assist plant establishment



Dune Management Technique Factsheet No. 5

Technique: Sediment recycling and dune reinforcement

Function and purpose

In the context of dune management, sediment recycling involves the mechanical shifting of sand and/ or shingle from a source area where there is an access to areas where there is a need to strengthen the dune defence (i.e. infill low points in the crest, give greater overall height and / or width. The sediment can be placed to reinforce the upper beach and dune toe, on the seaward face of the dune to increase width in a seaward direction, within low points or along the entire dune crest to raise the dune height, or on the landward side of the crest to give increased width in a landward direction. Sand can also be placed to build a new dune ridge or reinforce an existing ridge further inland.

Appropriate locations

Unless forming part of a much larger beach nourishment operation, sediment should be placed above the limit of normal wave run. If sediment is placed too far down the beach there is a significant risk that it will be dispersed alongshore or offshore. This option is generally only feasible if a potential source of suitable sandy sediment is available nearby and can be easily transported to the deposition site (e.g. from a nearby harbour from which lorry or dumper truck transport along the beach is possible).

Methods

In the source area sand can be transferred into tipper lorries using a front loader. Sediment can be tipped in piles at intervals along the dune front and then redistributed or re-profiled as necessary using a bulldozer or front loader. If access to the hind dune area is required a temporary access ramp and track into the dune system may need to be created. After placement part or all of the sand surface may need to be stabilized using fencing, brushwood, and vegetation planting. However, if the sediment contains significant shingle as well as sand a surface stabilizing armouring layer may be formed in a short period of time by wind deflation.

Effectiveness

This method can provide a short term solution to flood risk through narrow / low points in the dunes, but by itself is unlikely to provide a long term solution in areas where natural conditions favour beach lowering and shoreline recession.

Benefits

Can simultaneously improve the standard of coastal flood defence, provide dynamic surface conditions which promote the development of a range of early successional stage habitats / species, provide an improved recreational beach facility, and provide general landscape enhancement. Has a relatively low and short-lived negative environmental impact on natural systems; relatively low cost; encourages development of new mobile dunes and conditions attractive for a range of invertebrates.

Potential problems

Unless the surface of the deposited sand is stabilized there is a risk of windblown sand incursion onto recreation assets (e.g. golf courses), transport infrastructure (cycle ways, roads, rail lines), or into urban areas. The transport of sediment by lorry may involve short term closures or re-routing, and/ or other forms of environmental disturbance (noise, traffic congestion pollution, depending on the route taken).

Cost

Moderate (typically £5 to £50 per m³), depending on the means required to remove sand from the source area, the distance of travel required, the methods required for sand placement, the total volume of sediment to be moved and over what timescale, and whether any follow-up fencing / planting is required.

Key reference

SNH (2000) A Guide to Managing Coastal Erosion in Beach / Dune Systems. Scottish Natural Heritage, Perth. Available at: <http://www.snh.org.uk/publications/online/heritagemanagement/erosion/1.shtml>

Recent Welsh example

Baglan Burrows: placement of sand dredged from the Neath estuary approach channel to form new mobile dunes



Dune Management Technique Factsheet No. 6

Technique: Dune Face Geotextile Bag Protection

Function and purpose

Sand bags (sediment-filled geotextile containers) can be used in a variety of ways to provide short term protection to frontal dunes; they can be placed as detached reefs on the beach, or sub-tidally, to diffuse wave action, to form temporary groynes and headlands, or placed to form a revetment along the dune front.

Appropriate locations

Coastal areas of low to moderate wave energy where a short term / temporary solution is required to prevent dune breaching / overtopping; more suitable than rock armour in areas of high environmental sensitivity / high recreational use.

Methods

Bags are usually filled at the site where required using local materials (ideally sand). Gravel and or mud / gravel mixtures should not be used unless no other material is available, since fine mud can be 'leached' from the bags, leading to loss of volume and potentially structural collapse, and coarse, angular gravel is more likely to lead to tearing of the bags. For ease of handling, bag size is normally restricted to 3 m x 1.5 m x 0.5 m, although larger geotubes (up to 30 m long) can be used to provide an immobile 'core' to reconstructed frontal dune ridge, or to create submerged offshore breakwaters. Some excavation / re-profiling of the existing dune face is normally required to create a plane surface against which the bags can be stacked in multiple rows, forming an inclined revetment. The excavated material can be used to cover the bags on completion of the works, with vegetation planting and sand trapping fencing erected where appropriate. If designed with a seaward slope of less than 1 in 3, the sand bag revetment should allow windblown sand to pass uninterrupted from the beach into the dunes behind.

Effectiveness

This method can provide a short term fixed defence following storm damage, while other adaptive measures are being undertaken. Typical lifetime of the order of 5 years, but potentially longer if the bags are buried beneath a substantial thickness of sediment.

Benefits

Relatively quick to undertake (once consents have been obtained), relatively low impact on the environment, easily reversible (bags can be removed or emptied on site).

Potential problems

If the bags are filled with a mixture of sand and shingle and are subject to significant wave action there is a significant risk of the bags being ripped due to internal movement of sharp gravel, and to abrasion from wave-induced movement of beach gravel. Bags may also be damaged due to vandalism and people walking on them. Exposure to sunlight may cause gradual deterioration of the geofabric. As the bags are relatively impermeable and immobile they may induce wave reflection and beach scour along the protected frontage.

Cost

Low to moderate (£5000 to £25,000 per 100m length, depending on availability of local material to fill the bags, the size of the works and nature of additional measures required (e.g. sand cover, fencing, planting).

Key reference

SNH (2000) A Guide to Managing Coastal Erosion in Beach / Dune Systems. Scottish Natural Heritage, Perth. Available at: <http://www.snh.org.uk/publications/online/heritagemanagement/erosion/1.shtml>

Recent Welsh example

Aberdyfi Golf Club frontage: geotextile bag protection provided to the 12th Green following the winter storms of 2013-14





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