Joint Defra/EA Flood and Coastal Erosion
Risk Management R&D Programme

Sand dune processes and management for flood and coastal defence

Part 3: The geomorphological and management status of coastal dunes in England and Wales

R&D Technical Report FD1302/TR

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Joint Defra/EA Flood and Coastal Erosion Risk
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Part 3: The geomorphological and management status of coastal dunes in England and Wales

R&D Technical Report FD1392/TR

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Statement of use

This report provides a summary of research carried out to assess the significance of coastal dune systems for flood risk management in England and Wales, to document the nature of the underlying geomorphological processes involved, and to identify alternative strategies and techniques which can be used to manage coastal dunes primarily for the purposes of coastal flood defence, taking into account nature conservation interests and other uses of coastal dunes. The report considers the general effects of changes in climate and sea level on coastal dune systems, and examines the current problems and options for future management at five example sites. The report is intended to inform local engineers and other coastal managers concerned with practical dune management, and to act as stimulus for further research in this area.

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Executive summary

Background

Sand dune systems can provide an important natural coastal flood defence and are also of great importance from nature conservation, recreation and tourism perspectives. This project was based on a recognition that (a) considerable information exists about the ecology of coastal dune systems in England and Wales but geomorphological, sedimentological and engineering management aspects have been relatively neglected, and (b) recent changes in coastal management philosophy towards adaptation and risk management mean that there is increasing interest in developing new methods of managing coastal dunes as dynamic natural defences. To this end a better understanding of the physical nature of sand dune systems, and of sand dune processes, is required.

Project objectives

The main objectives were: (1) to compile information about the geomorphological and sedimentological character, flood defence significance and management status of coastal dune systems in England and Wales; (2) to review available methods for the management of coastal dunes; (3) to evaluate the effects of predicted climate and sea level change on dune systems, and to consider the implications of removing hard defences to recreate more dynamic dune systems; (4) to examine the issues and options for future management in relation to five case study areas; and (5) to identify aspects of best practice and requirements for further work.

Results

The results are summarised in this report which consists of five parts. Part 1 provides an overview of the project, the main issues addressed, the approaches used and the main conclusions. Part 2 presents a review of sand dune processes and the significance of coastal dunes for coastal flood risk management. Part 3 describes the methods used to obtain data and presents brief descriptions, location maps and database summaries for each dune site. Part 4 reviews available methods to manage and modify coastal dunes, and Part 5 discusses the problems and management options at the five example sites (Sefton Coast, Spurn Peninsula, Brancaster Bay, Studland, and Kenfig Burrows). Additional information is provided in publications and a PhD thesis which arise from the work (details given in Part 1).

Coastal dunes in England and Wales presently occupy an area of approximately 200 km^2. A total of 158 individual dune localities, grouped into 112 dune 'sites', were identified. Coastal Cell 9 has the largest total area of dunes (*c*. 48 km^2) followed by Cell 11, Cell 8 and Cell 1. The largest single system is located on the Sefton Coast (*c*. 20 km^2), but there are few systems larger than 5 km^2 and more than 50% of the sites are <1 km^2 in size. The largest systems occur on the west coasts of England and Wales but smaller systems in eastern and southern England are also locally of considerable flood risk management significance. Their importance in this regard lies primarily in their function as barriers to coastal flooding, and is dependent on the asset value of the land behind and the existence or otherwise of other flood defences. Dune systems are especially important where they protect high density

residential or industrial developments, high-grade agricultural land or habitats of international conservation importance. Compared with many other forms of defence, dunes are less visually intrusive, have greater value for wildlife and recreation, and are able to respond more readily to changes in environmental forcing factors (e.g. climate and sea level change, sediment supply conditions).

Virtually all dunefields in England and Wales have formed entirely in the last 5000 to 6000 years, and in most places the present dune topography is less than a few hundred years old. Dune migration occurred on a large scale during the Little Ice Age, but many sites still had extensive areas of bare sand as recently as the 1970's, largely as a result of human activities. Dune stabilisation measures since the 1950's, and particularly in the 1980's and 90's, have stabilised most dunefields to a high degree. Areas of aeolian activity are now restricted mainly to sections of eroding coast and a few inland blowouts which have remained active due to local wind acceleration and increased turbulence.

Approximately 35% of the total dune frontage in England and Wales has experienced net erosion or is protected by hard defences, 35% has experienced net stability and 30% net seawards accretion. The extent of frontal dune erosion may increase in the next century as a result of increased storminess and sea level rise, and this may have negative impacts on the extent of some dune habitats and the effectiveness of dune systems as flood defences. However, the consequences of such changes will vary from location to location, reflecting differences in natural processes and beach-dune sediment budgets.

Most dune systems in England and Wales are composed of quartz sands, and marine carbonate is important only in some systems in Devon and Cornwall and southwest Wales. The main sources of sand in the past were marine reworking of glacial sediments on the sea bed and in coastal cliffs. These sources are much less significant at the present time. Increased storminess and rising sea level are likely to cause more widespread erosion, leading to re-distribution of existing coastal sediments. Accretion can be expected at the down-drift ends of sediment transport cells, but dunes at the up-drift ends will experience accelerated erosion and greater risk of breaching/overtopping.

Conclusions and Recommendations

Wherever possible, coastal dune and beach systems should be allowed to respond naturally to changes in forcing factors and sediment supply conditions. Where accommodation space exists and conditions are favourable, frontal dunes should be allowed to roll back to establish a new equilibrium. However, in areas of low wind energy or strongly negative beach sediment budget, dune dissipation is likely to occur unless nourishment with fine-grained sand and artificial dune profiling are undertaken. It is recommended that a detailed Geomorphological Evaluation Study should be undertaken at each dune site, or group of sites, to assess the requirements and to identify the most appropriate management strategy. This will require nature conservation and other interests to be taken into account. Where not in existence, systematic monitoring programmes should be set up to provide early warning of dune change. Data should be obtained in a standardised format which can be exported for centralised analysis.

Contents

3.1 Introduction

This part of the report provides a summary of the main morphological, sedimentological and management characteristics of each of the main dune sites listed in Table 3.1. The data include information obtained from desk studies, field surveys and laboratory analyses of sediment samples. The attributes used to characterise each site are defined in Section 3.2. Section 3.3 contains general references and Section 3.4 contains brief descriptive summaries of each dune site together with additional site specific references. Maps showing the locations and physical setting of each site are provided as Figures 3.1 to 3.101. Summaries of the main attribute data for all the sites are contained in Tables 3.1 to 3.10. Database summary sheets for each site are provided in Appendix 3.1.

3.2. Definition of sand dune site attributes

3.2.1 Site and sub-site names

The dune systems included in this database include the majority of those listed in the *Sand Dune Vegetation Survey of Great Britain* (Radley, 1994; Dargie, 1995) together with a number of additions based on a consideration of other published sources, geological maps and fields surveys. Many of the site names used in the Sand Dune Vegetation Survey have been retained, although some sites have been re-named to provide a better reflection of their geomorphological character and environmental associations.

Most of the dune ‘sites’ identified in this survey represent discrete systems, although in some instances a ‘site’ is composed of a number of systems grouped together on the basis of their physical setting or genesis. Systems within the same bay or estuary have generally been grouped, since the processes which influence them are similar; examples include St Ives Bay in Cornwall, and the Duddon Estuary in Cumbria. Sections of coastline which once had a continuous stretch of aeolian sediments, but which have since been broken into separate surviving parts by urban development, have also been grouped together as ‘sites’ with each component identified as a sub-site, for example the frontage between Abergele and Point of Air in North Wales. Although some systems have been grouped it is recognised that they can differ substantially in terms of morphology and dynamics and should be treated individually for some management purposes.

3.2.2 Cell and sub-cell locations

The coastal cell / sub-cell within which each dune site occurs is identified, based on the cell boundaries defined by Motyka & Brampton (1993), and maps showing the distribution of dune sites within each cell are presented in Figures 3.1 to 3.11.

3.2.3 National grid reference

The geographical position of each dune site is defined by two six-figure national grid references which relate to the points on the coast where each dune site begins and ends.

3.2.4 Dune system size

3.2.4.1 Area

Dune system area values cited in the *Sand Dune Vegetation Survey of Great Britain* (Radley, 1994; Dargie, 1995) are given, where available. That study involved field mapping of vegetation community types onto aerial photograph overlays and Ordnance Survey base maps at a scale of 1:10,000 or 1:10,560, and the areas covered by each community type and each dune system as a whole were calculated using ARCINFO GIS software. The accuracy of the area estimates is dependent on the accuracy of the dune system boundaries defined on Ordnance Survey maps, air photographs and in field surveys. The work was carried out between 1987 and 1990 in England and between 1986 and 1991 in Wales, and consequently significant errors may arise where substantial erosion or accretion and/or notable vegetation change has occurred subsequently. Additional area information for dune sites in Wales was obtained from the report by Posford Duvivier Environment (1996) which gave estimates based on Ordnance Survey maps and field visits in 1993. The areal extent of blown sand indicated on the location maps in Figures 3.12 to 3.101 is taken primarily from geological maps published by the British Geological Survey, supplemented by observations taken during field visits and from aerial photographs.

Coastal Cell 7 has the largest total area of coastal dunes, followed by Cell 11 and Cell 7 (Figure 3.102). Approximately 50% of the sites can be classified as being of medium size (0.1 to 1.0 km^2), and 30% as large (1 to 5 km^2) (Figure 3.103).

3.2.4.2 Frontage length, minimum width and maximum width

The frontage length and minimum and maximum widths were measured for each dune site using 1:25,000 Ordnance Survey maps. The accuracy of these values therefore is governed by the accuracy of dune system boundaries on these maps; these do not always coincide with the limits of blown sand shown on geological maps. Values for the area and linear dimensions of each dune system are summarised in Table 3.1.

3.2.5 Morphology

Two morphological attributes have been determined: (1) morphology of the dune system as a whole; and (2) the morphology of individual dunes within the system.

3.2.5.1 Dune system morphology

For the purposes of this report, dune systems are classified at an initial level in terms of whether they occur on (a) the open coast, (b) within embayments, or (c) within estuaries. A further category, composite, can also be identified where dune systems extend over more than one geomorphological setting. At a second level, dune systems are classified according to the nature of the main landform type on which they occur or which they comprise: (1) barrier island; (2) barrier spit; (3) tombolo; (4) fringing open coast; (5) inland transgressive dune complex; and (6) ness. As discussed more fully in Part 2 of the report, further sub-divisions are made depending on whether single or multiple ridges are represented, and whether the dunes systems are climbing or non-climbing with regard to the terrain behind the shoreline.

The distribution of different dune system morphology types in England and Wales is shown in Figure 3.104. Barrier island types are restricted mainly to North Norfolk, but barrier spit complexes are widespread. Fringing dune complexes are most common in northeast England and parts of East Anglia. Inland transgressive systems are relatively poorly developed in England and Wales, being restricted mainly to more exposed parts of the west coast of England and Wales.

3.2.5.2 Dune morphology

Individual dunes can be classified in a number of different ways but for the purposes of this report the scheme proposed by Pye (1983) has been followed. Details are given in Part 2 of the report. A summary of the individual dune and dunefield morphological classifications assigned to each dune site is provided in Table 3.2.

Foredunes are present at almost all of the dune sites, and are followed in frequency of occurrence by hummocky dunes, embryo dunes and blowouts/incipient parabolic dunes in frontal dune areas. Well developed transgressive parabolic and elongate parabolic dunes are very rare (Figure 3.105).

On the east and south coasts of England a high proportion of dune sites have only foredunes and/or multiple shore parallel ridges, whereas on the west coast of England and Wales a majority of sites also have large areas of hummocky dunes and/or parabolic dunes (Figure 3.106).

3.2.6 Frontal dune erosion/accretion status

The frontal dune erosion/accretion status was recorded at each dune site during field visits carried out mainly between 1999 and 2001. In each case the percentage of dune frontage classified as *eroding*, *accreting* or *stable*, based on an assessment of the frontal dune morphology, was recorded. A fourth category, *protected*, was also included for dune frontages with coastal defence structures such as sea walls and revetments. For comparative purposes, this category can be combined with *eroding* since most protected sections of dune frontage would be eroding in the absence of defence structures. The percentages of the frontage in each category and at each dune site are given in Table 3.2.

It should be noted that the classification of the frontal dune erosion/accretion status was based largely on visual assessment at the time of field survey and may not always coincide with longer-term trends. However, the broader scale features of frontal dune morphology usually reflect processes operating over time periods of several years to decades except where there has been exceptional storm surge damage.

At some dune sites only one erosion/accretion status type was identified but at most sites a combination was observed on different parts of the frontage. Consequently the following classification scheme was employed:

1) *Net marine erosion*, where eroding or protected dunes constituted ≥ 55% of the dune frontage

2) *Net accretion*, where ≥ 55% of the dune frontage showed morphological evidence of progradation

3) *Net stable*, where characterised ≥ 55% of the dune frontage showed no evidence of net change

4) *Varied status*, where marine erosion, accretion or stable lengths of frontal dune all constituted less than 55% of the total frontage.

The survey data revealed no simple geographical pattern in frontal dune erosion/accretion status (Figure 3.107). Nationally, some 35% of the total dune frontage showed evidence of net stability, 30% net accretion, 24% net erosion and 11% was protected. Eroding and protected dunes represent a higher proportion of the total on the west coast than on the east or south coast (Figure 3.109).

Based on data for vegetation community types, the great majority of dune sites display a high degree of stability at the present time (i.e. a high proportion of the area is covered by relatively mature vegetation communities). The main exceptions occur in systems which are subject to very high visitor pressure or other forms of human disturbance (Figure 3.110).

3.2.7 Process regime

As discussed in Part 2 of this report, three main natural factors determine aeolian sand transport and potential for dune development and mobility: (1) wind regime; (2) precipitation; and (3) tidal range.

3.2.7.1 Wind regime and potential aeolian sand transport

Wind regime data were obtained from the Meteorological Office for a number of recording stations which give a broad representation of the coast of England and Wales (Table 3.3; Figure 3.111). Where possible, data were obtained for the same stations as the wind data, but where necessary from the nearest available station (Table 3.4).

In order to provide a representative medium-term average, a data run of at least 20 years is desirable. However, there are relatively few stations in England and Wales with a modern continuous record of this length. Where 20 years of continuous data were unavailable, the longest available run was used (the shortest runs being 7 years for Donna Nook and Pembrey Sands; Table 3.3).

Wind measurements are made hourly at all the stations used in this database with the exception of Tynemouth where measurements are taken every 3 hours. Fewer observations were recorded in some cases, which could be the result of data logging instrument failure. To overcome differences in data run length and number of routine observations, the frequency values were converted to a percentage of the total observations recorded at each station.

The wind regime has been described using several calculated parameters. Wind rose diagrams and resultant wind directions for each station are shown in Figure 3.112. At the great majority of stations the resultant wind direction is southwesterly, the main exceptions being Isle of Portland and Culdrose where it is westerly.

Wind speed and direction matrices were also used to calculate sand drift potentials using the method of Fryberger & Dean (1979). This method uses a modified form of the Lettau & Lettau (1978) equation:

$$Q \propto V^2 (V-V_t)\, t$$

where Q is the amount of sand drift, V is an average wind speed of a velocity category (in knots), V_t is the impact threshold wind velocity and t is the time that the wind blew, expressed as a percentage of the wind summary. The value of $V^2 (V-V_t)$ is divided by 100 to reduce the resultant magnitudes to workable figures for plotting sand roses. Values derived from this equation represent the sand moving capacity or *Drift Potential* (DP) at a station for the time period of the wind summary. The drift potential is expressed in vector units (VU) for each compass direction. A threshold velocity value of 11 knots was used in the calculation of the drift potentials.

A single resultant can then be derived from vector unit totals for each direction by vector resolution. *The Resultant Drift Direction* (RDD) is the net trend of sand drift under the influence of winds from different directions. The magnitude of the resultant drift direction is the *Resultant Drift Potential* (RDP). The RDP expresses, in vector units, the net sand transport potential when winds from various directions interact. The calculated sand drift potential is the maximum transport assuming all winds above the threshold can transport sand, however, these conditions can only really occur in deserts. The RDP/DP ratio provides an index of the directional variability of the wind and has also been calculated for each station. The RDP/DP ratio approaches unity when the wind usually comes from the same direction, whilst the ratio approaches zero where the wind comes from many directions, and the RDP is very low. Values of DP, RDP, RDD and the RDP/DP ratio for each meteorological station are given in Table 3.5. Figure 3.113 shows that there is considerable variation between stations in terms both of Drift Potential and Resultant Drift Direction. The highest potential sand transport occurs on the west coast of England and Wales where it is directed approximately from southwest to northeast. The lowest Drift Potentials are found on the east coast of England.

3.2.7.2 Rainfall and effect on potential aeolian sand transport

The mean annual rainfall (in millimetres) was obtained from the Meteorological Office for the reference period 1961 to 1990. Data for mean annual rainfall and mean annual number of rain days are shown in Table 3.4.

Both the amount and frequency of rainfall can influence the potential for aeolian sand transport and dune mobility (both directly by increasing the threshold velocity for movement of bare sand and indirectly through the influence on vegetation growth). A modified Index of Drift Potential incorporating the effect of precipitation ($Index_{DPP}$), and a modified Resultant Drift Potential Index taking into account precipitation ($Index_{RDPP}$), were calculated for each meteorological recording station (Table 3.4) and applied to nearby dune sites using formulae developed by Pye (1985) and Saye (2003).

3.2.7.3 Mean spring and mean neap tidal range

The tidal range at each dune site, defined as the difference in elevation between high and low water marks, was estimated from data in Admiralty Tide Tables for the nearest standard or secondary port (except Norfolk where values were obtained from a report on modelled tidal levels commissioned by the Environment Agency). Values for both spring tides and neap tides are given in Table 3.6.

The magnitude of the mean spring tidal range varies from less than 2 m on parts of the south coast and east coast to more than 11 m in areas such as the Bristol Channel and Severn estuary. However, there is only a very weak positive relationship between tidal range (and hence potential area exposed to wind action at low tide) and the size of individual dune systems (Figure 3.114). No significant relationship was found between mean spring tidal range and the erosion/accretion status of the frontal dunes at the time of survey (Figure 3.115).

3.2.8 Human influences and management status

The presence and type of human influences and management status were recorded at each site during field visits. The influences were classified into four groups according to their function: (1) sea defence; (2) sand stabilisation; (3) visitor access management; and (4) vegetation management for conservation. Only management techniques in use at the time of survey were recorded, thus historical stabilisation works that have fully restored areas or have been buried by later dune growth are not represented. The results are summarised in Table 3.7.

Cell 2 has the highest percentage of dune frontage protected by artificial structures, followed by Cell 3 and Cell 11, while Cell 1 has the lowest protected percentage (Figure 3.116). At the great majority of sites the proportion of protected dune frontage is less than 20% (Figure 3.117).

3.2.9 Hinterland use and flood defence significance

The flood defence significance of the dunes at each site was identified using Ordnance Survey maps at 1:25,000 scale, supplemented by aerial photography and field visits. Dune systems which provide protection against marine flooding for land uses on low-lying hinterland (below 5 m above Ordnance Datum) were defined as having a significant flood defence function. The flood defence significance of dune systems has been classified as low, medium or high, using a scale based on estimated economic value of the hinterland. Degrees of flood defence significance are discussed further in Part 2 of this report.

Land use types in the hinterland behind each dune system were recorded during the field surveys. Four categories of activities were defined for purposes of classification:

1) development (including infrastructure, housing, industrial and military uses)

2) recreation (including holiday chalets, caravans, camping), golf courses and general amenity)

3) agricultural

4) natural

Land uses of high monetary value were considered to be especially important from the viewpoint of flood defence and included industrial and residential property, infrastructure (major A roads, motorways and railway lines), agricultural land and recreational uses such as golf courses and holiday parks. Sand dunes which protect saltmarsh or areas of open water (e.g. in estuaries) were also considered to have a significant coastal flood defence function. Typically, sites with low flood defence significance protect isolated houses and/or small holiday parks and/or agricultural land, whilst those classed as high protect industrial works and/or extensive military establishments and/or towns with numerous houses and public buildings. Systems providing protection to an intermediate scale of activities were classed as medium. This classification is subjective and is not been based on detailed asset assessments or analysis of flood risks. It is intended only to indicate the general relative importance of sand dunes for flood defence. A summary of the flood defence significance assessments and hinterland uses for each site is provided in Table 3.7.

3.2.10 Dune system land use

The activities occurring within each dune system were also recorded as part of the survey. Five categories of activities were identified:

1) extraction (including sand and water)

2) conservation

3) recreation (including holiday chalets, caravans, camping, quad bikes, motorcycles, 4WD-trails, sunbathing, walking, cycling and golf courses)

4) agriculture (including cultivation, stock grazing and forestry)

5) development (including infrastructure, housing, industrial and military uses)

Most of the human activity data was collected during site visits but supplemented using other (mainly documentary) information. However, some forms of land use, especially seasonal ones, may be under-recorded. Results are summarised in Table 3.7 and Figure 3.118. Overall, recreational and nature conservation activities are dominant.

3.2.11 Conservation status

Most coastal dune sites are of importance for nature conservation and many have several national and/or international nature conservation designations. The principal designations are listed below:

Designation	**Responsible Organisation**	**Year adopted**	**Number of dune sites with designation**	**Total number of sites in England and Wales**
Biosphere Reserve	UNESCO	1995	6	4
National Nature Reserve (NNR)	Natural England Countryside Council for Wales	1949	36	282
Local Nature Reserve (LNR)	Local Authorities	1949	23	>1300
Area of Outstanding Natural Beauty (AONB)	Natural England Countryside Council for Wales	1949	60	39
Heritage Coast	Natural England Countryside Council for Wales	1972	57	43
Site of Special Scientific Interest (SSSI)	Natural England Countryside Council for Wales	1949	122	5240
Ramsar site	Joint Nature Conservation Committee	1975	50	76

Special Protection Area (SPA)	Joint Nature Conservation Committee	1979	57	97
Special Area of Conservation (SAC)	Joint Nature Conservation Committee	1979	71	319
Environmentally Sensitive Area (ESA)*	Natural England Countryside Council for Wales	1987	22	37
Geological Conservation Review (GCR) site	Joint Nature Conservation Committee	1977	34	19
National Park	National Park Authorities	1949	17	12
National Trust ownership	National Trust	1895	27	(1100 km of coastline)
Wildlife Trust Reserve	Royal Society of Wildlife Trusts	1912	20	2200
RSPB Reserve	Royal Society for the Protection of Birds	1889	9	79

*Superceded by the Environmental Stewardship scheme in 2005.

A summary of the known designations and/or relevant ownership/stewardship applicable to each dune site considered in this survey is provided in Table 3.8. Overall, the most common type of nature conservation designation applied to dune systems, or to adjoining areas, is Site of Special Scientific Interest (Figure 3.119).

The areas and percentages of each dune vegetation community identified in the Dune Vegetation Survey of Great Britain (Radley, 1994; Dargie, 1995), and present within each coast cell, are shown in Table 3.9. As discussed elsewhere in the report, the proportions of different community types have been used to provide a proxy measure of the degree of sand and dune mobility within each area. Values of the Index of Mobility / Stability for each site are shown in Figure 3.110. Values for each coastal cell are summarised in Table 3.9.

3.2.12 Sedimentological properties

3.2.12.1 Particle size characteristics

The particle size distribution of sand within dune systems exerts a significant influence on rates of aeolian sand transport, on moisture retention, and on vegetation growth. Sediment samples were collected from each dune site and analysed by laser granulometry using a Coulter LS 230 instrument, capable of analysing particles between 0.04 µm and 2000 µm. Sediment samples were collected along transects perpendicular to the coast at intervals along the dune frontage at each dune locality. A sampling interval of approximately 1 km was used along the dune frontage at larger sites. Surface samples (0-5 cm) were taken from the frontal dune crest and each hind dune ridge, where present. In the absence of distinct hind dune ridges, samples were taken either at regular intervals inland or where distinct changes in morphology or vegetation cover occurred. Embryo dunes forming to seaward of the foredune were also sampled where their development was significant. Where only an extensive frontal dune ridge or plateau was present, samples were taken from the stoss and lee slopes in addition to the crest. Two phases of development could be identified in some frontal dune ridges, leading to a stepped profile; in these instances both lower and upper sections were sampled. In some instances, samples were taken from depths of up to 50 cm to avoid zones that had undergone strong modification by soil forming processes. In total, 1544 samples were collected and analysed.

Statistical parameters to characterise the particle size distribution were obtained using the mathematical ‘method of moments’, which utilises the entire sample population. A geometric scale was used since as it places equal emphasis on small differences in fine particles and larger differences in coarse particles. Values for the average, minimum and maximum mean grain size recorded at each dune site are shown in Table 3.10. Full results and detailed discussion of observed trends are contained in Saye (2003).

Longshore variations in the mean particle size, sorting (D_{90} - D_{10} range) and skewness of the frontal dunes in each coastal cell are shown in Figures 3.120 - 3.129. Longshore variations in the average mean size and sorting (standard deviation) for the dune sites on the east, south and west coasts are shown in Figure 3.130. A quasi-cyclical pattern is evident on the east and west coasts. On the south coast there are fewer dune sites but a pronounced division is evident between sites 43b and 44, with marked coarsening at sites to the west.

3.2.12.2 Calcium oxide content

Calcium oxide content provides a proxy measure of the calcium carbonate content of dune sand, which in turn provides an indication of the proportion of shell material present. The calcium carbonate content is ecologically important since it affects soil pH and thus the vegetation species which can thrive. In this study the calcium oxide content was determined for a selected number of samples from each site by inductively-coupled plasma atomic emission spectrometry (ICP-AES). Concentrations of a suite of other major oxides and trace elements were also determined. A subset of 582 of the 1544 samples were analysed in this way. The number of samples selected at each site was dependent upon system size, with up to 11 samples being analysed from larger systems. A minimum of three samples was analysed from each system with the exception of Newbiggin Bay and Horse Shoe Point. A standardized 63-250 µm size fraction, obtained by dry sieving, was used in the analysis to minimise variation in the geochemical properties due to grain size.

Values for the average, minimum and maximum calcium oxide content at each site are shown in Table 3.10. Based on the results, the dune systems were assigned to one of four groups based on the average calcium oxide content: *very low* (< 1%); *low* (1-5%); *medium* (5-15%); and *high* (> 15%). Further details relating to the geochemical composition of the dune sediments is provided in Saye (2003).

Figure 3.131 shows the spatial pattern of calcium oxide content around the coast of England and Wales. Most sites with high (> 15%) calcium oxide content occur in the southwest of England, while the least calcareous sands occur in East Anglia and parts of northwest England.

The average silica content (a proxy for quartz mineral content) is generally greater than 90% in eastern England, southeast England, North Wales and much of northwest England. The lowest silica content is found in the dune sands of Devon and Cornwall, while south Wales and southwest Wales are intermediate (Figure 3.132).

Aluminium oxide concentrations are typically of the order of 1.5 to 2.0% on much of the coast of east and south-east England, reflecting a relatively low feldspar/quartz ratio. Concentrations on most of the west coast are generally slightly higher (2.0 to 4.0%), but are significantly higher in Devon and Cornwall (4 to 12%), reflecting a relative abundance of feldspars derived from local granitic sources (Figure 3.133).

The average relative abundances of the ten major oxides for (a) dune systems in England and Wales as a whole, (b) east coast sites, (c) south coast sites, and (d) west coast sites are compared in Figure 3.134. The largest variance is observed in silica and calcium oxide content, but the relative average abundances of all the oxides are broadly similar.

3.3 References

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3.4 Site descriptive summaries

Cell 1 St Abb's Head to Flamborough Head

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Site 1 Cocklawburn to Goswick

1a Cocklawburn Beach
1b Cocklawburn Dunes
1c Cheswick Links
1d Goswick Links

The Cocklawburn Beach dunefield is a small (*c*. 200 m x 100 m) embayment dunefield bounded on both sides by rocky outcrops. The dunes are mostly vegetated hummock dunes formed under conditions of heavy summer visitor pressure, backed by areas of undulating dune grassland. Since the 1990's visitor management has resulted in increased vegetation cover.

The Cheswick to Goswick dunefield extends over a longshore distance of *c*. 5 km southwards from a rocky outcrop (Far Skerr) and has a maximum width of *c*. 400 m. The dunes form two sub-parallel, vegetated ridges, each 10 to 20 m in height. The dunes and associated beaches have extended southwards as a barrier spit system, behind which lies a low-lying area of active and reclaimed marshes. The reclaimed lands drain via a sluice just north of Bea Point. The inland dunes near Cheswick form a golf course and northern part of the dunes near Far Skerr falls within the Cocklawburn Dunes reserve managed by the Northumberland Wildlife Trust.

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Site 2 Holy Island

Holy Island is formed around a core of Carboniferous limestones and quartz dolerite dykes, in turn surrounded and partially overlain by raised beach deposits, glacial till, alluvium and windblown sands. The main area of dunes forms a belt extending from the Snook at the northwestern extremity of the island to Emmanuel Head in the northeast. Fringing dunes also line the shore of Holy Island Sands adjacent to the road leading to Holy Island settlement and the castle. The dunes achieve a maximum crest height of 15 to 20 m, and between the ridges are slacks lying 2 to 5 m above OD. The dune vegetation has suffered from rabbit overgrazing and blowout development in the past but the problem has been successfully managed and the dunes are now largely vegetated and stable. Radiocarbon dating sandy peat and sandy organic matter within the dune sand sequence indicated an overall two sigma age range of 299 to 2780 years BP (Wilson *et al*., 2001).

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Site 3 Ross Links and Budle Bay

3a Ross Links and Budle Bay west

Ross Links is a composite dunefield which extends from Guile Point in the north to the western side of Budle Bay in the south. A narrow gap (Wide Open), periodically penetrated by the sea, separates the northern area of dunes (Old Law) from Ross Point. Most of the area of wind blown sand lies below 10 m OD, and in many places the sand is <2 m thick. In the north-western part of the area, dune ridges up to 16 m high occur in the inner part of a 200 m wide belt near the shore. Younger dune ridges up to 8 m high have formed as a result of recent shoreline progradation. In the east and southern parts of the area sub-parallel foredune ridges, 6 to 9 m high, form a zone 300 m wide behind the shore. These ridges have formed as a result of shoreline progradation over the last 50 to 100 years. Further inland the sand forms an older, undulating sand sheet which is partly used for agriculture and grazing, with planted woodland shelterbelts. These sands overlie raised beach and/or fluvio-glacial sand and gravel deposits at shallow depth, indicating their partially transgressive origin. Further inland the blown sands give way to low-lying areas of drift-covered Carboniferous limestone and bay-fill / estuarine alluvium which has been largely reclaimed for agricultural purposes. Radiocarbon dates on sandy organic matter within the Ross Links dune sequence indicated an overall two sigma radiocarbon age range of 886 to 5910 years BP (Orford *et al*., 2000).

3b Budle Bay east

On the east side of Budle Bay windblown sands form climbing dunes and sand sheets which rise to about 40 m above sea level, driven by north-westerly and northerly winds. Part of the area is occupied by a golf course.

<u>Reference and source of further information</u>

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Site 4 Bamburgh to Seahouses

4a Bamburgh
4b Redbarns Links
4c St Aidan's Dunes

This dune system, which includes Redbarn Links and St. Aidan's Dunes, forms a semi-continuous fringe between Bamburgh and The Tumblers rocks, near Seahouses. The dunes mostly represent transgressive sand sheet and hummock dune deposits, forming the links, with higher vegetated ridges, hummocks and former blowouts near the shore. Radiocarbon dates on sandy peat from the base of the St Aidan's dune complex indicated a two sigma radiocarbon age range of 3402 to 5275 BP (Orford *et al*., 2000). In the period following the Second World War these dunes, like many others on the northeast coast and elsewhere, were characterised by a significantly higher proportion of bare sand than is present today, with a number of large active blowouts.

Site 5 Annistead Dunes

The dunes between Snook Point and Beadnell essentially form a bay-fringing system although blown sand has also transgressed over high land to the south and west. Part of the main sand body (Annistead Links) is occupied by a golf course and the Annistead Dunes Nature Reserve. The dunes are largely vegetated at the present day.

Site 6 Beadnell Bay

6a Tughall Mill Links
6b Newton Links

Dunes in the northern part of Beadnell Bay (Tughall Mill Links) form a bay-fringing system which is separated from a bay barrier system (Newton Links) in the southern part of the bay by Brunton Burn. An area of low-lying alluvium and peat lies to the west of Newton Links. A radiocarbon date on sandy peat from the base of the sequence at Newton Links indicated a calibrated radiocarbon age range of 3860 to 4190 years BP (Orford *et al*., 2000). North of Brunton Burn the dune system is dominated by a single ridge up to 15 m high, the seaward face of which is scarped and has been eroding at least since the mid 1940's. Landwards of the ridge the dunes are mostly low hummock dunes (<3 m amplitude) which are now generally well vegetated. Immediately south of Brunton Burn several sub-parallel dune ridges, up to 14 m high, are present, forming a belt *c*. 350 m wide. Further to the south the system again consists largely of a single frontal dune ridge with hummock dunes behind.

References and sources of further information

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Site 7 Embleton Bay

Fringing bay dunes line the shore of Embleton Bay and Newton Haven just to the north, joined by a zone of transgressive dunes which overlie a bedrock 'high' beneath Embleton Links. The blown sand forms a series of dissected ridges near the sea and lower-lying hummocky terrain further inland. At the landward margin of the dune belt, which is *c*. 350 m wide, blown sand overlies raised beach and glacial drift deposits at shallow depth. An area of the inland dunes in the southern part of Embleton Bay is occupied by a golf course.

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Site 8 Sugar Sands to Seaton Point

8a Sugar Sands
8b Howdiemont Sands
8c Boulmer

Small bay-fringing dune systems occur at Sugar Sands, Howdiemont Sands and to the north and south of Boulmer. In places the dunes are transitional to transgressive climbing types.

Reference and source of further information

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Site 9 Alnmouth Bay

9a Alnmouth
9b Buston Links
9c Birling Links

The dunes of Alnmouth Bay can be divided into three parts on the basis of their morphology and mode of development. The Alnmouth dunes, on the north side of the Aln estuary mouth, is essentially a bay-fringing dune system. Buston Links, which extend from the south side of the River Aln to a rock outcrop at Birling Carrs, is essentially a barrier spit dune system which restricts the entrance to the Aln estuary. Birling Links (also called Warkworth Dunes) is also essentially a barrier spit dune system which extends southwards from Birling Carrs towards the mouth of the River Coquet estuary. All three dune systems contain transgressive dune elements. The Almouth dunes consist principally of a series of relatively high shore-parallel dune ridges behind the shore, to landwards of which is a much lower area of transgressive blown sand. Buston Links consist of dune ridges which have been dissected by blowouts and pedestrian pathways. There were a number of relatively large active blowouts in the 1940's (Steers, 1964, photograph 131) but these are now largely stabilised.

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Site 10 Amble to Hauxley

10a Amble Links
10b Hauxley Links

Dunes form a fringe along the coast between Amble and Bondi Carrs at the northern end of Druridge Bay. The blown sand generally forms a thin cover (2 to 4 m) over weathered sandstones and glacial drift, with a maximum width of *c*. 200 m. Radiocarbon dating of sandy peat and sandy organic matter within and below the dune sand sequence at Amble indicated an overall two sigma calibrated age range of 776 to 1560 years BP (Wilson *et al*., 2001).

References and sources of further information

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Site 11 Druridge Bay

Fringing dunes occur along virtually the entire length of Druridge Bay. The landward margin of the blown sand belt is transgressive over the generally low-lying areas behind (at a level of 3 to 10 m OD). At the northern end of Druridge Bay the dunes have transgressed over freshwater deposits and peats are now exposed on the foreshore. Radiocarbon dating of sandy peat and sandy organic matter within and below the dune sand sequence indicated a two sigma calibrated age range of 507 to 2720 years BP (Orford *et al*., 2000). The dunes have, in the past, suffered the effects of overgrazing (by livestock and rabbits) and sand extraction, but management measures in the last 15 to 20 years have resulted in widespread vegetation recovery. Several parts of the dunes and adjoining areas are now designated nature reserves, including the former open cast workings.

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Site 12 Snab Point to Beacon Point

12a Cresswell Dunes
12b Lyne Sands

Two areas of dunes occur near Lynemouth, separated by the River Lyne. The first area (Cresswell Dunes) extends from Snab Point to Lynemouth and the second lies to landward of Lyne Sands. Both dune areas are essentially bay fringing systems, although the Lynemouth system has a spit component at its southern end and the Lyne Sands system contains a transgressive component. The beach and frontal dunes on either side of the River Lyne have been significantly affected by the tipping of mining waste.

Site 13 Beacon Point to Newbiggin Point

A small fringing dune system, <100 m wide, extends for a distance of *c*. 1 km between Beacon Point and Newbiggin Point. The adjoining beach is now very narrow and lies behind a rocky shore platform. The dunes are generally well vegetated and part lies within the Newbiggin Golf Club.

Site 14 Newbiggin Bay

Dunes formerly fringed Newbiggin Bay, forming a belt 100 to 200 m wide. However, a large proportion of the blown sand area is now covered by urban development. Blown sand areas near Spittal Point have also been partially buried by tipping of mining waste.

Site 15 North Seaton to North Blyth

15a North Seaton
15b Cambois to North Blyth

A small area of barrier spit dunes occurs on the north side of the River Wansbeck estuary, and a larger belt of mainly fringing dunes extends from the south side of the estuary, past Cambois, to form a further spit dune complex on the north side of the River Blyth estuary. The maximum width of the blown sand belt is *c*. 200 m, but significant areas have been affected by coal waste tipping and urban development.

Site 16 South Blyth to Seaton Sluice

Blown sand forms a belt extending from South Beach, Blyth, to the north side of Seaton Sluice. The northern part has been buried by urban and industrial development, but the southern two thirds of the system is preserved and now partly managed as part of the Blyth to Seaton Sluice Dunes Nature Reserve.

The dunes essentially represent a bay-fringing system, although the landward margin displays transgressive characteristics.

References and sources of further information

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Site 17 St Mary's Island to Tynemouth

17a St Mary's Island
17b Whitley Links
17c Long Sands

Small areas of fringing bay dunes occur behind Whitley Sands at Whitley Bay, and Long Sands at Tynemouth.

Site 18 South Shields

A small area of blown sand is located on the south side of the mouth of the River Tyne, at South Shields. The dunes have been partly levelled and built on, and only a small area (The Bents) remains adjacent to Herd Sand. Much of the beach at South Shields suffered falling levels and backshore erosion during the later twentieth century, partly due to sand extraction for industrial purposes.

Site 19 Whitburn Bay

A small area of narrow fringing bay dunes backs the shore at Whitburn Sands, north of Sunderland. The dunes are <50 to 100 m wide and largely vegetated.

Site 20 Hart Warren Dunes

Bay-fringing dunes occur along a 5 km stretch of shore to the north of Hartlepool, forming part of the Durham Coast National Nature Reserve and the Hart Warren Dunes Nature Reserve. The eastern part of the blown sand belt is now built on, and the inland blown sand at Hart Warren forms part of Hartlepool Golf Course.

Site 21 Hartlepool to Marske-by-the-Sea

21a Carr House Sands and Seaton Dunes
21b Coatham Sands
21c Redcar to Marske-by-the-Sea

Areas of blown sand extend northwards from the mouth of the River Tees at North Gare Sands to Seaton Sands and Carr House Sands. Dunes also extend from the southern side of the Tees Mouth from Coatham sands towards Redcar. The coastal morphology of the area has been strongly controlled by pier construction and land reclamation around the entrance to the Tees, and the northern part of the blown sand area has largely been built upon. Although the remaining dunes at Seaton Sands have suffered serious degradation due to visitor pressure in the past, much of the area is today managed as part of the Seaton Dunes Nature Reserve and the Teesmouth National Nature Reserve.

Before construction of the harbour entrance piers and land reclamation within the Tees estuary, fringing estuarine shore dunes formed in a north-south belt south of Coatham. These are now relict and mostly built-on. Fringing bay dunes also formed along the open coast shore between Coatham and Redcar. Following the Tees reclamations, rapid sediment accumulation led to the seaward progradation of dunes between the South Gare breakwater and Redcar. Sediment accumulation has since been greatly reduced and the beaches and frontal dunes on both sides of the Tees entrance now exist in a state of dynamic equilibrium. The dunes at South Gare to Coatham and between Redcar and Marske have also been subject to heavy visitor pressure earlier this century, although management measures in the past 30 years have helped to stabilise the sand and encourage vegetation re-growth. .

Cell 2 Flamborough Head to The Wash

General references and sources of further information

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Site 22 Spurn Peninsula

Dunes of variable height and width occur along most of the Spurn Peninsula which forms a spit extending southwards from the glacial till cliffs near Kilnsea across the mouth of the Humber estuary. The Holderness cliffs and sand-shingle-spit have been receding landwards since before Roman times, although recession has been episodic with periods of storm-induced rapid erosion separated by periods of relatively little change. A major breach occurred in 1849, and was widened by further storms in the following years. The First Edition Ordnance Survey maps, based on surveys in 1851, show the Spurn Peninsula as a series of islets at high water. Similar events occurred in earlier centuries, with periods of breaching and overwash separated by periods of healing and vertical accretion. In the late eighteenth century marram-covered dunes apparently extended along the entire length of the spit, but after about 1800 high tides and storm waves increasingly caused frontal dune erosion and partial overwash, especially around the 'neck' at the northern end of the spit (de Boer, 1964, 1981).

Following the storms of 1849-1851, remedial works were carried out to close the breaches and a programme of marram planting undertaken along the northern neck. However, the main breach was not completely closed until 1855. A chalk rock embankment was constructed at the southern end of the spit to retard northward movement of sediment on the landward side. In 1864 five groynes were constructed on the seaward side of the spit, three at the site of the former main breach, and two in front of the narrow neck at High Bents. A further six groynes were built between 1864 and 1870, together with another chalk bank across the main breach. Artificial 'dunes', in the form of small piles of sand, were built and planted with marram. By 1878 a belt of dunes 60 yards wide and two miles long had formed along the neck of Spurn, fronted by a newly accreted beach more than 100 yards wide (Pickwell, 1878). Further groynes were added up to outbreak of the First World War, extending the system southwards to the lifeboat station and northwards to the area near Warren Cottage at the southern end of Holderness.

During the First World War gun batteries were constructed at Spurn Point and Kilnsea, and a railway built to service them (Hartley, 1876). An earth bank was also constructed to provide additional flood protection between Kilnsea and Easington. During the inter-war years the coast protection works were maintained and extended, and a concrete road was constructed along the spit between 1939 and 1942. However, a major storm in 1942 caused significant erosion which damaged both the road and railway. Repairs were made in the form of a length of wall constructed of concrete-filled sand bags backed by chalk rubble. The railway remained in service until 1951.

The storm surge of 1953, which was driven by north-westerly winds, caused relatively limited damage to the seaward side of Spurn although the side facing the Humber estuary at the southern end of the spit suffered erosion and damage to buildings. The embankment between Easington and Kilnsea was also breached or overtopped.

After 1953 less attention was paid to the maintenance and improvement of the sea defences than previously, and in 1960, when Spurn was purchased by the Yorkshire Naturalist’s Trust, expenditure of maintenance virtually ceased. There was significant storm damage to the concrete road in 1960 and again in 1976 and 1978. Ad-hoc protection works were undertaken in some places, including the dumping of rubble from demolished buildings. Erosion of the Holderness cliffs and the beach and frontal dunes along much of the length of the Peninsula accelerated during the 1960’s, 1970’s and early 1980’s, in common with many other parts of the east coast. Since that time erosion along the northern half of the Peninsula has continued, albeit at a slower rate. Longshore drift has ensured a supply of new sand to the southern part of the spit, and both lateral and vertical dune accretion has occurred on both sides of the tip. There remains a significant risk of major overwash or a major breach across the neck of the spit.

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Site 23 Cleethorpes and Humberston

Dunes occur along much of the shore between Cleethorpes and Humberston Fitties. They represent open coast fringing dunes in the north, evolving into barrier spit dunes towards the south. In the past 15 years growth of saltmarsh vegetation on the beach at Cleethorpes has cut off the supply of sand to the dunes, and in places new embryo dunes have developed to seaward.

References and sources of further information

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Travell, A. (1994) *Aeolian Processes and Environments on the Lincolnshire Coast: Implications for Coastal Flood Protection*. MSc Thesis, University of Reading.

Site 24 Horse Shoe Point

A narrow belt (50 m wide) of open coast fringing dunes occurs over a distance of *c*. 1 km north of Horse Shoe Point. Recent growth of saltmarsh vegetation on the upper beach has largely cut off the supply of sand to these dunes.

Reference and source of further information

Travell, A. (1994) *Aeolian Processes and Environments on the Lincolnshire Coast: Implications for Coastal Flood Protection*. MSc Thesis, University of Reading.

Site 25 Somercotes Haven to Mablethorpe

25a Somercotes Haven to Saltfleet Haven

A belt of open coast fringing dunes occurs between the breakwater on the east side of Somercotes Haven and the entrance to Saltfleet Haven. The belt reaches its maximum development near Donna Nook where the maximum width is about 300 m. Growth of saltmarsh vegetation on the foreshore has effectively cut off the supply of sand to the dunes, which are now largely vegetated. Embryo dunes and small hummock dunes have started to form around vegetation on parts of the new marsh. These dunes systems provide an important element of the natural flood defence for neighbouring low-lying areas of east Lincolnshire.

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25b Saltfleet Haven to Mablethorpe

South of Saltfleet Haven open coast fringing dunes form a narrow belt (50 m wide) which increases in width towards the south, achieving a maximum of *c*.

800 m north of Mablethorpe. These dunes have experienced significant seawards progradation in recent decades. At Mablethorpe itself the dune frontage is protected by hard defences. Until the 1950's, the belt of dunes extended as an almost continuous barrier southwards to Chapel St. Leonards, but erosion during and following the 1953 storm surge has removed the dunes between Mablethorpe and Sandilands. Recent beach nourishment carried out as part of the 'Lincshore Scheme' has led to the accumulation of aeolian deposits in front of the hard defences in some places, but no true dune ridge has yet been established.

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Site 26 Sutton on Sea to Chapel St. Leonards

In the 1940's sections of this coast were backed by dunes 10 to 15 m high which had bare sand exposed on the seaward face (Steers, 1964, photograph 92). However, serious erosion occurred during the 1953 storm surge and later storm events. Today the dunes are much lower (typically 4 to 8 m OD) and are reinforced on their seaward side by revetments. The maximum width of dunes is about 300 m, but typically less than 100 m. A major beach nourishment scheme was carried out between 1994 and 2000. This has resulted in renewed dune growth along much of the shore.

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Site 27 Seathorne to Gibraltar Point

Dunes back the shoreline between the Butlins holiday camp at Ingoldmells and Gibraltar Point, forming part of a major spit complex which has grown from north to south over the past several centuries. North of Skegness the dunes and underlying beach ridges are attached to the mainland shore and the dune morphology is dominated by hummock dunes and small blowouts, most of which are now re-vegetated. To the south of Skegness several distinct dune-capped ridges become apparent, displaying varying degrees of disruption by blowouts. The intervening swales (slacks) once contained marsh vegetation which subsequently evolved into dune slack communities as seawards and longshore growth of the system continued. The inland dune ridges are now very largely vegetated and some form part of the Skegness Golf Club.

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Cell 3 The Wash to The Thames

<u>General references and sources of further information</u>

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Site 28 Old Hunstanton to Holme Dunes

Sand dunes form a capping to a barrier spit complex between Old Hunstanton and Holme next the Sea, to the west of Thornham Harbour. A SW-NE trending spit system attached to the Chalk cliffs at Old Hunstanton encloses an area of reclaimed saltmarsh. Further to the east, at Holme Dunes, a two-ended barrier spit complex has developed in response to littoral drift divide in this area. Drift from the east has formed a small dune-capped spit at Gore Point, while at west sands westerly drift has formed a spit which recurves into the entrance to Thornham Harbour. Much of the seaward dune frontage at Old Hunstanton has experienced erosion in recent decades, due to transfer of sand towards the northeast, and a variety of protection methods have been employed, including chestnut paling fencing, wicker gabions, rubble-filled metal gabions and a beach dewatering system. The eastern end of this system has remained stable or has experienced slight accretion on the new recurves. Most of the frontage of Holme Dunes has also experienced net erosion for several decades in response to bi-directional drift away from the centre of the system. In this area zig-zag groynes, brushwood fencing and beach drainage measures have all been employed, but with limited success.

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Site 29 Brancaster Bay

Dunes form a low barrier along the western shore of Brancaster Bay, from East Sands to the Royal West Norfolk Golf Club. In places the dunes are now only 1 m high and are prone to overwashing and/or breaching during storms. Two significant breaches at Titchwell have resulted in reactivation of former reclaimed marsh areas behind. The dunes have been eroding at least since the 1920's, with episodes of rapid storm-induced retreat between 1930 and 1932, in 1953 and in the 1970's. The clubhouse of the Royal West Norfolk Golf Club has been protected by rock armour and now acts as a strong point which has retarded retreat of the adjoining sections of dune frontage. The dunes immediately east of the clubhouse are also protected by a length of concrete wall and by wooden groynes which are now in a state of disrepair. Further east the dunes are unprotected and continue to erode. Sand is transported along this part of the shore towards the east, into Brancaster Harbour, where new spit recurves, capped by dunes, continue to form.

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Site 30 Scolt Head Island

Scolt Head Island is a barrier island consisting of a sand and shingle main outer ridge and several recurves with intervening salt marshes. There is a drift divide towards the east of the island, with sand moved west along most of the shore towards Far Point and Bight Hills but also to the east towards Norton Hills and the entrance to Burnham Harbour. In the area of the drift divide the beach sediment budget is negative and the dunes behind the shore are relatively much lower and narrower than to either side. This area was subject to storm surge washover in 1953 and 1978. The dunes provide important protection against flooding for the reclaimed marshes and settlements between Burnham Deepdale and Burnham Overy Staithe, including the River Burn valley.

Visitor pressure on Scolt Head Island is generally low and most of the dunes are well vegetated, primarily with marram. However, the seaward faces of Wire

Hills and Norton Hills are scarped by wave erosion, and there are localised blowouts initiated by rabbit grazing and other factors.

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Site 31 Holkham Bay

Dunes form a wide barrier (200 to 800 m) along the shore between the eastern side of Burnham Harbour and the western side of the entrance to Wells Harbour, a distance of 7 km. The dunes are narrowest at Holkham Gap, which represents the position of a former tidal channel which drained the now reclaimed marshes at Holkham. The dune barrier has probably been in existence for more than 2000 years, but has grown in size considerably since the Little Ice Age, and especially in the last 300 years, partly as a result of embanking and reclamation of the adjoining marshes which has reduced the tidal flows in the tidal channels which cross the intertidal flats. Dune formation at Holkham was artificially encouraged by fencing and tree plantation in the eighteenth and nineteenth centuries. More recently, a new barrier dune system has started to develop across the entrance to Holkham Gap, extending eastwards towards Wells Harbour.

Heavy visitor pressure around Holkham Gap resulted in significant degeneration of parts of the dunes by the late 1960's. Restoration work was started in 1973 using fencing, boardwalks and vegetation re-seeding. Visitor control measures have been maintained around the gap, but the younger dune ridges which have formed further seaward on the former tidal flat remain subject to the effects of trampling.

<u>References and sources of further information</u>

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Site 32 Wells-next-the-Sea to Morston

32a East Hills
32b Stiffkey Meals
32c Morston Meals

Dunes form an arcuate barrier ridge on the eastern side of Bob Hall's Sand, on the eastern side of Wells Harbour. Low dunes also occur on top of former back-beach sand ridges within the marshes between Wells-next-the-Sea and Morston. Most of these ridges formed as a result of erosion at the former end of the inner marsh systems which formed along this open coast shore from the early Holocene onwards. In the last 60 years new marsh systems have formed at Warham, Stiffkey and Morston, cutting off the low dune ridges from their sand supply.

<u>Reference and source of further information</u>

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Site 33 Blakeney Point

In the 1940's Blakeney main beach was backed only by a low ridge and gravel washover fans (Steers, 1964, photograph 140), but the western end of the spit was covered by dune ridges which showed healthy marram growth and deposition of new sand (Steers, 1964). Today the dunes comprise one main area near Blakeney Point and a number of smaller areas which cap sand and shingle recurves formed during the growth of the spit complex from east to west.

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Site 34 Northeast Norfolk Coast

34a Happisburgh to Winterton Ness

Dunes form a narrow (<50 to *c*. 100 m wide) fringing barrier along the open coast between a point just north of Eccles on Sea and Winterton Ness. The maximum crest height is *c*. 10 m but significantly lower in many places. The dune ridge at Horsey was breached by the storm surge of 1938, but by the mid 1940's new dunes several metres high had developed, aided by marram planting. Further breaching at Sea Palling occurred during the 1953 storm, leading to serious flooding of the low-lying hinterland.

A major sea defence scheme was undertaken during the 1990's, involving construction of a series of artificial reefs at Sea Palling and Waxham, together with beach nourishment. This has re-vitalised the sand supply to the dunes, which have experienced vertical and lateral growth. In places new dunes have formed to seaward of the concrete sea wall which protects the seaward side of the main dune system.

<u>References and sources of further information</u>

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34b Winterton Ness to Hemsby

South of Winterton Ness the dune belt increases in width to a maximum of *c*. 600 m just north of Winterton-on-Sea. Dune ridges have grown seawards in front of the former cliff line. A large part of this area now forms the Winterton Dunes National Nature Reserve. The blown sand belt continues southwards as far as Newport, although at the southern end of the system the dunes have been levelled and built upon. Active and vegetated dunes are present as far as Hemsby (The Marrams).

34c Caistor-on-Sea to Great Yarmouth

Blown sand deposits reappear just to the north of Caistor-on-Sea and continue southwards as far as the entrance to Great Yarmouth harbour. Most of the area has been levelled and built upon, although a significant dune area remains between the northern end of Great Yarmouth and Caistor (North Beach, or Caistor Ness, and North Denes). Part of this area is occupied by the Great Yarmouth Golf Club. The dunes in this area have grown seaward since the 1930's in the shelter of an offshore bank (Middle Scroby Sand).

<u>Reference and source of further information</u>

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Site 35 Suffolk Coast

35a Gunton Denes and Lowestoft Denes

Blown sand deposits occur again between a point just south of Corton and Lowestoft Ness. Near Corton the aeolian deposits represent cliff-top dune and sand-sheet sediments which today receive little or no supply from the modern beach. Much of the blown sand at Lowestoft has been built upon, although partially vegetated dunes still occur behind the shore at the northern end of the town. Lowestoft Ness is *c*. 4 km long and 300 m wide at its widest point. Although it is a progradation feature, it has experienced erosion over the past century, and the shoreline is now largely fixed by groynes and sea walls.

35b Kessingland

Low dunes (The Denes) overlie some of the shingle and mixed sand-shingle ridge deposits to the south of Kessingland, where a foreland (ness) has recently formed in front of an abandoned cliff line. Older dunes cap a small spit at the eastern end of Kessingland Level and form a ridge abutting the low Crag cliffs to the south.

35c Covehithe Broad

A short, discontinuous belt of low dunes occurs on the sand-shingle barrier at the eastern end of Covehithe Broad.

35d Southwold

Dunes (locally called The Denes) have formed on top of sand and shingle beach deposits which have accumulated on the north side of the North Pier at the entrance to the River Blyth estuary.

35e Walberswick

Dunes have formed on an area formerly known as The Flats on the southern side of the South Pier at the entrance to the River Blyth. The dunes have grown in two stages, burying a concrete sea wall which protects the entrance to the Dunwich River and wharf-side area at Walberswick. Dune growth has been encouraged by fencing and marram planting undertaken by the Environment Agency since 1991.

35f Minsmere to Sizewell

A narrow belt of dunes extends from the southern end of Minsmere Cliffs to Sizewell Cliff. The dunes form part of the protection for the Minsmere Levels, Sizewell Belts and Sizewell nuclear power stations. The dunes at the northern end of the system were levelled by storm surges in 1938 and 1953, but were re-built by bulldozing of the sand and marram planting (Steers, 1964). The dunes in the central and southern parts of the system have experienced accretion for much of the past 60 years, but in the past decade the dune frontage between Minsmere Sluice and Sizewell B Power Station has again started to erode. At Sizewell Gap the dunes are underlain by an artificial clay embankment to provide added flood protection. A gravelly clay bank also underlies much of the dune frontage north of Minsmere Sluice. The shore around Minsmere Sluice is currently stable, but the dunes and clay bank further north are also currently eroding, creating a potential risk of breach at the extreme northern end where the dune belt is narrowest and lowest.

<u>References and sources of further information</u>

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35g Thorpeness

Dunes occur on the southern side of a glacial till headland at Thorpeness, north of Aldeburgh. The dune system originated as a barrier spit complex on the northern side of The Haven, a former small estuary of the Hundred River which was blocked off in the late nineteenth century. The former Haven entrance and the shore to the south now consist of a shingle ridge system which has prograded into the bay over the last 100 years. The dunes form part of the flood defence for the reclaimed land behind the barrier. The morphology of the dunes has been affected by visitor pressure and by house building close to the shore.

Cell 4 The Thames to Selsey Bill

<u>General references and sources of further information</u>

BMT (1996) *Dover Harbour to Beachy Head Shoreline Management Plan*. BMT Marine Projects Ltd., Bath.

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Site 36 Sandwich Bay

Low dunes occur as cappings on many of the sand and gravel beach ridges which have grown northwards from Deal towards Pegwell Bay and the mouth of the River Stour. Inland is an extensive area of low lying land (Lydden Valley and the River Stour floodplain). Many of the ridges and intervening swales fall within three golf courses within the area (Royal Cinque Ports Golf Links, Royal St. Georges's Golf Links and Princes's Golf Links). In the south (Tenants Hills) the system consists of a shingle beach backed by dunes up to *c*. 10 m high, gradually changing northwards to multiple sand beach ridges with lower dunes and eventually to a shell ridge at the distal end (Shell Ness). Sandwich Bay acts a sink for marine sediments transported from the north and from the south, and the adjacent shoreline has been subject to long-term accretion.

<u>Reference and source of further information</u>

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Site 37 Romney Sands

A small area of dunes has formed at the mouth of a small river near Greatstone-on-Sea, located on the northern side of the Dungeness foreland complex. Other areas of blown sand, now separated from the sea, occur in a SW-NE trending belt north of New Romney and in the area inland of Greatstone-on-Sea.

Site 38 Camber Sands

A significant area of dunes has formed at the mouth of the River Rother, opposite Rye Harbour on the northern side of Rye Bay. The dunes are a significant part of the flood defence for Camber village and adjoining parts of Dungeness. They suffered severe degradation as a result of military training activities during the Second World War. Restoration work, including fencing and marram planting, began in 1947. However, severe visitor pressure during the 1960's resulted in further degradation, with blown sand invading roads and adjoining properties. Sand was also removed from the dunes to build Dungeness nuclear power station during the 1960's. Further restoration measures by East Sussex County Council undertaken since 1967 lead to reduced sand blowing and increased vegetation cover. Measures employed included disc-harrowing into the sand a mixture of chopped straw, hydraulic spraying with a mixture of seed, fertilizer and water, and application of a surface mulch of chopped straw and bitumen. Shore-parallel fencing was also employed to trap sand blown from the beach. Although the system remains managed, with fenced pathways, heavy visitor pressure maintains areas of bare sand in some areas. The frontal dunes have a positive sediment budget and display slow shoreward progradation. Used Christmas trees are used to trap sand in degraded areas.

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Site 39 Littlehampton

39a East Beach
39b West Beach

Dunes cap a small barrier spit complex at the mouth of the River Arun, west of Littlehampton. Much of the area is now occupied by a golf course. There is also a small area of blown sand on east side of the Arun mouth which is used as a recreational area. The barrier is a relic of a once more laterally extensive system which extended from Middeleton-on-Sea to Littlehampton, and still serves an important flood defence function for the Arun Valley. Littoral drift along the shore occurs from west to east, resulting in erosion at the western end of the system and net stability or slight accretion at the eastern end.

Cell 5 Selsey Bill to Portland Bill

<u>General references and sources of further information</u>

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Site 40 East Head, West Wittering

Dunes cover a recurved spit (East Head) on the eastern side of the entrance to Chichester Harbour, near West Wittering. Littoral sediment drift in this area is from east to west, into Chichester Harbour. The seaward end of the beach-dune complex is experiencing erosion, but there has been recent net accretion at the northern (Chichester Harbour) end.

Site 41 Sinah Common, Hayling Island

A spit and back-barrier spit complex has developed from east to west along the frontage of Hayling Island, forming a recurve into Langstone Harbour. The spit is mostly composed on shingle, but becomes more sandy and with better dune development towards the west. Much of the area (Sinah Common) has the form of an undulating sand sheet with hummock dunes and is now occupied by Hayling Golf Club.

Site 42 Poole Harbour Entrance

42a Sandbanks

The Sandbanks Peninsula (otherwise known as the North Haven Peninsula) on the northern side of the entrance to Poole Harbour is composed largely of marine sands overlain by blown sand with a single ridge of dunes which achieves a maximum height of 16 m OD. The position of the spit has been maintained since the late nineteenth century by groynes and sea walls. Much of the Peninsula is now covered by residential development.

42b Studland

The Studland Peninsula (otherwise known as the South Haven Peninsula) on the south side of the Poole Harbour entrance consists of a two-component barrier spit dune complex which is of flood defence importance to the lower lying areas of South Haven Peninsula and Poole Harbour. Dunes have formed along the frontages of two bays, Studland Bay and Shell Bay. Several shore-parallel ridges are present, separated by slacks (depressions) which represent areas of former salt marsh. The morphology of the area has evolved over a period of some 400 years, most recently in response to the construction of a training wall on the south side of the Harbour entrance channel. Littoral sediment drift is generally northerly along the South Haven frontage and southerly along the North Haven frontage. The frontal dunes at the southern end of Studland Bay have suffered sediment starvation and erosion at a rate of up to 3 m per annum in recent decades, exacerbated by high visitor pressure. This has posed a threat to the Knoll Cafe, car park and visitor centre. By contrast, there has been seawards accretion of up to 2 m per annum at the northern end of the system. The National Trust, which owns a large part of the southern end of the Peninsula, favours a policy of long-term managed retreat but has employed some short-term sea defences to retard the rate of erosion (The National Trust, 2001).

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Cell 6 Portland Bill to Lands End

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Site 43 Exe Estuary

43a The Maer, Exmouth
43b Dawlish Warren

On the eastern side of the Exe estuary sand dunes occur on a small barrier spit which protects a flat area of alluvium (The Maer) deposited by Littleham Brook. The area is now managed as a Local Nature Reserve by East Devon District Council. The more inland older dunes have been partially flattened for recreational purposes, but higher, more recent dunes occur close to the beach.

The dunes of Dawlish Warren are developed on a 2 km long barrier spit which has developed in a SW-NE direction across the western side of the River Exe estuary. Behind the spit is an extensive area of saltmarsh and intertidal flats. The spit was formerly highly mobile, but for much of the last century its movement has been restricted by coast protection works including gabion walling, groynes, a concrete wall and rock revetment. The more inland dunes now form part of The Warren Golf Club.

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Site 44 Bigbury Bay

44a Thurlestone Sands
44b Leas Foot Sand
44c Yarmouth Sand
44d Bantham Ham
44e Cockleridge Ham
44f Bigbury-on-Sea
44g Burgh Island
44h Challaborough
44i Ayrmer Cove
44j Westcombe Beach

Much of Bigbury Bay is backed by cliffs composed of shales and slates. Small dune systems have developed at several locations behind small rock-bounded sandy beaches, including near Warren Point, Bigbury-on-Sea and in the estuary of the River Avon. Morphological types present include bay-head barrier, bay-fringing, estuarine shore fringing, and climbing. Some parts of the dune frontage are eroding and partly protected by rock armour, gabions and short lengths of wall, but others are unprotected and stable or accreting.

Site 45 Par Sands

Par Sands are backed by bay-head fringing dunes which protect a small low-lying area in the floodplain of the River Par. Much of the modern beach sand consists of quartzose sand waste washed down from China Clay workings to the north of St Austell. The dunes are subject to heavy visitor pressure and are partly occupied by a camping and caravan site.

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Site 46 Kennack Towans

A small area of finging dunes has formed behind the beach at Kennack Sands on the east side of the Lizard Peninsula.

Site 47 The Towans, Mullion

The Towans is a climbing dune system formed of sand blown from a pocket beach in Jangye-ryn, about 3 km northwest of Mullion. Part of the area is used as Mullion Golf Club.

Site 48 Praa sands

Sand dunes, up to 15 m high, back the wide sandy beach of Praa Sands. Parts of the dune frontage are now protected by privately-owned sea walls.

Site 49 Marazion

A fringe of sand dunes occurs between the beach and the road leading to Penzance, west of Marazion. Behind lies the low-lying Marazion Marsh, an important RSPB reserve. The dune frontage is now largely protected by stone and concrete sea walls, or by gabions.

Cell 7 Lands End to The Severn Estuary

<u>General references and sources of further information</u>

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Site 50 Whitesand Bay

A large complex of bay fringing and climbing dunes occupies the central and southern parts of Whitesand Bay, east of Sennen Cove. The dunes are prone to heavy visitor pressure in the summer months, and work has been required to control access and stabilise the dunes in the last 30 years.

Site 51 St Ives Bay

The dunes of eastern St Ives Bay form the second largest dune system in Cornwall. Three main sub-divisions can be recognized: (a) the Lelant Towans on the west side of the Hayle estuary; (b) Hayle Towans to Gwithian Towans between the east side of the Hayle estuary and the mouth of the Red River; and (c) Godrevy Towans to the north of the Red River. Dunes began to from in this area *c*. 5000 years ago and sand movement/ accumulations has continued episodically ever since. Human activities have had a profound influence on the area since Neolithic times, and have included agriculture, sand extraction, explosives manufacture and recreational activities. Large quantities of sand have been mined for aggregate and soil improvement purposes in some areas, notably Gwithian and Phillack Towans. Current planning permissions allow for continued sand extraction until 2042. Numerous deep mine shafts have also been dug within the dunes in the search for tin and other metals. Serious attempts at dune restoration began in 1979 and methods used have included re-profiling, fencing, marram planting and access control measures. Recent management policy of Cornwall County Council has considered that 10 to 25% bare sand is desirable within the dune system in order to attain biodiversity targets.

51a Lelant Towans

The seaward frontage of Lelant Towans is eroding, impacting on the West Cornwall Golf Course. The frontage facing the estuary is largely protected.

51b Hayle Towans, Upton Towans and Gwithian Towans

The dune frontage is eroding in places, most notably around public access points. The seaward faces of the climbing and cliff top dunes have suffered severe wind erosion in the past, although sand stabilisation works have been undertaken in the past 20 years.

51c Godrevy Towans

Godrevy Towans represents the northernmost component of the St. Ives Bay dune grouping, located on the north side of the Red River. The dunes are mainly climbing types and their morphology has been strongly influenced by a range of human activities.

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Site 52 Porth Towan

A small area of fringing and climbing dunes is found at the head of the small bay where a small river enters the sea. The more inland sand is partly built on, but nearer the sea areas of active and vegetated dune remain. Gabions, netting and other measures have been employed to control sand movement.

Site 53 Perran Bay

Climbing dunes back much of the 3 km long shore (Perran Beach) between Perranporth and Ligger Point. Blown sand extends more than 2 km inland and climbing dunes have buried a number of medieval and earlier buildings. The eastern limit of the dunes is provided by a small river which flows into Holywell Bay. Some 940 acres of dunes are owned/managed by the MOD. Scrub invasion in recent years has been countered by grazing management to enhance biodiversity. Other parts of the dunes are subject to heavy visitor pressure and sand control measures have been employed for many years.

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Site 54 Holywell Bay

Climbing dunes and transgressive sand sheets also extend almost 2 km inland behind Holywell Beach, a 1 km long pocket beach sandwiched between Penhale Point and Kelsey Head. North-eastwards movement of the sand has been limited by a small stream which flows into Porth Joke.

Site 55 Crantock Bay

Crantock Beach is an 800 m long pocket beach sandwiched between rocky headlands at Pentire Point West and Pentire Point East. The sandy beach is backed by a dune belt up to 400 m wide at the mouth of the Gannel estuary, southwest of Newquay. The dunes are of fringing and climbing/transgressive types. The dunes are subject to heavy visitor pressure and extensive dune protection and stabilization works have been carried out in the past 30 years.

Site 56 Fistral Bay

Fistral Bay at Newquay is backed by low fringing dunes and blown sand is also present as a cliff-tip cover in the area of Newquay Golf Club.

Site 57 Berryl's Point to Trevose Head

57a Mawgan Porth

Mawgan Porth is a small cove (1 km wide) sandwiched between Berryl's Point and Trenance Point. The beach is backed by fringing dunes, and blown sand penetrates up the valley of a tributary of the River Menalhyl leading to the beach. The dunes have experienced erosion during much of this century. Fencing and other stabilisation measures have been used in the last 30 years to control sand movement onto properties along the Trenance sea front.

57b Constantine Bay

A small area of fringing bay dunes backs Constantine Beach. The dunes are subject to heavy visitor pressure and have been fenced and planted in the last 30 years to control sand movement. Blown sand extends 1 km inland, and this area is owned by the large Trevose Golf Club.

Site 58 Camel Estuary

58a Harbour Cove
58b Rock to Daymer Bay

Estuarine fringing dunes occur behind Harbour Cove on the north-western side of the Camel estuary north of Padstow and also between the lifeboat station at Rock and Daymer Bay on the eastern shore of the estuary. Immediately north of Rock the dunes are partially of climbing type, surrounding and partially overlying Cassock Hill and Brea Hill. The St Enodoc Golf Course occupies most of the area. Between Cassock Hill and Brea Hill is an area of younger dunes lying seaward of an old cliff line. These dunes have formed since 1923 (Hepburn, 1943). Considerable quantities of the calcium-carbonate rich dune sand (50 to 70% $CaCO_3$ in some places) have been removed from the Camel estuary dunes for agricultural liming purposes.

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Site 59 Widemouth Bay

Two small areas of dunes occur inland of rock-bound coves at Widemouth Sand in the southern part of Bude Bay.

Site 60 Bude

Dunes occur inland of Bude Haven, north of Bude. Part of the area is now occupied by the Bude and North Cornwall Golf Club.

Site 61 Taw Estuary

61a Northam Burrows

Northam Burrows is an estuary-mouth barrier spit and back-marsh complex located on the southern side of the Taw-Torridge estuary. The southern part of the barrier ridge consists of a cobble upper beach ridge with a sandy lower beach. The gravel becomes finer towards the north and the proportion of sand increases. Dunes are well-developed along the northern part of the barrier. Inland the dunes are mainly fixed by vegetation but areas of bare sand and mobile dunes occur closer to the sea. The present morphology of the area differs only in detail from that shown on the First Edition Ordnance Survey map of 1809, although progressive northwards extension of shingle in the later nineteenth century reduced the sand supply to the dunes. Following seawards accretion in the later nineteenth and earlier twentieth centuries, the northern part of the gravel ridge began to erode in the 1930's. Narrowing of the dunes at the northern end of the complex presented an increasing threat of marine flooding and in 1978 this section of the shore was strengthened using rock armour. In effect there are now two separate areas of dunes, the easternmost of which is linked to higher ground near Appledore by a flood embankment.

The Royal North Devon Golf Course has existed on part of the back-barrier area since 1864. However, uncontrolled access to the Burrows and overgrazing by sheep, cattle, horses and rabbits meant that by the 1960's the dunes were in a degraded condition with extensive areas of bare sand. Subsequent management of the dunes has included fencing to control livestock movements and visitor access, sand fencing to trap sand, marram planting and periodic bulldozing of sand and shingle to form a protective ridge on the back-beach. The area was designated a SSSI in 1988. Much of the area is now managed by Devon County Council as a Country Park.

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61b Instow Sands

On the east side of the River Torridge, at Instow, a wide expanse of intertidal sand is backed by dunes. The dunes form low barrier ridges which act as partial flood defence for Instow and Barton Marshes.

61c Braunton Burrows

Braunton Burrows is a large dune complex adjacent to a wide sandy beach at Saunton Sands. The dunes represent a wide barrier spit system which protects an extensive low-lying area including Braunton Marsh, the Chivenor military airfield and industrial developments on the outskirts of Barnstaple. In the central part of the system, where the dunes are best developed and achieve a maximum height of 30 m OD, three main shore-parallel ridges are present, separated by slacks. To the north and south only two main ridges are discernible, disrupted to varying degrees by former blowouts and small parabolic dunes. The dunes suffered from heavy military use during the Second World War, and there is evidence that there was extensive instability prior to that date. Dune stabilization works were initiated in the 1950's, involving fencing and marram planting over up to 6% of the total area. Although vegetation cover increased significantly, the dune system continued to increase in both volume and height due to continued sand input from the beach. However, erosion of the spit (The Neck) at the southern end of the system has been an ongoing problem, despite attempts at shore stabilization using groynes. The site was designated an National Nature Reserve in 1964, but lack of grazing caused a dispute between the landowner and English Nature which resulted, uniquely, in the site being de-declared as an National Nature Reserve in 1996. An experimental grazing programme was re-established in 1998, and it remains a SSSI, SAC and UNESCO Biosphere Reserve.

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Site 62 Croyde Burrows

Bay fringing dunes form a belt up to 500 m wide to the west of Croyde village. The dunes are subject to heavy visitor pressure and various management measures have been employed to protect the vegetation and control sand movement.

Site 63 Woolacombe Warren

The wide sandy beach at Morte Bay is backed by fringing and climbing dunes which rest against, and partially bury, the edge of Woolacombe Down (owned by the National Trust). Dunes reach their greatest development in the northern part of the bay between Mill Rock and Woolacombe.

Site 64 Berrow and Brean

Bay-barrier dunes form a 10 km south-north trending belt between Burnham-on-Sea and Brean Down, north of the River Parrett estuary in Bridgwater Bay. The dunes attain a maximum width of 1 km and protect a large of area of the Somerset Levels from marine flooding. A smaller SW-NE trending belt of low barrier spit dunes occurs at Stert Flats on the west side of the Parrett estuary. Until *c*. 1910 the tidal flats to seaward of the dunes at Berrow and Brean were sandy and up to 4 km wide at low spring tides. However, after *c*. 1910 marsh vegetation began to colonise the shore and the higher tidal flats became increasing muddy, effectively cutting off the sand supply to the dunes.

North of Burnham-on-Sea the dunes have suffered destabilisation due to visitor pressure, and stabilisation works have been carried out. A large part of the dune area at Berrow is occupied by the Burnham and Berrow Golf Club and the dunes are generally well vegetated. North of Brean the dune belt is very narrow, reaching a minimum of <50 m near Brean Down. The dune toe in this area has been protected by gabions and a low wall.

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Site 65 Weston Bay

Blown sand fringes almost the whole of Weston Bay but in the north the former dunes have been levelled and built-upon during the development of Weston-super-Mare. In the southern part of the bay, near Uphill, dune topography remains, albeit partly modified during the construction of the Weston-super-Mare Golf Course.

Site 66 Sand Bay

Sand Bay consists of a low lying area which formerly lay behind a natural sand and shingle barrier, 100 to 250 m wide and capped by low dunes, which linked the flanking headlands of Worlebury Hill and Middle Hope. Prior to 1981 the seaward side of the dunes was protected by a pitched stone and concrete slabwork revetment. The dune crest was significantly degraded due to visitor pressure over many years. In December 1981 the crest was overtopped by waves combined with a surge tide, leading to flooding of properties behind. A beach nourishment scheme using sand dredged from the Severn Estuary was carried out in 1983-84. The upper part of the new beach face was planted with marram to trap sand and give a natural appearance. Since that time there has been localised growth of new embryo dunes in front and on top of the old sea wall.

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Cell 8 The Severn Estuary to St. David's Head

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Site 67 Merthyr-Mawr Warren

The Merthyr-Mawr Warren and Newton Burrows dune system covers approximately 932 ha to the northwest of the Ogmore River. The system can be classified as composite, having originated as a bay-fringing dune system which evolved into a transgressive climbing system during stormy periods of the Little Ice Age. The main source of sand was provided by the wide sandy beaches of Traeth yr Afon and the Black Rocks area. Dune formation commenced at least 2500 years ago, and during and after the Little Ice Age sand climbed onto the Carboniferous limestone escarpment behind. Sand blowing and dune encroachment remained a significant problem until the 1960's. Between 1937 and 1973 sand and gravel was extracted commercially from the frontal dunes, resulting in a temporary breakthrough by the sea in 1977 and 1978. The system has since been heavily managed and vegetation cover has re-established itself over most of the area. Parts of the system at Newton have been built on for residential and industrial purposes.

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Site 68 Swansea Bay

The coastline of Swansea Bay consists of rock headlands with shore platforms at its eastern and western ends and intervening sandy beaches, many of which are backed by dunes. There is a general clockwise sediment circulation pattern around the bay, resulting in net sediment transport towards the east. The central section of the bay is generally low lying with extensive sandy beaches, long sections of which have been eroding in recent decades. The Bay appears to act essentially as a closed sediment system which, prior to human interference, was in a state of dynamic equilibrium with contemporary processes. Sand supply to the shoreline from offshore sources is apparently low, and there is relatively little modern day input from rivers and coastal cliff erosion. Erosion has occurred primarily at the up-drift ends of local sediment transport cells and in places where harbour works, reclamation of the foreshore, and beach sand extraction have disturbed the natural sedimentary regime.

68a Kenfig Burrows

Kenfig Burrows originated as a bay-fringing system and evolved into a transgressive- climbing system. During the Little Ice Age, mobile dunes reached a point some 4 km inland of the present shore, on the eastern side of the line now taken by the M4 motorway, burying a number of medieval settlements in the process.

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68b Margam Burrows

Like Kenfig Burrows, from which it is separated by the Afon Kenfig (or Cynffig), Margam Burrows represents a bay-fringing dune system which evolved into a partly transgressive system. A belt of blown sand, 500 to 1200 m wide, extends along the shore from the Afon Kenfig to the mouth of the Afon Neath at Baglan, but much of the former dune area behind Margam sands and Aberavon Sands is now occupied by the Margam and Port Talbot steelworks and other industrial installations. However, an area of dune topography is preserved between the Afon Kenfig and Margam Moors.

<u>Reference and source of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

68c Baglan Burrows

Although most of the former blown sand belt at Baglan Burrows is now built on, some 2.5 km of coastal frontage between Aberavon Sands and the River Neath estuary at Baglan Bay is still backed by fringing dunes which provide a significant flood defence function to the industrial developments behind. In recent decades new foredune ridges have accreted in this area, mainly due to the impact of breakwater construction and stabilization of the course of the main River Neath navigation channel.

<u>Reference and source of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

68d Crymlyn Burrows

Crymlyn Burrows was initiated as a bay-fringing dune system but in the past century there has been recent accretion of a new dune-capped barrier spit on the west side of the River Neath estuary mouth. As at Baglan, this accretion is attributable to breakwater construction and stabilization of the River Neath approach channel. The older dunes further inland are now largely levelled for industrial and railway infrastructure purposes.

<u>Reference and source of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

68e Black Pill Burrows

Blown sand fringes much of the shore of western Swansea Bay between Swansea marina and West Cross, but much is now built upon and dune topography is now only preserved between Brynmill and Black Pill at the mouth of the Clyne River. Dunes originally extended further eastward and formed a barrier which prevented marine flooding of the low-lying land behind, but shoreline erosion has resulted in recession of the barrier and has exposed Iron Age peat and the remains of a submerged forest on the foreshore. Very little sand is supplied to the beach and dunes in this area at the present day, and much of the frontage is protected by hard defences. The dunes between the University and Black Pill now form part of a pitch and putt golf course.

<u>References and sources of further information</u>

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Site 69 Oxwich Bay

69a Pennard Burrows

Pennard Burrows represents a climbing and cliff top dune system at the eastern end of Oxwich Bay, close to the village of Southgate and adjacent to Pennard Pill. The source of sand was provided by the sandy beach of Threecliff Bay, but in recent decades erosion has removed the bay fringing dunes in this area and there is now little supply of aeolian sand to the dunes further inland. The main phase of sand blowing occurred between the fourteenth and sixteenth centuries, when the castle and former village of Pennard were overwhelmed by blowing sand. Sand incursion continued until the end of the eighteenth century, but has been minor in the last 200 years. Much of the dune area is now occupied by Pennard Golf Club.

<u>Reference and source of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

69b Penmaen Burrows

Penmaen Burrows represents another area of climbing and cliff top dunes on the west side of Threecliff Bay. Blowing sand during the Little Ice Age covered a medieval settlement including the remains of a fortified farmstead and church, but there has been little activity in the past two centuries.

69c Nicholaston Burrows

Nicholaston Burrows is a bay fringing and partly climbing dune system in the centre of Oxwich Bay. The system appears to have formed some time after the initiation of the Oxwich Burrows dunes to the west, as a result of progressive accretion of sand around the shoreline of Oxwich Bay. In recent decades the supply of sand appears to have diminished, and the dunes have become partially degraded due to visitor pressure.

<u>Reference and source of further information</u>

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69d Oxwich Burrows

The Oxwich Bay dunes represent a bay head barrier system which protects a low-lying wetland area behind. Hummock dunes, blowouts and parabolic dunes are found, formed mainly under the influence of ESE and SE winds. The importance of south-westerly winds increases towards the east. Visitor pressure has been heavy, notably at the western end of the system. The main dune-capped beach ridge probably first formed *c*. 2500 years ago, enclosing a brackish lagoon which was drained during the sixteenth century.

<u>References and sources of further information</u>

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Site 70 Port Eynon Bay

Port Eynon Bay is backed by a small bay-fringing and climbing dune system formed by easterly and south-easterly winds. The dunes were highly unstable with active sand blowing prior to *c*. 1978, mainly due to visitor pressure, but are now largely stabilised by management measures. The shore of Port Eynon Bay is backed by low cliffs and landslips, and there is little active supply of sand to the dunes.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 71 Rhossilli Bay

71a Rhossilli
71b Hillend Burrows
71c Llangennith Burrows

Rhossili Bay contains a series of solifluction terraces fronted by a wide sandy beach. Climbing dunes form a ramp at the back of the beach and have partially buried the solifluction terraces, especially in the central and northern parts of the bay, beyond the northern limit of Rhossili Down. Sand transport has mostly occurred under the influence of south-westerly winds. The original village of Rhossili was located on the solifluction terraces, and the remains of a church and a farm have been discovered beneath the dunes (Bridges, 1987, p 31). Some of the climbing dunes were still active in the 1940's.

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Site 72 Burry Holms to Whiteford Point

72a Broughton Burrows, Delvid Burrows and Hills Burrows

Between the rock outcrops of Burry Holms and Hills Tor lies an extensive area of blown sand composed of climbing dunes at Broughton Burrows and bay fringing dunes around the margin of Broughton Bay. Broughton Burrows is contiguous with Llangwennith Burrows, and much of the sand in both areas has been transported by south-westerly winds from Rhossili Bay. The fringing dunes around Broughton Bay have been formed of sand from beaches in the bay transported by north-westerly winds.

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72b Whiteford Burrows

The dunes of Whiteford Burrows have accumulated on and around a marine sand and gravel barrier which links the mainland at Hills Tor with an outlier of glacial till which underlies the blown sand at Whiteford Point. The dune-capped barrier, which has the plan morphology of a spit, partially blocks the entrance to the Burry Inlet. Saltmarshes and tidal flats have formed in the back-barrier area. The dunes now form a belt 400 to 600 m wide which acts as the primary sea defence. The largest dunes occur at the north-east end and attain a height of more than 20 m close to the sea. Eastward of the main ridge is an area of lower, hummocky dune terrain, while to the west of the main dune ridge is a younger dune ridge which is eroding in the south and accreting in the north. Net sediment drift is towards the north-east and then into the Burry Inlet.

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Site 73 Pembrey Burrows

Pembrey Burrows is a barrier spit complex which has grown eastwards towards the entrance to the Burry Inlet. Before 1830 the coast to the west of Pembrey was open to the sea, fronted by estuarine shore dunes which now form part of the Ashburnham Golf Club. Further inland a belt of older blown sand and low dunes extended eastwards towards Burry Port; much of this area is now covered by urban and industrial development. Sea walls constructed during the eighteenth and early nineteenth century extended dry land further north and west, and by the 1870's a new sand spit had begun to develop further to seaward at Pembrey, initiating saltmarsh development behind. The Pembrey dunes represent the southern end of a large dune system which extends over a distance of 9 km towards the Gwendraeth estuary and which protects a large low-lying area from marine flooding. Much of the area is owned by the Ministry of Defence, including the now disused Pembrey airfield. In the 1940's a large part of Pembrey Burrows was planted with coniferous forest, and today is managed by the Forestry Commission as Pembrey Forest. Near the mouth of the Gwendraeth estuary the net drift direction is westerly, and a second dune-capped barrier spit system exists at Tywyn Point. Much of the seaward frontage of the Pembrey to Tywyn dunes has experienced erosion in recent decades, especially in the zone subject to upper foreshore sediment transport divergence.

Reference and source of further information

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Site 74 Laugharne Burrows and Pendine Burrows

Barrier spit dunes extend over a distance of 9km between Ginst Point, at the eastern end of Laugharne sands, and the village of Pendine at the western end of Pendine Sands. The dune system achieves a maximum width of *c*.1 km in its central section and protects a large area of low lying land from marine flooding (West Marsh and East Marsh, partly owned by the Ministry of Defence). The spit complex has grown from west to east towards the mouth of the River Taf estuary. The dunes for 5 km to the west of Ginst point suffered severe erosion during much of the later twentieth century, creating a risk of breaching and flooding of low-lying land behind. However, protection works in the 1960's successfully prevented a major breakthrough. Management measures included construction of a 2 km long rip rap embankment, recharge of parts of the beach using quarry waste, and dune restoration works. To the west the beach has shown net accretion with development of new foredunes. Further west at Pendine the beach and frontal dunes have shown a long-term trend for net erosion, although the rates of recession and inland sand blowing have been slowed by dune protection measures, including masonry and concrete walls near Pendine village.

<u>References and sources of further information</u>

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Site 75 The Burrows, Tenby

Fringing bay dunes back the shore of South Beach between Tenby and Giltar Point. Visitor pressure is heavy and the dune ridges have been dissected by a series of blowouts and small parabolic dunes formed mainly under the influence of south-easterly winds. The dune frontage at the south end shows a tendency for erosion, and is partly protected by gabions. Parts of the system are used by Tenby Golf Club and as a rifle range.

<u>Reference and source of further information</u>

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Site 76 Lydstep Haven

Lydstep Haven is a small east-facing bay cut into Old Red Sandstone which is bounded by more resistant Carboniferous limestone headlands (Proud Giltar and Lydstep Point). The sandy beach at the head of the bay is backed by fringing dunes and climbing dunes.

Site 77 Manorbier Bay

At the eastern end of Manorbier Bay a sandy beach overlies a wave cut platform and abuts a cliff-line cut into Old Red Sandstone and Pleistocene solifluction deposits. Climbing dunes and cliff top dunes occur behind the beach. Large areas of bare sand were present in the mid 1940's but the sand is now mostly stabilised.

Site 78 Freshwater East

Fringing dunes and climbing dunes occur behind the south-east facing beach at Freshwater East. At the western end of the bay the dunes form a barrier which protects low-lying land in the lower Freshwater valley.

<u>Reference and source of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 79 Stackpole Warren

Blown sand covers an area of *c*. 2 km inland of Stackpole Head and Saddle Point, north of St. Govan's Head. Three separate areas of dunes are identifiable at the present day. Bay fringing and transgressive dunes back the small east-facing pocket beach at Barafundle Bay. Further west, climbing and cliff top dunes reach an elevation of 41 m OD at Stackpole Warren, while further bay-fringing dunes back the shore at Broad Haven. Broad Haven and a small pocket beach to the east of Saddle Point probably formed the major sources of sand in the past, but there is limited supply of new sand to Stackpole Warren at the present day.

<u>References and sources of further information</u>

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Site 80 Linney, Brownslade and Broomhill Burrows

80a Linney Burrows and Brownslade Burrows
80b Gupton Burrows, Broomhill Burrows and Kilpaison Burrows

This large composite dune system backs a 4 km long west-facing bay between Linney Head and Angle Bay. The dune system originated as a bay-head barrier system which evolved into a transgressive climbing dune system during the Little Ice Age. At the present day aeolian sand is supplied from two beaches (Frainslake Sands and Freshwater West) which are separated by a 1.5 km long intertidal rock outcrop. Submerged forest beds outcrop on the foreshore at Freshwater West, indicating barrier recession. At the northern end of the system, in the area of Kilpaison Burrows, south-westerly winds have caused sand to climb to an elevation of >65 m OD, while some sand has been transported as far as the southern shore of Angle Bay. These systems have experienced relatively little human interference, and there are no man-made dune defences.

<u>References and sources of further information</u>

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Site 81 The Burrows, Whitesands Bay

Dunes form a finging / transgressive climbing system behind the west-facing Whitesands Bay, south of St. David’s Head. The blown sand has extended up to 1.5 km inland over a coastal length of *c*.1 km. Part of the dune frontage at the northern end of the bay is degraded and now protected by a rock revetment, but most of the inland dunes are stabilised by vegetation.

<u>Reference and source of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Cell 9 St David's Head to Bardsey Sound

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Site 82 Newport Bay

Estuarine shore fringing dunes form a triangular projection (The Bennet) onto the east side of Newport Sands at the mouth of the Afon Nyfer in southern Cardigan Bay. Blown sand has also moved inland as climbing dunes to the east of The Bennet, and this area is now occupied by Newport Golf Club. Sand transport has taken place under the influence of south-westerly, westerly and north-westerly winds.

<u>Reference and source of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 83 Teifi Estuary

83a Poppit Sands

Fringing dunes occur along the southern side of a large area of sandy tidal flats (Poppit Sands) at the mouth of the Teifi estuary, formed mainly by the influence of north-westerly winds. The frontal dunes have experienced erosion in recent decades, partly due to marine processes and partly to visitor pressure.

References and sources of further information

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Posford Haskoning (2001/02) *Teifi Estuary Development Strategy*. Posford Haskoning, Cardiff.

83b Towyn Warren

Fringing and climbing dunes occur along the southern side of the Pen yr Ergyd Peninsula, and on the adjoining higher ground on the east side of the Teifi estuary, north-west of Cardigan. At Towyn Warren blown sands extend up to 120 m OD, having been blown by south-westerly and north-westerly winds from the adjacent tidal flats. This area is occupied by Cardigan Golf Club. The base of the Pen yr Ergyd spit has experienced erosion in recent years.

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Posford Haskoning (2001/02) *Teifi Estuary - Morphological Development of the Estuary and Pen yr Ergyd Spit*. Report to Ceredigion Council. Posford Haskoning, Cardiff.

Site 84 Ynyslas

Dunes occur at the northern end of a large spit system which extends northwards from Borth towards the mouth of the Afon Dyfi (River Dovey) estuary. Landward recession of the spit has exposed back barrier deposits, including freshwater peat with *in situ* tree stumps, on the foreshore north of Borth. The most seaward dunes consist of discontinuous ridges and hummock dunes, dissected by blowouts and small parabolic dunes. Behind lies an area of low, undulating dune topography which is partly transgressive over the back-barrier deposits.

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Site 85 Aberdovey to Tywyn

Blown sand forms a continuous belt along the coast between Aberdovey and the south side of a boulder clay promontory on which Tywyn is located. Further areas of blown sand occur on the north side of the boulder clay ridge. A further area of blown sand on the north side of Tywyn has been built upon, and another further north forms part of a low barrier system at the mouth of the Afon Dysynni (the lower part of which is now occupied by the Broadwater). 'High' dunes are now found only in two areas, along the Aberdovey Golf Club frontage, and just to the south of Tywyn. Between these two areas a shingle ridge overlies aeolian sand sheet and hummock dune deposits. To landwards of the shingle ridge and blown sand belt is an area of grazing marsh (Penllyn Marshes) which is underlain by back-barrier peat and estuarine silts. Peat with *in situ* tree stumps also outcrops on the adjoining foreshore, indicating long-term retreat of the barrier. The dune frontage at Tywyn is protected by rock armour, and rock has also been placed along certain areas of the frontage between the Penllyn drainage outfall and the northern end of Aberdovey Golf Club. The Aberdovey Golf Club frontage has experience periodic erosion at least since the 1980's, and a variety of protection and restoration measures have been employed, including brushwood fencing, timber revetment and nourishment of low points in the frontal dune ridge using sand dredged from Aberdovey harbour.

<u>References and sources of further information</u>

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Site 86 Mawddach Estuary

86a Fairbourne spit

A large gravel and sand spit complex extends across the Mawddach estuary northwards from Fairbourne. Much of the spit consists of gravel, but recurves at the northern end are predominantly sandy and backed by dunes. The main source of coarser sediment is probably the large gravel fans at Llwyngwril to the south, but the sand is probably mainly derived from offshore sources and partly from the river. The Mawddach estuary is predominantly sandy and, like the Dovey estuary, has acted as a long-term sink for sandy sediment. A photograph in Steers (1964) shows areas of both vegetated sand un-vegetated, mobile dunes.

<u>Reference and source of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Steers, J.A. (1964) *The Coastline of England and Wales*. Second Edition. Cambridge University Press, Cambridge, 750 pp.

86b Barmouth

Blown sand forms a narrow (<400 m wide) foreland adjacent to a fossil cliffline at Barmouth, on the north side of the Mawddach estuary. For a large part of the twentieth century the beach at Barmouth suffered from erosion, and a variety of coastal defences have been constructed to deal with the problem. However, since the construction of a new breakwater south of the lifeboat station there has been major sand accretion in front of the sea walls and groynes, including growth of new sand dunes. The process has been aided by onshore dumping of dredged sand from the harbour. Formerly degraded dunes at Ynys y Brawd have been planted with marram. However, dune development, aided by the spread of marram, has been so successful in recent years that concerns have been expressed in some quarters at the loss of sea view from the promenade and a potential threat to the recently acquired EU Blue Flag status of Barmouth beach.

Reference and source of further information

Boardman, H.W. (1923-4) Coast erosion and its effects and problems at Barmouth. *Proceedings of the Institute of Mechanical and Civil Engineers* **50**.

Site 87 Morfa Dyffryn and Llandanwg

87a Morfa Dyffryn

Morfa Dyffryn is a cuspate feature formed in front of an old cliff line. It consists of an extensive sand flat which is fringed by dunes up to 12 m high. The feature formed as a tombolo ridge between the mainland shore near Dyffryn and an outlier of glacial till which forms the core of Shell Island. The boulder clay cliffs at Shell Island are eroding and have supplied sediment to form a spit (Bar Newydd) which extends into the southern side of the estuary of the River Artro. Behind the dune-capped barrier and Shell Island lies a low-lying area of blown sand which has been levelled to create the RAF Llanbedr airfield. The dunes on the landward side of the main system are well vegetated with marram except where visitor pressure is particularly heavy, but the more seaward dunes have suffered significant marine erosion in recent decades, especially at the southern end and in areas closest to the holiday accommodation around Llanenddwyn. Several control measures have been implemented, including timber revetments and dumping of construction waste, with limited effect.

References and sources of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Pye, K. & Saye, S.E. (2005) *The Geomorphological Response of Welsh Sand Dunes to Sea Level Rise over the Next 100 Years and the Management Implications for SAC and SSSI Sites*. CCW Contractor Report No. 670, Contract FC-7302271, 47pp plus appendices.

87b Llandanwg

The River Artro enters the sea through a narrow channel which separates the Llandanwg barrier spit from the Bar Newydd spit. The spit is capped by dunes up to 6 m high and provides protection for the village of Llanbedr and the Artro Valley. The dunes have been eroding on their seaward side for many years. A thirteenth century church located midway along the spit is founded on, and surrounded by, sand dunes which are now only 20 to 30 m wide in places. Severe damage was caused by high tides and south-westerly winds in early February 2002. Sand stabilization methods have since been employed for several years by the Llandanwg Sand Dunes Protection Group, including chestnut fencing, planting of used Christmas trees, and marram planting. Hundreds of tons of sand were imported to the site from the south side of the river in 2003. However, much of the seaward side of the dunes still consists of bare sand, and periodic storm erosion is exacerbated by visitor pressure during the summer months. Erosion also occurs on the landward side of the southern part of the dunes due to undercutting by the River Artro.

Site 88 Dwyryd-Glaslyn Estuary

88a Morfa Harlech

Morfa Harlech is a broadly triangular shaped foreland, capped by dunes on its seaward side, which abuts an old cliff line cut into Cambrian rocks. The main dunes form a barrier spit system with several recurves which extends into the Glaslyn estuary, but transgressive dunes and sand sheets have extended landwards, partly burying the back-barrier deposits, which are now largely reclaimed. In the 1940’s the dunes generally had a cover of marram vegetation but numerous blowouts and small parabolic dunes were present in the frontal dune ridge and further inland. Considerable efforts have been made since the 1970’s to stabilise the dunes using fencing, boardwalks and marram planting, but a considerable number of blowouts remain active and visitor pressure remains a problem around the most popular beach access points at the southern end of the system. The dunes closest to Harlech Castle, which include the Royal St. David’s Golf Club, are generally well vegetated. Dunes facing the South Bank are periodically subject to erosion as a result of migration of the Afon Glaslyn channel.

<u>References and sources of further information</u>

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Pye, K. & Saye, S.E. (2005) *The Geomorphological Response of Welsh Sand Dunes to Sea Level Rise over the Next 100 Years and the Management Implications for SAC and SSSI Sites*. CCW Contractor Report No. 670, Contract FC-7302271, 47 pp plus appendices.

88b Morfa Bychan

The dune system is located on the northern side of the Dwyryd - Glaslyn estuary between Criccieth and Porthmadog. Blown sand extends almost 2 km from the shoreline but much is now built on. The modern dunes are *c*. 150 to 200 m wide and *c*. 350 m of frontage is protected by rock revetment to reduce erosion caused by northward movement of the Afon Glaslyn channel. The dunes are prone to significant pressure from visitors.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 89 Morfa Abererch

Dunes act as the primary defence against flooding for the low-lying hinterland of Morfa Abererch and the flood plain of the Afon Erch, which includes the Cambrian Coast railway line and the Glan y Don Industrial Estate. The dunes form a capping to a barrier beach which connects the east side of Pwlheli Harbour with a rock outcrop at Pen-ychain. Sediment transport along the Abererch frontage is generally from east to west. The dunes are typically low (<4 m) and narrow (<50 m wide). Visitor pressure is significant during the summer months. A storm in November 2000 caused severe marine erosion. Subsequent repairs included importation of sand from outside and erection of a line of zig-zag chestnut paling dune fencing to trap blown sand. Further proposals by the Environment Agency Wales include further protection of a 400 m length of dune frontage using sheet piling buried by imported shingle.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 90 Pwllheli and Traeth Crugan

Dunes fringe most of the shore between Carreg yr Imbill and Carreg y Defaid, including Pwlheli South Beach and most of the length of Traeth Crugan, with the exception of the extreme western end of Traeth Crugan where an earth embankment provides the primary flood defence. The dune system is effectively a tombolo barrier type system. Landward of the dunes the land level is generally low, and the dunes provide the primary flood defence for a significant part of Pwllheli town, Pwllheli Golf Club, and agricultural land to the west. There is very little, if any, natural supply of sediment to the western end of Traeth Crugan at the present day, resulting in beach erosion for most of this century, but especially since the 1960's. However, continuing littoral drift from west to east within the bay has encouraged seawards progradation and vertical growth of the dunes at the eastern end of Traeth Crugan and along Pwllheli South Beach since the 1950's. The dune frontage along much of the southern and central part of Traeth Crugan is now protected by a rock armour revetment, and the beach has been recharged with sediment dredged from Pwllheli harbour in the last few years. Apart from a short length of sea wall near Carreg yr Imbill, the dunes at the eastern end of the system are unprotected. The dune belt in this area is relatively wide (100 m) and high (10 m), and the backshore receives sufficient sand to provide stability for the dune toe. Further west, at South Beach, the dunes are protected by a masonry wall which has been buried by dune sand. Sand blowing onto the esplanade has been a problem in this area, but new sand trapping measures have been employed as part of a recent esplanade regeneration scheme.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 91 Abersoch

91a The Warren, Abersoch

Abersoch has two beaches, separated by the rocky headland of Penbennar, which form sub-compartments of the St Tudwal's Road bay. Bay-fringing dune systems occur behind both beaches. The dunes behind the North Abersoch beach (The Warren) are <100 m wide and suffer from recreational pressure and some protection for the dune toe against wave erosion has been provided by dumping of rubble to provide an ad-hoc revetment.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

91b Morfa Gors

Between Abersoch and Machroes the dunes are also subject to heavy visitor pressure and inland sand blowing is a significant problem. The maximum width of dunes is *c*. 250 m, and a significant area forms part of Abersoch Golf Club. Part of the dune toe is protected by rock revetment and groynes.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 92 Tai Morfa

An area of cliff top dunes occurs above the low land-slipped cliffs at the eastern end of Porth Neigwl (Hell's Mouth) bay. The dunes receive little sand from the beach at the present day and are largely vegetated. A smaller area of cliff top dunes also occurs inland from Porth Ceriad further to the east.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Cell 10 Bardsey Sound to Great Orme's Head

General reference and source of further information

Welsby, J. & Motyka, J.M. (1989) *A Macro Review of the Coastline of England and Wales. Volume 7. River Wye to the Great Orme, including Anglesey*. Report SR 206, HR Wallingford, Wallingford, 110 pp plus bibliography and figures.

Site 93 Morfa Dinlle

The dunes at Morfa Dinlle form a capping on a 1.5 km long multiple ridge shingle and sand spit system which extends in a SW-NE direction from the Lleyn Peninsula towards the Menai Strait. Some blown sand has also transgressed eastwards over the back-barrier deposits adjoining Foryd Bay. This area has been largely levelled during the construction of the airfield at Caernarfon Airport. Dunes are widest (600 m) and highest at the northern end of the system.

References and sources of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Pye, K. & Saye, S.E. (2005) *The Geomorphological Response of Welsh Sand Dunes to Sea Level Rise over the Next 100 Years and the Management Implications for SAC and SSSI Sites*. CCW Contractor Report No. 670, Contract FC-7302271, 47 pp plus appendices.

Site 94 Newborough Warren

At Newborough Warren southwesterly winds have blown sand inland from two main beaches (Malltraeth Bay and Llanddwyn Bay) which are separated by a rocky promontory (Llanddwyn Island). The rock ridge continues through the dune system but is now largely covered by coniferous plantations (Newborough Forest). The dunes behind Malltraeth Beach project into the southern part of the River Cefni estuary, which is fringed by saltmarsh on its eastern side. A dune-capped sand and shingle barrier spit also extends eastwards from Llanddwyn Bay into the Menai Strait at Abermenai Point. Blown sand extends up to 4 km inland from the present shore. Much of the sand incursion appears to have occurred during the thirteenth and fourteenth centuries, as in other parts of Wales and England. In the western part of the site the dunes are largely planted with conifers, but in the east grazed dune grassland is dominant. In the 1950's over 75% of the area was covered by mobile dunes and slacks, but at the time of the Sand Dune Survey of England and Wales in 1991 only about 6% of the site was classified as mobile and open. Growth of the coniferous plantations may have contributed to a fall in the groundwater table and a drying of the slacks during the 1990's, although climatic factors have probably also played a role. The frontal dunes have traditionally suffered from high visitor pressure, especially around beach access points, but management measures in the last 20 years have controlled this problem. The dune frontage along much of Malltraeth Bay continues to erode due to a negative sediment budget, but significant sections of the beach and frontal dunes in Llanddwyn Bay have experienced accretion in recent years. The erosion/accretion status of the backshore and frontal dunes is closely linked to changes in the morphology and position of banks and runnels on the lower foreshore and in the nearshore zone.

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Pye, K. & Saye, S.E. (2005) *The Geomorphological Response of Welsh Sand Dunes to Sea Level Rise over the Next 100 Years and the Management Implications for SAC and SSSI Sites*. CCW Contractor Report No. 670, Contract FC-7302271, 47 pp plus appendices.

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Site 95 Porth Twyn-mawr

A small area of bay-fringing and transgressive, partly climbing dunes occurs inland of several closely-spaced pocket beaches between the rock headlands of Pen-y-Parc and Dinas Bach. The dunes have been affected by sand extraction in the past, creating wet slack areas. Although there is some stock grazing, visitor pressure is relatively low. The dunes have little coastal defence importance.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 96 Tywyn Aberffraw

The Aberffraw dunes represent a bay head barrier system which lies behind a 1 km long, wide sandy beach (Traeth Mawr). The north-western margin of the dunefield is defined by the Afon Ffraw, but along the southeastern margin dunes have begun to climb the adjoining slopes. The inland limit is defined by a shallow lake, Llyn Coron, formed by partial blocking of the Afon Ffraw by the migrating dunes. The bedrock geology in this part of Anglesey has a pronounced SW-NE strike which exerts a strong influence on both the general topography and the dunefield morphology. Well-vegetated foredunes and hummock dunes occur immediately behind the beach, but further inland a series of transgressive parabolic dunes occur upon, and adjacent to, low-lying deflational sand plains with low hummock dune topography. Ground penetrating radar studies and luminescence dating have established three major phases of sand deposition in the last 700 years, with initial sand invasion commencing around 1331 AD (Bailey *et al*., 2001). Analysis of air photographs indicated migration rates of the parabolic dunes between 1940 and 1993 of 0.0 to 3.6 m per annum, with an average of 1 m per annum. During the same period the foredune ridge moved seawards slightly due to accretion of new marine sand. The percentage of bare sand in the dunefield as a whole decreased from 28% in 1940 to 5% in 1982 and 6% in 1993 (Bailey & Bristow, 2004). Grazing pressure (from rabbits and ponies) is high in parts of the system, but visitor pressure is concentrated around access points and a number of main paths which traverse the dunes. The dune frontage is stable, with net vertical accretion of the frontal dunes in recent years. Some active blowouts and small parabolic dunes remain, although several have been stabilized using fencing, brashings and marram planting.

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Site 97 Tywyn Fferam and Tywyn Llyn

97a Tywyn Fferam
97b Tywyn Llyn

Bay fringing barrier dunes occur behind a 2 km long sandy beach (Traeth Llydan) south of Rhosneigr. The maximum width of the system is 300 m at its western end, where there are multiple ridges, becoming narrower to the south-east. Behind the barrier at the north-western end is an area of low-lying ground and the Llyn Maelog lake. Recreational pressure in the area is high, leading to some internal erosion. The Tywyn Llyn dunes provide some protection for a road, houses and a caravan site. Most of the dune frontage now shows net stability, although short sections have been protected by walls in the past. The frontage at Tywyn Fferam has also experienced erosion in the past, but shows overall net stability, despite heavy visitor pressure. Access is now controlled by fencing and boardwalk walkways.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 98 Tywyn Trewan

Dunes form a narrow fringe behind Traeth Cymyran and a belt up to 600 m wide behind the adjoining Traeth Crigyll, immediately north of Rhosneigr. The dunes form a significant component of the flood defences for an area of low-lying land which contains the strategically important RAF Valley airfield, part of which is developed on levelled windblown sand. The Afon Crigyll enters the sea at the southern end of Traeth Crigyll, and dunes have formed on a small spit along its western side. Along much of the frontage the dunes are stable or show slight net accretion, although those on the south side of Afon Crigyll show evidence of erosion. A concrete wall has been built along part of the frontage and fencing erected to trap sand and restrict visitor movements.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 99 Tywyn-gywyn

Dunes form a bay-fringing and partly climbing system in the south-eastern corner of Holyhead Bay, north of the mouth of the Afon Alaw. Fringing dunes occur along most of the frontage between the Penial Dowyn promontory and the river, but are widest at the southern end, where there are multiple shore-parallel ridges. Maximum dune height approaches 5 m. The system provides protection for an area of agricultural land and parts of the dunes themselves are used for stock grazing. The dune frontage is generally stable although there is some erosion in areas of high visitor pressure.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 100 Tywyn-mawr

A small single fringing dune ridge (Twyn-mawr) occurs behind the sandy beach at Porth Twyn Mawr, on the east side of Holyhead Bay. The width of the system varies from 10 to 50 m and the maximum dune height is <3 m. The dunes provide protection for agricultural land (pasture) behind. Visitor pressure is moderate, and fencing has been erected in places to control access. Regeneration of eroded areas has been undertaken using brashings and marram planting.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 101 Dulas Bay and Ligwy Bay

101a Dulas Bay

Small bay fringing dunes form a ridge along the backshore of Traeth yr Ora, which fronts Dulas Bay. The dunes are partly climbing, and separate the beach from the estuary of the Afon Goch (Traeth Dulas) to the west. Damage to the dune vegetation from visitor pressure and vehicles has been a problem but has been reducing by fencing and construction of posts around the dunes. The dunes have provided limited coastal defence for a small area of agricultural land.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

101b Ligwy Bay

Small bay fringing dunes also occur along the backshore of Traeth Ligwy, which fronts Ligwy Bay. The width of the dunes varies from 10 to 30 m and the maximum height is <3 m. The beaches and frontal dunes are subject to considerable visitor pressure. Fencing and old Christmas trees have been employed to restrict visitor movement and to trap sand. The dunes provide protection for some agricultural land and visitor car parks.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 102 Red Wharf Bay

Dunes form a fringe around the wide sandy beach of Red Wharf Bay (Traeth Coch). The dunes are generally narrow (<50 m) and low (<3 m) but are best developed on the southern side of the bay which is exposed to north-westerly and northerly winds. The dunes and beach experience heavy visitor pressure in the summer months. Fencing, walkways and car parks have been constructed to protect the vegetation. The dunes provide some degree of protection to agricultural land, saltmarsh, a road and a small number of buildings. No coastal defence works have been constructed.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Site 103 Conwy Bay

Conway Bay is partly sheltered from wave action and has acted as a long-term sediment sink. Sources of sediment include the River Conwy, which drains a significant part of the North Wales hills, offshore sources in the south-eastern Irish Sea, and drifted material from the Menai Strait.

103a Conwy Morfa

Conwy Morfa, located east of Penmaen-bach Point, consists of a sand and shingle beach, backed by an area of stabilised sand dunes, which ends in a spit at the mouth of the River Conwy estuary. The dune system can be classified as an estuarine spit system which has been widened by inland movement of transgressive dunes which have partially buried the back-barrier sediments. Parts of the inland margin of the dune system are built on and much of the remainder is used by Conwy Golf Club. The dunes have some coastal defence function for roads, a caravan park and the golf course. The frontage is largely eroding and there are some old defence works in an advanced state of disrepair. Fencing and marram planting has been undertaken in several areas to re-stabilise the sand.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

103b Deganwy and Llandudno

Blown sand fringes much of the eastern side of Conwy Bay and forms a separate tongue which extends inland from the east side of the Conwy estuary south of Deganwy. The dunes originated as bay and shore fringing dunes but have transgressed a considerable distance inland, now occurring partly as climbing and cliff top dunes. South of Great Orme's Head, sand has been transported across the narrow neck of low-lying land as far as Llandudno Bay. Most of the blown sand now lies beneath urban development, but dune topography is preserved near the shore between Deganwy and Llandudno West Shore, notably at North Wales Golf Club. The dune frontage facing Conwy Bay has experienced some erosion, especially on the more exposed Llandudno West Shore, although the dune frontage adjacent to the railway line is protected by defence works.

Reference and source of further information

Posford Duvivier Environment (1996) *The Role of Dune Management in Coastal Defence: An Environmental, Technical and Economic Evaluation*. Report No. A7699 prepared for the Countryside Council for Wales and The Welsh Office. Posford Duvivier Environment, Peterborough.

Cell 11 Great Orme's Head to The Solway Firth

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Site 104 Abergele to Point of Ayr

Dunes once formed a continuous barrier spit dune complex which extended westwards from Abergele to Point of Ayr, broken only by the outlet of the River Clwyd which has varied in position from time to time. Urban development, coast protection works and erosion have since broken the dune system into discrete sub-systems.

104a Kinmel Dunes

Eastward growth of the spit has been accompanied by narrowing and lowering at its western end, and two areas of blown sand now exist. To the east of Abergele, partially bare, active and vegetated fixed dunes occur on the seaward side of the railway, and provide limited protection to it. Further east, at the eastern end of Kinmel Bay (Foryd), the dune system consists of a relatively narrow (5 to 100 m) belt of dune-capped ridges and is partially protected by a rubble mound, walling and groynes. The dunes help to protect a caravan park and industrial buildings. Damage from visitor pressure is significant. The site is managed as a Local Nature Reserve.

Reference and source of further information

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104b Rhyl to Prestatyn

Blown sand forms a belt up to 1 km wide east of the River Clywd mouth, between Rhyl and Prestatyn. Much of this frontage is now developed for permanent and holiday residential purposes, and the coast has been protected with groynes and concrete walls for many years. Nevertheless, falling beach levels and erosion of the coast remains a problem in several areas. Modified dune topography remains at Rhyl Golf Course and behind Ffrith Beach. At the latter location the dune toe has been protected by rock armour, but storm erosion is continuing, with undermining and seaward sliding of the rock armour.

104c Gronant Dunes and The Warren, Talacre

The largest remaining part of the barrier spit dune system occurs between Prestatyn and Point of Ayr. The dunes consist of several ridges separated by wind slacks. The back-barrier area consists of reclaimed and active saltmarsh, broken into sections by sand and gravel ridges which reflect the eastern growth of the spit complex towards the River Dee estuary. The shore around the lighthouse at the Point of Air, which was built in the mid eighteenth century, has been subject to erosion for many decades, while the spit has continued to grow in an easterly direction. To the west of Point of Ayr, the dune frontage was subject to erosion throughout most of the period 1960 to 2000, due partly to marine processes, visitor pressure and sand extraction. However, a beach nourishment operation in 2003 raised beach levels and has brought a temporary halt to recession. Low points in the frontal dunes were also infilled to assist formation of a continuous barrier ridge. The nourishment scheme has increased the supply of sand to areas inland and has stimulated vegetation growth in many areas. The innermost parts of the blown sand/dune belt are generally well vegetated and stable, being occupied by Prestatyn Golf Club and several caravan parks. There is also housing and industrial development behind the dune system, including the BHP Billiton gas terminal. In the central and western parts of the system the dune belt is 200 to 500 m wide but in the west is much narrower (50 to 100 m). Dune protection works have included improvements to pedestrian access, fencing and marram planting.

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Site 105 Wirral Peninsula

105a West Kirby to Leasowe

Dunes extend in an arc from West Kirby at the eastern entrance to the Dee estuary to Leasowe on the mid north Wirral coast. The dunes provide a natural flood defence for low-lying areas inland of Hoylake, Leasowe and Wallasey. The remains of a 1 km wide former tidal channel separate this dune system from the Leasowe to New Brighton dunes. This channel, adjacent to Leasowe lighthouse, may at one time have been connected with the Inner Mersey estuary via The Floats between Seacombe and Birkenhead; a small river draining the central part of the north Wirral almost certainly drained into it. The channel and adjoining lowlands became infilled with silts and peat during the mid to later Holocene. At this time a continuous system of fringing dunes may have developed along the North Wirral coast, although it must have remained narrow and low in the Leasowe area. Erosion has since removed any traces of dunes in this area, and recession of the adjoining beaches and dunes has exposed back-barrier peat and silt deposits on the foreshore, notably between Dove Point and Leasowe. The West Kirby to Leasowe dune system is anchored by the rock outcrop at Hilbre Point, and the blown sand belt attains its maximum width (>1.5 km) in this area. The dune frontage between Hoylake and Wallasey is now protected by an embankment, but a significant section between Wallasey and the New Brighton promenade is unprotected. Sections of the frontage between West Kirby and Hoylake are also unprotected and are slowly accreting seawards. There is also a small area of embryo dunes in Leasowe Bay, seawards of coast defences, protected by inshore breakwaters. Some 70% of the remaining dune habitat lies within golf courses (the Royal Liverpool Golf Club and Hoylake Golf Club). Dune management measures have included fencing, marram planting and tree planting. At West Kirby and Hoylake accumulation of blown sand on the promenade and in adjoining properties is a continuing problem which reportedly requires an annual expenditure of at least £70,000 in terms of removal and clean-up costs.

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105b Leasowe to New Brighton

The width of the Leasowe to New Brighton blown sand belt generally increases to towards the east and attains a maximum width of *c*. 1.5 km near Wallasey. The land behind the dunes in this area is low-lying, particularly at Bidston Moss and Wallasey Pool (which today comprise the West and East Floats of Birkenhead Docks). These areas are potentially at risk from tidal flooding. Around New Brighton the blown sand has climbed over low hills composed on New Red Sandstone and glacial till. There is now relatively little supply of wind blown sand over the new embankment to the dunes, which are generally well vegetated except in areas of heavy visitor pressure. Large areas are now occupied by golf courses (Leasowe Golf Club, Warren Golf Club and Wallasey Golf Club).

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Site 106 Sefton Coast

106a Seaforth to Hightown

Blown sand extends over a distance of >10 km and up to 2 km inland between Bootle and Hightown along the eastern shore of the Outer Mersey estuary. However, much of the more inland sand has been levelled and built upon or is used for agricultural purposes. Active and vegetated dunes are restricted to a coastal strip between Seaforth container terminal and the south side of the River Alt at Hightown. The best developed areas of dunes occur at Hightown itself, although the frontal dunes in this area are eroding. The coastal frontage at Crosby and Blundellsands is now protected by a sea wall, and there is little aeolian accumulation. Further south, at Waterloo and Seaforth, accumulation of sand on the backshore in the past 20 to 30 years has favoured the development of new dunes in front, on top and behind the promenade, and blowing sand presents a periodic problem for properties at the landward margin of the dunes. Most of the immediate hinterland in this area lies above present storm surge level, but the dunes between the River Alt and Hightown are important to the flood defence of low-lying agricultural areas in the River Alt valley and adjoining areas of the West Lancashire Plain behind Formby.

106b Hightown to Marshside

Blown sand forms a continuous belt extending from the River Alt at Hightown to Marshside on the southern side of the Ribble estuary. Actively forming dunes occur along most of this frontage. Between Birkdale and Marshside the dunes are protected by a concrete promenade, and large areas have been levelled for urban development in and around Southport. However, sand blowing along this frontage still occurs and small vegetated dunes are actively developing in front, on top, or behind the promenade and coastal road. Frontal dune accretion occurs between the River Alt mouth and just south of Formby Point, and from the Ainsdale/Southport northwards, but the frontal dunes between Formby Point and the Ainsdale/Southport boundary have been eroding for the past century. The blown sand belt reaches a maximum of >4 km at Formby Point, although the belt of high dunes (up to 20 m) is <2 km wide. The dunes protect a very large area of west Lancashire and north Merseyside from tidal inundation. The dunes are of major recreational and nature conservation importance, containing several internally-renowned golf courses (including Royal Birkdale Golf Club) and having numerous national and international nature conservation designations. Prior to the late 1970's the dunes were in a fairly degraded condition, chiefly the result of visitor pressure, military activities and sand extraction. Since 1978 strong emphasis has been placed on dune management and there has been widespread recovery of the dune vegetation.

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Site 107 Fylde Coast

107a Lytham to Blackpool

Dunes formerly extended along the shoreline of the southern Fylde from Lytham on the north shore of the Ribble estuary to Blackpool. Much of the blown sand area is now built upon or has been topographically modified to create Blackpool Airport and the Royal Lytham and St. Annes Golf Club courses. However, vegetated and partially vegetated dunes remain near the shore between Blackpool South Shore and St. Annes. Sand has been extracted from the foreshore at Lytham for many years and has been stockpiled on the backshore, creating additional sources of sand for aeolian transport. The dunes protect a low-lying area on Lytham Moss from marine flooding.

107b Fleetwood to Pilling

Dunes once formed a continuous belt across the northern Fylde Peninsula at Fleetwood with a further continuous belt on the eastern side of the River Wyre estuary between Knott End-on-Sea and Pilling Sands on the south-western shore of Morecambe Bay. Much of the blown sand at Fleetwood is now built upon and protected by sea walls, although an area of modified dune topography remains at Fleetwood Golf Course near Rossall Point and at Knott End Golf Club. Some dunes also remain to the east of Knott End-on-Sea, although the shore facing Preesall Sands is now protected by rock revetment and/or a sea wall, and there is very little modern day transport of blown sand to the dunes. The Fleetwood dune sub-system is best considered as a bay-fringing/ transgressive system, while the Knott End to Pilling sub-system is best considered as a barrier-spit dune system which provides partial flood protection for the low-lying land around Pilling Moss. It is likely that the Fleetwood system formerly extended southwards along the open coast to Bispham, and dune remnants are found in the area of Blackpool North Shore Golf Club and at Cleveleys.

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Site 108 Walney Island

108a South End Haws
108b North End Haws

Walney Island consists of a core of glacial till against which late Holocene marine deposits have accumulated. The western side of the island is exposed to moderate wave action and sediments have been eroded from the central part of the island and moved by littoral drift both to the north and to the south. Small dune-capped spit complexes have developed at each end of the island (South End Haws and North End Haws). In the lee of these spits, and on the margins of the channel between Walney Island and Barrow-in-Furness, areas of saltmarsh have formed. The dune-spit complexes act as important wave breaks and have been designated as nature reserves.

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Site 109 Duddon Estuary

The River Duddon estuary is a large SW-NE trending funnel-shaped estuary which has two dune complexes at its mouth (Haverigg Haws on the north side and North End Haws on Walney Island on the south side) and three estuarine fringing dune systems in the outer part of the estuary (Sandscale Haws and Askam in Furness to Dunnerholme on the south side and Hodbarrow on the north side).

109a Sandscale Haws

Sandscale Haws has formed at the eastern margin of a large sand bank (Duddon Sands) and protrudes into the estuary as a large 'foreland'. The dunes overlie and partly lie seawards of older raised beach deposits. Much of the area is now a National Nature Reserve.

109b Askam in Furness to Dunnerholme

The Askam in Furness to Dunnerholme dunes form an estuarine shore fringing system which rests on raised beach deposits linking two outcrops of bedrock. Similar raised beach deposits occur along much of both sides of the estuary, which has experienced glacio-isostatic uplift in the later Holocene period.

109c Hodbarrow

Estuarine shore fringing dunes form a narrow belt (100 to 200 m wide) between Millom and Hodbarrow Point. The dunes mainly rest on raised beach deposits which link a number of low bedrock outcrops.

109d Haverigg Haws and Kirksanton Haws

Haverigg Haws dune system has the plan form of an estuarine barrier spit dune complex but it is more appropriately considered as a composite open coast-estuarine shore fringing type, since there are no back-barrier sediments on the landward side. The dunes on the open coast north of Haverigg Point form a fringe which varies in width from <50 m to *c*. 500 m. The dunes are mainly hummock types and degraded foredune ridges but the landward margin of the sand belt is transgressive in places. On the estuarine shore between Haverigg Point and the Haverigg lifeboat station the degraded foredune ridges and hummock dunes form a belt 150 to 200 m wide.

Site 110 Esk Estuary

110a Eskmeals Dunes

The Eskmeals Dunes overlie raised beach deposits which form the southernmost of a pair of barrier spits at the mouth of the River Esk estuary. The dunes extend over a linear distance of *c*. 5 km and attain a maximum width of *c*. 1 km. To the east is a low-lying area including grazing lands and the valley of the River Esk. The dunes have been used as a Ministry of Defence firing range for many years.

110b Drigg Dunes

On the northern side of the Esk estuary dunes also overlie raised beach deposits which represent a barrier spit which has grown southwards from Drigg. The dune frontage is *c*. 7 km long and attains a maximum width of >1 km at the southern end. North of Drigg the dunes essentially form an open coast fringing system which is separated into two parts by coastal protection works and urban development at Seascale. South of Drigg the dunes form a barrier system which protects saltmarsh, intertidal flats and reclaimed grazing land along the lower course of the River Irt.

Site 111 Seascale to Braystones

Dunes form a narrow barrier spit system (<50 m wide) extending parallel to the coast over a distance of *c*. 3 km in front of Sellafield frontage and the BNFL Sellafield nuclear reprocessing facility. The barrier diverts the mouth of the River Ehen more than 2 km to the south, and provides an important flood defence for the lower Ehen valley. The river now crosses the beach to the sea opposite the BNFL facility.

Site 112 Maryport to Grune Point

Narrow (<50 m wide) fringing dunes overlie raised beach deposits along most of the coast between Maryport and Grune Point. At several points the dunes are little wider, notably at Maryport Golf Club (2 km north of Maryport), Mawbray Bank to the north of Dubmill Point, and Blitterlees Bank to the south of Silloth (which is utilised by Silloth on Solway Golf Club). Small areas of blown sand also occur on top of raised beach deposits on the SW-NE trending barrier spit complex of Grune on the southern side of Moricambe Bay.

Tables

Table 3.1 Location and dimensions of coastal sand dune systems in England and Wales. Data sources: (i) Dargie (1995); (ii) Posford Duvivier (1996)

DUNE SYSTEM					DIMENSIONS			
SUB-CELL	SITE	SITE NAME	SUB-SITE NAME	GRID REFERENCE	AREA (km2)	LENGTH (km)	MINIMUM WIDTH (km)	MAXIMUM WIDTH (km)
1a	1	Cocklawburn to Goswick		NU 025488 NU 075436	1.6 (i)	6.83	0.025	0.600
1a	2	Holy Island		NU 092438 NU 139437	2.07 (i)	5.15	0.100	0.725
1a	3a	Ross Links and Budle Bay	Ross Links and Budle Bay west	NU 131405 NU 144360	3.48 (inc. Budle Bay) (i)	5.28	0.100	1.000
1a	3b	Ross Links and Budle Bay	Budle Bay east	NU 153353 NU 170359	3.48 (inc. Ross Links) (i)	2.00	0.025	0.550
1a	4	Bamburgh to Seahouses		NU 179354 NU 214324	0.92 (i)	5.08	0.050	0.325
1a	5	Annstead Dunes		NU 225318 NU 232295	0.16 (i)	2.35	0.025	0.175
1a	6	Beadnell Bay		NU 235289 NU 240259	0.62 (i)	4.98	0.025	0.300
1a	7	Embleton Bay		NU 245240 NU 253223	0.61 (i)	2.43	0.025	0.150
1a	8a+b	Sugar Sands to Seaton Point	Sugar Sands and Howdiemont Sands	NU 259163 NU 267155	0.09 (i)	1.03	0.020	0.050
1a	8c	Sugar Sands to Seaton Point	Boulmer	NU 266141 NU 262126		2.00	0.005	0.150
1a	9a	Alnmouth Bay	Alnmouth	NU 247103 NU 257113	0.05 (i)	1.40	0.025	0.150
1a	9b	Alnmouth Bay	Buston Links	NU 247102 NU 252080	0.35 (i)	2.38	0.050	0.300
1a	9c	Alnmouth Bay	Birling Links	NU 252080 NU 267049	0.76 (i)	3.10	0.050	0.250
1a	10	Amble to Hauxley		NU 273047 NU 287024	0.25 (i)	2.60	0.050	0.150
1a	11	Druridge Bay		NU 287021 NZ 296935	1.35 (i)	10.30	0.025	0.225
1a	12	Snab Point to Beacon Point		NZ 303926 NZ 312892	0.19 (Lynemouth only) (i)	2.05	0.050	0.200
1a	13	Beacon Point to Newbiggin Point		NZ 317892 NZ 318879	0.69 (inc. Lyne Sands) (i)	0.85	0.010	0.025
1a	14	Newbiggin Bay		NZ 308865 NZ 313880		0.35	0.005	0.020
1a	15a	North Seaton to North Blyth	North Seaton	NZ 305856 NZ 301854	0.03 (i)	0.40	0.050	0.300
1a	15b	North Seaton to North Blyth	Cambois to North Blyth	NZ 306842 NZ 313829	0.16 (i)	1.55	0.050	0.100
1a	16	South Blyth to Seaton Sluice		NZ 320790 NZ 337768	0.37 (i)	4.00	0.005	0.125
1a	17c	St Mary's Island to Tynemouth	Long Sands	NZ 349744 NZ 354730		0.88	0.025	0.075
1b	18	South Shields		NZ 366683 NZ 378671		0.78	0.005	0.200
1b	19	Whitburn Bay		NZ 406602 NZ 409613		0.40	0.005	0.015
1c	20	Hart Warren Dunes		NZ 482376 NZ 520346	0.35 (i)	3.90	0.025	0.150
1c	21a	Hartlepool to Marske-by-the-Sea	Carr House Sands and Seaton Dunes	NZ 518320 NZ 535276	0.77 (i)	2.88	0.025	0.175
1c	21b	Hartlepool to Marske-by-the-Sea	Coatham Sands	NZ 557277 NZ 607252	2.17 (inc. Redcar and Markse Sands) (i)	4.80	0.025	0.575
1c	21c	Hartlepool to Marske-by-the-Sea	Redcar to Marske-by-the-Sea	NZ 607252 NZ 633231	2.17 (inc. South Gare & Coatham Sands) (i)	3.00	0.005	0.025
2a	22	Spurn Peninsula		TA 398107 TA 422141	0.64 (i)	5.00	0.025	0.275
2b	23	Cleethorpes and Humberston		TA 310085 TA 340046	0.25 (i)	3.53	0.010	0.090
2b	24	Horse Shoe Point		TA 378026 TA 382019	8.59 (inc. Somercotes Haven to Mablethorpe) (i)	0.93	0.020	0.050
2c	25	Somercotes Haven to Mablethorpe		TA 408008 TF 515841	8.59 (inc. Horse Shoe Point) (i)	18.13	0.050	0.450
2c	26	Sutton on Sea to Chapel St Leonards		TF 520828 TF 574687	0.96 (i)	11.93	0.010	0.100
2c	27	Seathorne to Gibraltar Point		TF 574673 TF 562577	2.8 (i)	8.20	0.020	1.000
3a	28	Old Hunstanton to Holme Dunes		TF 686430 TF 727448	1.34 (i)	5.48	0.025	0.500
3a	29	Brancaster Bay		TF 738452 TF 796455	1.08 (i)	5.60	0.025	0.300
3a	30	Scolt Head Island		TF 788467 TF 848460	0.8 (i)	6.83	0.025	0.200
3a	31	Holkham Bay		TF 848457 TF 914456	2.66 (i)	7.20	0.075	0.500
3a	32	Wells-next-the-Sea to Morston		TF 918450 TF 000448		5.50	0.005	0.175
3a	33	Blakeney Point		TF 990458 TG 045455	1.09 (i)	1.93	0.050	0.500
3b	34a	Northeast Norfolk Coast	Happisburgh to Winterton Ness	TG 393303 TG 484220	3.02 (inc.Winterton-ness to Scratby) (i)	12.50	0.025	0.125
3b	34b	Northeast Norfolk Coast	Winterton Ness to Hemsby	TG 484220 TG 514156	3.02 (inc. Happisburgh to Horsey) (i)	7.00	0.010	0.450
3b	34c	Northeast Norfolk Coast	Caister-on-Sea to Great Yarmouth	TG 523135 TG 531078	1.37 (i)	5.68	0.025	0.300
3b	35a	Suffolk Coast	Gunton Denes and Lowestoft Denes	TM 546968 TM 546921		1.05	0.010	0.100
3b	35b	Suffolk Coast	Kessingland	TM 536852 TM 533833		1.80	0.010	0.400
3b	35c	Suffolk Coast	Covehithe Broad	TM 523810 TM 521805		0.40	0.005	0.020
3b	35d	Suffolk Coast	Southwold	TM 509756 TM 506746		1.00	0.010	0.100
3b	35e	Suffolk Coast	Walberswick	TM 505747 TM 501744		0.04	0.010	0.025
3b	35f	Suffolk Coast	Minsmere to Sizewell	TM 478673 TM 478623		5.00	0.005	0.050
3b	35g	Suffolk Coast	Thorpeness	TM 475601 TM 470587		1.50	0.010	0.080
4b	36	Sandwich Bay		TR 351622 TR 362581	4.81 (i)	8.20	0.050	0.750
4c	37	Romney Sands		TR 082222 TR 083236	0.77 (i)	1.25	0.020	0.060
4c	38	Camber Sands		TQ 947185 TQ 972184	1.01 (i)	2.08	0.025	0.200
4d	39b	Littlehampton	East Beach	TQ 028013 TQ 029013		0.10	0.005	0.020
4d	39b	Littlehampton	West Beach	TQ 015010 TQ 028011	0.16 (i)	1.20	0.050	0.100
5a	40	East Head, West Wittering		SZ 765984 SZ 771993	0.21 (i)	1.00	0.075	0.300
5a	41	Sinah Common, Hayling Island		SZ 689997 SZ 695989	0.93 (i)	1.50	0.020	0.100
5f	42a	Poole Harbour Entrance	Sandbanks	SZ 050885 SZ 038870		2.00	0.020	0.700
5f	42b	Poole Harbour Entrance	Studland	SZ 036868 SZ 038828	2.04 (i)	3.63	0.010	0.375
6a	43a	Exe Estuary	The Maer, Exmouth	SY 010799 SY 003801		0.80	0.005	0.050
6b	43b	Exe Estuary	Dawlish Warren	SX 980784 SX 993802	0.46 (i)	1.75	0.025	0.400
6c	44	Bigbury Bay		SX 676414 SX 635478		1.80	0.010	0.150
6d	45	Par Sands		SX 078533 SX 087531	0.09 (i)	0.88	0.050	0.075
6d	46	Kennack Towans		SW 734165 SW 739168	0.12 (i)	0.48	0.025	0.100
6e	47	The Towans, Mullion		SW 658208 SW 666198	0.46 (i)	0.45	0.050	0.600
6e	48	Praa Sands		SW 575282 SW 587274		0.55	0.050	0.125
6e	49	Marazion		SW 482311 SW 517306	0.04 (i)	0.63	0.010	0.050
7a	50	Whitesand Bay		SW 355264 SW 360271	0.38 (i)	0.78	0.050	0.700
7a	51a	St Ives Bay	Lelant Towans	SW 539385 SW 552375	0.1 (i)	1.20	0.075	0.500
7a	51b	St Ives Bay	Hayle Towans, Upton Towans and Gwithian Towans	SW 549383 SW 583422	2.94 (i)	4.05	0.075	1.150
7a	51c	St Ives Bay	Godrevy Towans	SW 582423 SW 582427	0.76 (i)	0.55	0.525	1.025
7a	52	Porth Towan		SW 690480 SW 691483		0.18	0.025	0.125
7a	53	Perran Bay		SW 757544 SW 762581	5.42 (i)	3.20	0.700	1.800
7a	54	Holywell Bay		SW 764592 SW 767599	0.7 (i)	0.60	0.025	0.500
7a	55	Crantock Bay		SW 783607 SW 789611	0.2 (i)	0.85	0.025	0.200
7a	56	Fistral Bay		SW 793617 SW 800626	0.41 (i)	0.45	0.375	0.450
7a	57b	Berryl's Point to Trevose Head	Mawgan Porth	SW 849672 SW 848677		0.40	0.020	0.050
7a	57b	Berryl's Point to Trevose Head	Constantine Bay	SW 856743 SW 858752	0.76 (i)	0.83	0.050	0.775
7b	58b	Camel Estuary	Rock to Daymer Bay	SW 935751 SW 928776	0.96 (i)	1.75	0.025	0.375
7b	59	Widemouth Bay		SS 197016 SS 199026		0.45	0.010	0.050

Table 3.1 continued.

DUNE SYSTEM					DIMENSIONS			
SUB-CELL	**SITE**	**SITE NAME**	**SUB-SITE NAME**	**GRID REFERENCE**	**AREA (km2)**	**LENGTH (km)**	**MINIMUM WIDTH (km)**	**MAXIMUM WIDTH (km)**
7b	**60**	Bude		SS 202072 SS 206065		0.15	0.025	0.200
7c	**61a**	Taw Estuary	Northam Burrows	SS 437303 SS 446319	1.34 (i)	1.55	0.050	0.625
7c	**61b**	Taw Estuary	Instow Sands	SS 472308 SS 475319	0.32 (i)	0.68	0.025	0.075
7c	**61c**	Taw Estuary	Braunton Burrows	SS 446377 SS 466319	8.99 (i)	6.05	0.075	2.050
7c	**62**	Croyde Burrows		SS 435389 SS 435395	0.19 (i)	0.65	0.100	0.275
7c	**63**	Woolacombe Warren		SS 454424 SS 457436	0.46 (i)	2.60	0.025	0.175
7d	**64**	Berrow and Brean		ST 296586 ST 302487	1.77 (i)	7.00	0.050	0.600
7d	**65**	Weston Bay		ST 310582 ST 317614	0.05 (i)	0.95	0.125	0.500
7d	**66**	Sand Bay		ST 328632 ST 330660	0.22 (i)	2.30	0.015	0.075
8b	**67**	Merthyr-mawr Warren		SS 846770 SS 874766	3.42 (i) 3.61 (ii)	2.65	0.400	1.750
8b	**68a**	Swansea Bay	Kenfig Burrows	SS 779834 SS 790802	6.02 (i) 5.19 (ii)	3.25	1.000	2.275
8b	**68b**	Swansea Bay	Margam Burrows	SS 781833 SS 773847	1.01 (i) 0.98 (ii)	0.95	0.050	0.225
8b	**68c**	Swansea Bay	Baglan Burrows	SS 726927 SS 733907	0.78 (i) 0.63 (ii)	1.88	0.075	0.675
8b	**68d**	Swansea Bay	Crymlyn Burrows	SS 696926 SS 721928	1.18 (i) 0.58 (ii)	2.85	0.025	0.250
8b	**68e**	Swansea Bay	Black Pill Burrows	SS 622909 SS 643921	0.16 (i) 0.03 (ii)	1.75	0.005	0.025
8b	**69a**	Oxwich Bay	Pennard Burrows	SS 539879 SS 542875	0.87 (i)	0.93	1.000	1.450
8b	**69b**	Oxwich Bay	Penmaen Burrows	SS 535880 SS 539881	0.17 (i) 0.06 (ii)	0.35	0.075	0.150
8b	**69c**	Oxwich Bay	Nicholaston Burrows	SS 516877 SS 525878	0.17 (i) 0.20 (ii)	0.80	0.075	0.350
8b	**69d**	Oxwich Bay	Oxwich Burrows	SS 503863 SS 517876	0.76 (i) 0.53 (ii)	1.85	0.200	0.450
8b	**70**	Port-Eynon Bay		SS 469849 SS 481855	0.19 (i) 0.17 (ii)	0.98	0.050	0.200
8c	**71**	Rhossilli Bay		SS 404925 SS 414900	0.58 (ii)	2.60	0.075	1.300
8c	**72a**	Burry Holms to Whiteford Point	Broughton Burrows, Delvid Burrows and Hills Burrows	SS 416930 SS 430940	1.87 (ii)	1.03	0.100	0.175
8c	**72b**	Burry Holms to Whiteford Point	Whiteford Burrows	SS 430940 SS 449968		3.38	0.100	0.575
8c	**73**	Pembrey Burrows		SN 357064 SN 436002	5.92 [15.59 – inc. afforested dune] (i) 3.56 (ii)	12.20	0.010	2.450
8c	**74**	Laugharne Burrows and Pendine Burrows		SN 233080 SN 326081	6.03 (i) 7.61 (ii)	8.65	0.075	1.175
8c	**75**	The Burrows, Tenby		SS 122986 SS 131001	0.92 (i) 0.44 (ii)	1.53	0.075	0.325
8c	**76**	Lydstep Haven		SS 091978 SS 125983	0.23 (i)	0.10	0.025	0.100
8c	**77**	Manorbier Bay		SS 061974 SS 061976	0.10 (i)	0.25	0.025	0.075
8c	**78**	Freshwater East		SS 017975 SS 022981	0.17 (i) 0.16 (ii)	0.93	0.025	0.200
8c	**79**	Stackpole Warren		SR 990949 SR 976944	1.79 (i) 0.61 (ii)	1.75	0.050	0.700
8d	**80a**	Linney, Brownslade and Broomhill Burrows	Linney Burrows and Brownslade Burrows	SR 889971 SR 887988	2.53 (i) 2.13 (ii)	1.63	0.225	1.500
8d	**80b**	Linney, Brownslade and Broomhill Burrows	Gupton Burrows, Broomhill Burrows and Kilpaison Burrows	SR 885995 SR 882005	1.83 (i) 1.32 (ii)	1.05	0.050	1.875
8d	**81**	The Burrows, Whitesands Bay		SM 733267 SM 733270	0.28 (i)	0.60	0.050	0.650
9a	**82**	Newport Bay		SN 056400 SN 054406	0.20 (i) 0.08 (ii)	0.50	0.050	0.500
9a	**83a**	Teifi Estuary	Poppit Sands	SN 149488 SN 160484	0.11 (i) 0.02 (ii)	0.98	0.025	0.150
9a	**83b**	Teifi Estuary	Towyn Warren	SN 162493 SN 164485	0.30 (i) 0.04 (ii)	0.33	0.050	0.300
9a	**84**	Ynyslas		SN 608896 SN 608946	0.68 (i) 0.98 (ii)	2.18	0.100	0.750
9a	**85**	Aberdovey to Tywyn		SN 580999 SN 614959	1.11 (i) 0.81 (ii)	3.50	0.025	0.250
9a	**86a**	Mawddach Estuary	Fairbourne spit	SH 616150 SH 611142	0.155 (i) 0.05 (ii)	0.90	0.025	0.075
9a	**86b**	Mawddach Estuary	Barmouth	SH 599177 SH 613155		2.60	0.010	0.050
9a	**87**	Morfa Dyffryn		SH 579212 SH 551261	3.13 (i) 2.44 (ii)	5.28	0.025	1.000
9a	**88a**	Dwyryd-Glaslyn Estuary	Morfa Harlech	SH 572353 SH 574297	3.41 (i) 4.23 (ii)	7.50	0.050	1.150
9b	**88b**	Dwyryd-Glaslyn Estuary	Morfa Bychan	SH 524375 SH 554369	1.69 (i) 0.52 (ii)	3.25	0.050	0.475
9b	**89**	Morfa Abererch		SH 399358 SH 432354	0.45 (i) 0.17 (ii)	5.20	0.010	0.050
9b	**90**	Pwllheli and Traeth Crugan		SH 342327 SH 386342	0.22 (i) 0.17 (ii)	4.45	0.025	0.075
9b	**91a**	Abersoch	The Warren	SH 329303 SH 314284	0.05 (ii)	2.25	0.025	0.125
9b	**91b**	Abersoch	Morfa Gors	SH 313281 SH 318265	0.04 (ii)	1.75	0.015	0.050
9b	**92**	Tai Morfa		SH 281265 SH 291255	0.20 (i) 0.25 (ii)	1.40	0.025	0.350
10a	**93**	Morfa Dinlle		SH 432582 SH 440610	0.67 (i) 0.90 (ii)	3.05	0.025	0.700
10b	**94**	Newborough Warren		SH 386655 SH 443613	5.92 [12.57 – inc. afforested dune] (i) [13.79 inc. afforested dune] (ii)	9.65	0.050	3.250
10b	**95**	Porth Twyn-mawr		SH 365652 SH 370660	0.25 (i) 0.16 (ii)	0.75	0.050	0.450
10b	**96**	Tywyn Aberffraw		SH 353675 SH 369699	2.48 (i) 1.89 (ii)	0.85	1.750	2.550
10b	**97a**	Tywyn Fferam and Tywyn Llyn	Tywyn Fferam	SH 327719 SH 329715	0.15 (ii)	1.13	0.075	0.350
10b	**97b**	Tywyn Fferam and Tywyn Llyn	Tywyn Llyn	SH 321725 SH 325721	0.11 (ii)	0.53	0.075	0.400
10b	**98**	Tywyn Trewan		SH 301761 SH 320740	1.92 (i) 0.56 (ii)	2.73	0.075	0.575
10b	**99**	Tywyn-gywyn		SH 293818 SH 294811	0.17 (i) 0.18 (ii)	1.05	0.025	0.325
10b	**100**	Tywyn-mawr		SH 288839 SH 289836	0.05 (ii)	0.90	0.010	0.050
10b	**101a**	Dulas Bay and Lligwy Bay	Dulas Bay	SH 489887 SH 490885	0.04 (i) 0.03 (ii)	0.58	0.020	0.050
10b	**101b**	Dulas Bay and Lligwy Bay	Lligwy Bay	SH 493877 SH 499871	0.03 (i) 0.14 (ii)	0.70	0.010	0.050
10b	**102**	Red Wharf Bay		SH 561805 SH 573809	0.063 (i) 0.045 (ii)	1.93	0.010	0.050
10c	**103a**	Conwy Bay	Conwy Morfa	SH 753784 SH 774792	0.75 (i) inc. Deganwy 0.14 (ii)	2.43	0.025	0.100
10c	**103b**	Conwy Bay	Deganwy and Llandudno	SH 770821 SH 776796	0.025 (ii)	1.63	0.025	0.100
11a	**104a**	Abergele to Point of Ayr	Kinmel Dunes	SH 975801 SH 994810	0.11 (i) 0.05 (ii)	1.10	0.010	0.150
11a	**104b**	Abergele to Point of Ayr	Rhyl to Prestatyn	SJ 025824 SJ 057836	0.53 (i)	2.25	0.005	0.050
11a	**104c**	Abergele to Point of Ayr	Gronant Dunes and The Warren, Talacre	SJ 065840 SJ 130851	1.90 (i) 1.84 (ii)	6.50	0.025	0.400
11a	**105**	Wirral Peninsula		SJ 209867 SJ 310943	1.57 (i)	3.60	0.010	0.675
11b	**106a**	Sefton Coast	Seaforth to Hightown	SJ 310982 SD 295032	1.55 (i)	6.10	0.050	1.750
11b	**106b**	Sefton Coast	Hightown to Marshside	SD 290029 SD 340198	18.01 (i)	20.20	0.050	2.050
11b	**107a**	Fylde Coast	Lytham to Blackpool	SD 306360 SD 380274	0.57 (inc. Fleetwood) (i)	4.93	0.025	0.825
11b	**107b**	Fylde Coast	Fleetwood to Pilling	SD 311471 SD 314479	0.57 (inc. Lytham-Blackpool) (i)	3.63	0.005	0.525
11d	**108**	Walney Island		SD 233619 SD 181737	2.23 (i)	7.15	0.050	0.575
11d	**109a**	Duddon Estuary	Sandscale Haws	SD 185739 SD 190758	1.99 (i)	3.40	0.100	1.300
11d	**109b**	Duddon Estuary	Askam in Furness to Dunnerholme	SD 206775 SD 211797		2.20	0.025	0.250
11d	**109c**	Duddon Estuary	Hodbarrow	SD 193793 SD 181781		1.50	0.010	0.050
11d	**109d**	Duddon Estuary	Haverigg Haws and Kirksanton Haws	SD 131792 SD 161782	1.3 (i)	3.63	0.050	0.425
11d	**110a**	Esk Estuary	Eskmeals Dunes	SD 081912 SD 084959	2.27 (i)	1.70	0.150	0.725
11d	**110b**	Esk Estuary	Drigg Dunes	SD 071953 NY 038009	3.45 (i)	6.48	0.025	1.325
11d	**111**	Seascale to Braystones		NY 036013 NY 003056		3.10	0.010	0.050
11e	**112**	Maryport to Grune Point		NY 052386 NY 123560	3.77 (i)	14.43	0.010	0.650

Table 3.2 Morphological classification and frontal dune erosion/accretion status of dune systems in England and Wales

DUNE SYSTEM			DUNE SYSTEM MORPHOLOGY			DUNE MORPHOLOGICAL FEATURES									EROSION/ACCRETION STATUS OF FRONTAL DUNES					
SUB-CELL	SITE	SITE NAME	COASTAL SETTING	PREDOMINANT DUNE SYSTEM MORPHOLOGY	DUNE SYSTEM MORPHOLOGY SUB-CATEGORY	EMBRYO DUNES	FOREDUNE	MULTIPLE SHORE-PARALLEL RIDGES	HUMMOCKY	BLOWOUT IN FRONTAL DUNE	BLOWOUT IN HIND DUNE	PARABOLIC	ELONGATE PARABOLIC	SAND SHEET	EROSION (%)	ACCRETION (%)	STABLE (%)	PROTECTED (%)	EROSION & PROTECTION (%)	EROSION/ACCRETION STATUS
1a	**1**	Cocklawburn to Goswick	OPEN COAST	BARRIER SPIT	SINGLE		X	X	X	X	X			X	30	51	19	0	30	VARIABLE STATUS
1a	**2**	Holy Island	OPEN COAST	TOMBOLO			X	X	X	X	X				9	19	72	0	9	NET STABLE
1a	**3a**	Ross Links and Budle Bay west	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X	X		X				X	35	65	0	0	35	NET ACCRETION
1a	**3b**	Budle Bay east	ESTUARINE	FRINGING	CLIMBING	X	X			X					13	46	41	0	13	VARIABLE STATUS
1a	**4**	Bamburgh to Seahouses	OPEN COAST	FRINGING	NON-CLIMBING		X	X	X	X	X				27	7	66	0	27	NET STABLE
1a	**5**	Annstead Dunes	EMBAYMENT	FRINGING	NON-CLIMBING		X	X							15	0	85	0	15	NET STABLE
1a	**6**	Beadnell Bay	EMBAYMENT	FRINGING	NON-CLIMBING		X	X		X					64	9	27	0	64	NET MARINE EROSION
1a	**7**	Embleton Bay	EMBAYMENT	FRINGING	NON-CLIMBING	X	X								3	2	95	0	3	NET STABLE
1a	**8a+b**	Sugar Sands and Howdiemont Sands	EMBAYMENT	FRINGING	CLIMBING		X								49	39	12	0	49	VARIABLE STATUS
1a	**8c**	Boulmer	OPEN COAST	FRINGING	NON-CLIMBING		X								0	11	89	0	0	NET STABLE
1a	**9a**	Alnmouth	OPEN COAST	FRINGING	NON-CLIMBING		X								100	0	0	0	100	MARINE EROSION ONLY
1a	**9b**	Buston Links	OPEN COAST	BARRIER SPIT	SINGLE	X	X	X		X					7	11	82	0	7	NET STABLE
1a	**9c**	Birling Links	OPEN COAST	BARRIER SPIT	SINGLE	X	X	X							8	34	58	0	8	NET STABLE
1a	**10**	Amble to Hauxley	OPEN COAST	FRINGING	CLIMBING		X			X					60	0	40	0	60	NET MARINE EROSION
1a	**11**	Druridge Bay	EMBAYMENT	FRINGING	NON-CLIMBING		X	X		X					83	4	13	0	83	NET MARINE EROSION
1a	**12**	Snab Point to Beacon Point	OPEN COAST	FRINGING	CLIMBING		X		X	X	X				15	0	85	0	15	NET STABLE
1a	**13**	Beacon Point to Newbiggin Point	OPEN COAST	FRINGING	NON-CLIMBING		X								100	0	0	0	100	MARINE EROSION ONLY
1a	**14**	Newbiggin Bay	EMBAYMENT	FRINGING	CLIMBING		X								0	100	0	0	0	ACCRETION ONLY
1a	**15a**	North Seaton	ESTUARINE	BARRIER SPIT	SINGLE		X	X							0	100	0	0	0	ACCRETION ONLY
1a	**15b**	Cambois to North Blyth	OPEN COAST	FRINGING	NON-CLIMBING		X			X					87	0	13	0	87	NET MARINE EROSION
1a	**16**	South Blyth to Seaton Sluice	OPEN COAST	FRINGING	NON-CLIMBING	X	X			X					57	21	23	0	57	NET MARINE EROSION
1a	**17c**	Long Sands	EMBAYMENT	FRINGING	CLIMBING		X								100	0	0	0	100	MARINE EROSION ONLY
1b	**18**	South Shields	OPEN COAST	FRINGING	NON-CLIMBING	X	X		X	X					81	19	0	0	81	NET MARINE EROSION
1b	**19**	Whitburn Bay	EMBAYMENT	FRINGING	NON-CLIMBING		X								0	100	0	0	0	ACCRETION ONLY
1c	**20**	Hart Warren Dunes	OPEN COAST	FRINGING	CLIMBING	X	X	X		X					63	37	0	0	63	NET MARINE EROSION
1c	**21a**	Carr House Sands and Seaton Dunes	ESTUARINE	BARRIER SPIT	SINGLE	X	X			X					0	0	100	0	0	STABLE ONLY
1c	**21b**	Coatham Sands	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X	X		X	X				47	53	0	0	47	VARIABLE STATUS
1c	**21c**	Redcar to Marske-by-the-Sea	OPEN COAST	FRINGING	NON-CLIMBING		X								0	33	33	35	35	VARIABLE STATUS
2a	**22**	Spurn Peninsula	ESTUARINE	BARRIER SPIT	SINGLE		X	X							0	18	45	37	37	VARIABLE STATUS
2b	**23**	Cleethorpes and Humberston	OPEN COAST	BARRIER SPIT	MULTIPLE		X	X							0	78	17	5	5	NET ACCRETION
2b	**24**	Horse Shoe Point	OPEN COAST	BARRIER SPIT	SINGLE	X	X								0	100	0	0	0	ACCRETION ONLY
2c	**25**	Somercotes Haven to Mablethorpe	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X	X							0	31	69	0	0	NET STABLE
2c	**26**	Sutton on Sea to Chapel St Leonards	OPEN COAST	BARRIER SPIT	SINGLE		X								0	5	30	65	65	NET PROTECTED
2c	**27**	Seathorne to Gibraltar Point	OPEN COAST	BARRIER SPIT	MULTIPLE		X	X							2	47	12	39	41	VARIABLE STATUS
3a	**28**	Old Hunstanton to Holme Dunes	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X	X							5	55	4	37	42	NET ACCRETION
3a	**29**	Brancaster Bay	OPEN COAST	BARRIER ISLAND			X	X							10	30	33	27	37	VARIABLE STATUS
3a	**30**	Scolt Head Island	OPEN COAST	BARRIER ISLAND			X								31	37	32	0	31	VARIABLE STATUS
3a	**31**	Holkham Bay	OPEN COAST	BARRIER ISLAND		X	X	X	X		X	X			9	82	6	2	12	NET ACCRETION
3a	**32**	Wells-next-the-Sea to Morston	OPEN COAST	BARRIER ISLAND		X	X								0	18	82	0	0	NET STABLE
3a	**33**	Blakeney Point	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X	X	X		X				0	56	44	0	0	NET ACCRETION
3b	**34a**	Happisburgh to Winterton Ness	OPEN COAST	BARRIER SPIT	SINGLE		X								0	35	0	65	65	NET PROTECTED
3b	**34b**	Winterton Ness to Hemsby	OPEN COAST	NESS		X	X		X						41	46	14	0	41	VARIABLE STATUS
3b	**34c**	Caister-on-Sea to Great Yarmouth	OPEN COAST	BARRIER SPIT	SINGLE	X	X	X							27	59	5	9	36	NET ACCRETION
3b	**35a**	Gunton Denes and Lowestoft Denes	OPEN COAST	FRINGING	CLIMBING		X	X							0	81	0	19	19	NET ACCRETION
3b	**35b**	Kessingland	OPEN COAST	FRINGING	NON-CLIMBING				X											
3b	**35c**	Covehithe Broad	OPEN COAST	FRINGING	NON-CLIMBING	X			X											
3b	**35d**	Southwold	OPEN COAST	FRINGING	NON-CLIMBING	X			X											
3b	**35e**	Walberswick	OPEN COAST	FRINGING	NON-CLIMBING				X	X										
3b	**35f**	Minsmere to Sizewell	OPEN COAST	FRINGING	NON-CLIMBING			X	X											
3b	**35g**	Thorpeness	OPEN COAST	BARRIER SPIT	SINGLE				X	X										
4b	**36**	Sandwich Bay	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X	X							0	29	71	0	0	NET STABLE
4c	**37**	Romney Sands	OPEN COAST	FRINGING	NON-CLIMBING		X	X							0	38	62	0	0	NET STABLE
4c	**38**	Camber Sands	OPEN COAST	BARRIER SPIT	MULTIPLE		X		X	X					0	41	59	0	0	NET STABLE
4d	**39b**	East Beach, Littlehampton	OPEN COAST	BARRIER SPIT	SINGLE				X											
4d	**39b**	West Beach, Littlehampton	OPEN COAST	FRINGING	NON-CLIMBING		X	X		X					0	0	100	0	0	STABLE ONLY
5a	**40**	East Head, West Wittering	ESTUARINE	BARRIER SPIT	SINGLE		X	X	X	X					93	7	0	0	93	NET MARINE EROSION
5a	**41**	Sinah Common, Hayling Island	ESTUARINE	BARRIER SPIT	SINGLE		X		X	X	X				0	0	100	0	0	STABLE ONLY
5f	**42b**	Sandbanks	ESTUARINE	BARRIER SPIT	SINGLE				X					X						
5f	**42b**	Studland	ESTUARINE	BARRIER SPIT	SINGLE	X	X	X		X					0	22	78	0	0	NET STABLE
6a	**43a**	The Maer, Exmouth	OPEN COAST	BARRIER SPIT	SINGLE			X						X						
6b	**43b**	Dawlish Warren	ESTUARINE	BARRIER SPIT	SINGLE	X	X	X							0	61	39	0	0	NET ACCRETION
6c	**44**	Bigbury Bay	EMBAYMENT	BAY-HEAD BARRIER		X	X	X			X				29	26	44	0	29	VARIABLE STATUS
6d	**45**	Par Sands	EMBAYMENT	BAY-HEAD BARRIER		X	X								0	100	0	0	0	ACCRETION ONLY
6d	**46**	Kennack Towans	EMBAYMENT	FRINGING	CLIMBING		X		X						0	0	63	37	37	NET STABLE
6e	**47**	The Towans, Mullion	EMBAYMENT	TRANSGRESSIVE	CLIMBING	X	X		X						0	33	39	28	28	VARIABLE STATUS
6e	**48**	Praa Sands	EMBAYMENT	FRINGING	CLIMBING		X								0	0	95	5	5	NET STABLE
6e	**49**	Marazion	EMBAYMENT	BAY-HEAD BARRIER			X								0	48	52	0	0	VARIABLE STATUS
7a	**50**	Whitesand Bay	EMBAYMENT	TRANSGRESSIVE	CLIMBING		X		X	X					29	13	10	48	77	NET MARINE EROSION & PROTECTED
7a	**51a**	Lelant Towans	EMBAYMENT	TRANSGRESSIVE	CLIMBING	X	X	X			X				4	67	29	0	4	NET ACCRETION
7a	**51b**	Hayle Towans, Upton Towans and Gwithian Towans	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING		X		X	X	X	X			57	0	41	2	59	NET MARINE EROSION
7a	**51c**	Godrevy Towans	EMBAYMENT	TRANSGRESSIVE	CLIFF-TOP				X		X				0	0	100	0	0	STABLE ONLY
7a	**52**	Porth Towan	EMBAYMENT	FRINGING	NON-CLIMBING		X								0	14	86	0	0	NET STABLE
7a	**53**	Perran Bay	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING		X		X	X	X			X	4	50	46	0	4	VARIABLE STATUS
7a	**54**	Holywell Bay	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING		X		X	X	X				0	0	100	0	0	STABLE ONLY
7a	**55**	Crantock Bay	EMBAYMENT	FRINGING	NON-CLIMBING		X		X	X	X				0	0	100	0	0	STABLE ONLY
7a	**56**	Fistral Bay	EMBAYMENT	TRANSGRESSIVE	CLIMBING		X								83	0	0	17	100	MARINE EROSION & PROTECTED ONLY
7a	**57a**	Mawgan Porth	EMBAYMENT	TRANSGRESSIVE	CLIMBING			X	X					X						
7a	**57b**	Constantine Bay	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING	X	X		X						12	24	64	0	12	NET STABLE
7b	**58b**	Rock to Daymer Bay	ESTUARINE	TRANSGRESSIVE	CLIMBING	X	X	X	X	X					20	60	20	0	20	NET ACCRETION
7b	**59**	Widemouth Bay	EMBAYMENT	FRINGING	CLIMBING		X		X	X					50	0	0	50	100	MARINE EROSION & PROTECTED ONLY

Table 3.2 continued.

DUNE SYSTEM			DUNE SYSTEM MORPHOLOGY			DUNE MORPHOLOGICAL FEATURES									EROSION/ACCRETION STATUS OF FRONTAL DUNES					
SUB-CELL	SITE	SITE NAME	COASTAL SETTING	DUNE SYSTEM MORPHOLOGY	DUNE SYSTEM MORPHOLOGY SUB-CATEGORY	EMBRYO DUNES	FOREDUNE	MULTIPLE SHORE-PARALLEL RIDGES	HUMMOCKY	BLOWOUT IN FRONTAL DUNE	BLOWOUT IN HIND DUNE	PARABOLIC	ELONGATE PARABOLIC	SAND SHEET	EROSION (%)	ACCRETION (%)	STABLE (%)	PROTECTED (%)	EROSION & PROTECTION (%)	EROSION/ACCRETION STATUS
7b	60	Bude	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING	X	X		X						0	50	0	50	50	VARIABLE STATUS
7c	61a	Northam Burrows	ESTUARINE	BARRIER SPIT	SINGLE	X	X	X	X	X	X			X	31	29	40	0	31	VARIABLE STATUS
7c	61b	Instow Sands	ESTUARINE	FRINGING	NON-CLIMBING	X	X			X					0	48	52	0	0	VARIABLE STATUS
7c	61c	Braunton Burrows	OPEN COAST	TRANSGRESSIVE	NON-CLIMBING	X	X		X	X	X	X		X	33	30	35	2	35	VARIABLE STATUS
7c	62	Croyde Burrows	EMBAYMENT	FRINGING	NON-CLIMBING		X		X	X	X				0	0	100	0	0	STABLE ONLY
7c	63	Woolacombe Warren	EMBAYMENT	FRINGING	NON-CLIMBING		X		X						71	0	10	19	90	NET MARINE EROSION
7d	64	Berrow and Brean	EMBAYMENT	BAY-HEAD BARRIER			X	X	X	X					18	10	68	5	23	NET STABLE
7d	65	Weston Bay	EMBAYMENT	BAY-HEAD BARRIER			X		X						0	0	100	0	0	STABLE ONLY
7d	66	Sand Bay	EMBAYMENT	BAY-HEAD BARRIER			X	X							0	0	100	0	0	STABLE ONLY
8b	67	Merthyr-mawr Warren	OPEN COAST	TRANSGRESSIVE	NON-CLIMBING	X	X		X	X	X				9	47	43	0	9	VARIABLE STATUS
8b	68a	Kenfig Burrows	OPEN COAST	TRANSGRESSIVE	NON-CLIMBING		X		X	X	X	X			68	0	32	0	68	NET MARINE EROSION
8b	68b	Margam Burrows	OPEN COAST	TRANSGRESSIVE	NON-CLIMBING		X		X		X				74	26	0	0	74	NET MARINE EROSION
8b	68c	Baglan Burrows	EMBAYMENT	BAY-HEAD BARRIER		X	X		X	X					93	7	0	0	93	NET MARINE EROSION
8b	68d	Crymlyn Burrows	EMBAYMENT	BAY-HEAD BARRIER		X	X	X							34	39	0	27	61	NET MARINE EROSION & PROTECTED
8b	68e	Black Pill Burrows	EMBAYMENT	FRINGING	NON-CLIMBING		X								36	31	0	33	69	NET MARINE EROSION & PROTECTED
8b	69a	Pennard Burrows	EMBAYMENT	TRANSGRESSIVE	CLIMBING	X			X		X				0	11	89	0	0	NET STABLE
8b	69b	Penmaen Burrows	EMBAYMENT	BAY-HEAD BARRIER		X	X		X						86	14	0	0	86	NET MARINE EROSION
8b	69c	Nicholaston Burrows	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING	X	X		X						28	69	3	0	28	NET ACCRETION
8b	69d	Oxwich Burrows	EMBAYMENT	BAY-HEAD BARRIER		X	X		X						50	0	50	0	50	VARIABLE STATUS
8b	70	Port-Eynon Bay	EMBAYMENT	FRINGING	NON-CLIMBING		X		X						74	0	26	0	74	NET MARINE EROSION
8c	71	Rhossilli Bay	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING		X		X	X	X				0	0	100	0	0	STABLE ONLY
8c	72a	Broughton Burrows, Delvid Burrows and Hills Burrows	EMBAYMENT	FRINGING	NON-CLIMBING		X		X	X					71	0	0	29	100	MARINE EROSION & PROTECTED ONLY
8c	72b	Whiteford Burrows	ESTUARINE	BARRIER SPIT	SINGLE	X	X		X		X				47	53	0	0	47	VARIABLE STATUS
8c	73	Pembrey Burrows	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X	X	X	X					58	31	4	7	65	NET MARINE EROSION
8c	74	Laugharne Burrows and Pendine Burrows	OPEN COAST	BARRIER SPIT	SINGLE	X	X	X							42	17	25	15	57	NET MARINE EROSION & PROTECTED
8c	75	The Burrows, Tenby	EMBAYMENT	BAY-HEAD BARRIER			X		X	X					48	0	16	36	84	NET MARINE EROSION & PROTECTED
8c	76	Lydstep Haven	EMBAYMENT	FRINGING	CLIMBING				X						0	0	0	100	100	PROTECTED ONLY
8c	77	Manorbier Bay	EMBAYMENT	FRINGING	CLIMBING		X		X						0	0	100	0	0	STABLE ONLY
8c	78	Freshwater East	EMBAYMENT	FRINGING	CLIMBING		X		X	X					5	86	0	8	14	NET ACCRETION
8c	79	Stackpole Warren	EMBAYMENT	TRANSGRESSIVE	CLIFF-TOP		X		X	X	X				0	0	100	0	0	STABLE ONLY
8d	80a	Linney Burrows and Brownslade Burrows	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING		X		X	X	X	X		X	0	12	88	0	0	NET STABLE
8d	80b	Gupton Burrows, Broomhill Burrows and Kilpaison Burrows	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING		X		X	X	X				0	0	100	0	0	STABLE ONLY
8d	81	The Burrows, Whitesands Bay	EMBAYMENT	TRANSGRESSIVE	CLIMBING		X		X						58	0	21	21	79	NET MARINE EROSION
9a	82	Newport Bay	ESTUARINE	BARRIER SPIT	SINGLE		X		X	X					0	25	75	0	0	NET STABLE
9a	83a	Poppit Sands	ESTUARINE	BARRIER SPIT	PAIRED	X	X	X							44	56	0	0	44	NET ACCRETION
9a	83b	Towyn Warren	ESTUARINE	BARRIER SPIT	PAIRED		X		X	X					0	0	0	100	100	PROTECTED
9a	84	Ynyslas	ESTUARINE	BARRIER SPIT	SINGLE	X	X		X	X	X				0	52	48	0	0	VARIABLE STATUS
9a	85	Aberdovey to Tywyn	OPEN COAST	FRINGING	NON-CLIMBING	X	X		X	X					64	24	13	0	64	NET MARINE EROSION
9a	86a	Fairbourne spit	ESTUARINE	BARRIER SPIT	SINGLE		X			X					0	0	89	11	11	NET STABLE
9a	86b	Barmouth	OPEN COAST	FRINGING	NON-CLIMBING	X	X		X											
9a	87	Morfa Dyffryn	OPEN COAST	BARRIER SPIT	SINGLE		X		X	X	X	X			0	0	96	4	4	NET STABLE
9a	88a	Morfa Harlech	OPEN COAST	BARRIER SPIT	SINGLE	X	X	X	X	X					10	66	24	0	10	NET ACCRETION
9b	88b	Morfa Bychan	OPEN COAST	BARRIER SPIT	SINGLE	X	X	X							23	29	48	0	23	VARIABLE STATUS
9b	89	Morfa Abererch	OPEN COAST	FRINGING	NON-CLIMBING	X	X								31	7	62	0	31	NET STABLE
9b	90	Pwllheli and Traeth Crugan	OPEN COAST	BARRIER SPIT	SINGLE	X	X								19	45	18	19	37	VARIABLE STATUS
9b	91a	The Warren, Abersoch	EMBAYMENT	FRINGING	CLIMBING		X			X					36	0	16	49	84	NET MARINE EROSION & PROTECTED
9b	91b	Morfa Gors	EMBAYMENT	FRINGING	NON-CLIMBING		X								0	0	54	46	46	VARIABLE STATUS
9b	92	Tai Morfa	EMBAYMENT	FRINGING	CLIMBING		X		X						39	4	57	0	39	NET STABLE
10a	93	Morfa Dinlle	OPEN COAST	BARRIER SPIT	SINGLE		X	X		X	X				0	44	56	0	0	NET STABLE
10b	94	Newborough Warren	OPEN COAST	TRANSGRESSIVE	NON-CLIMBING	X	X	X	X	X	X	X		X	28	39	32	1	30	VARIABLE STATUS
10b	95	Porth Twyn-mawr	EMBAYMENT	TRANSGRESSIVE	CLIMBING		X		X						0	0	100	0	0	STABLE ONLY
10b	96	Tywyn Aberffraw	EMBAYMENT	TRANSGRESSIVE	NON-CLIMBING	X	X		X		X	X		X	0	50	50	0	0	VARIABLE STATUS
10b	97a	Tywyn Fferam	EMBAYMENT	FRINGING	NON-CLIMBING	X	X			X					13	47	40	0	13	VARIABLE STATUS
10b	97b	Tywyn Llyn	EMBAYMENT	BAY-HEAD BARRIER		X	X		X	X				X	0	81	19	0	0	NET ACCRETION
10b	98	Tywyn Trewan	EMBAYMENT	BAY-HEAD BARRIER		X	X		X	X					8	60	26	6	15	NET ACCRETION
10b	99	Tywyn-gywyn	ESTUARINE	BARRIER SPIT	SINGLE		X		X						43	57	0	0	43	NET ACCRETION
10b	100	Tywyn-mawr	EMBAYMENT	FRINGING	NON-CLIMBING	X	X								50	50	0	0	50	VARIABLE STATUS
10b	101a	Dulas Bay	ESTUARINE	BARRIER SPIT	SINGLE	X			X						0	65	35	0	0	NET ACCRETION
10b	101b	Lligwy Bay	EMBAYMENT	FRINGING	NON-CLIMBING		X								0	18	82	0	0	NET STABLE
10b	102	Red Wharf Bay	EMBAYMENT	BAY-HEAD BARRIER		X	X								0	57	43	0	0	NET ACCRETION
10c	103a	Conwy Morfa	ESTUARINE	BARRIER SPIT	SINGLE	X	X		X						32	26	42	0	32	VARIABLE STATUS
10c	103b	Deganwy and Llandudno	ESTUARINE	FRINGING	CLIMBING	X	X								0	17	25	58	58	NET PROTECTED
11a	104a	Kinmel Dunes	OPEN COAST	BARRIER SPIT	SINGLE	X	X		X						0	36	16	48	48	VARIABLE STATUS
11a	104b	Rhyl to Prestatyn	OPEN COAST	BARRIER SPIT	SINGLE		X								0	0	0	100	100	PROTECTED ONLY
11a	104c	Gronant Dunes and The Warren, Talacre	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X	X	X		X				31	18	33	18	49	VARIABLE STATUS
11a	105	Wirral Peninsula	OPEN COAST	FRINGING	NON-CLIMBING	X	X		X		X				13	23	0	64	77	NET PROTECTED
11b	106a	Seaforth to Hightown	OPEN COAST	TRANSGRESSIVE	NON-CLIMBING	X	X		X	X	X				9	20	0	70	80	NET PROTECTED
11b	106b	Hightown to Marshside	OPEN COAST	TRANSGRESSIVE	NON-CLIMBING	X	X	X	X	X	X			X	26	60	15	0	26	NET ACCRETION
11b	107a	Lytham to Blackpool	OPEN COAST	TRANSGRESSIVE	NON-CLIMBING	X	X		X	X	X			X	0	82	18	0	0	NET ACCRETION
11b	107b	Fleetwood to Pilling	OPEN COAST	FRINGING	NON-CLIMBING	X	X								0	52	0	48	48	VARIABLE STATUS
11d	108	Walney Island	OPEN COAST	BARRIER SPIT	MULTIPLE	X	X		X	X	X				53	14	33	0	53	VARIABLE STATUS
11d	109a	Sandscale Haws	ESTUARINE	BARRIER SPIT	SINGLE	X	X	X	X	X	X	X	X	X	43	42	15	0	43	VARIABLE STATUS
11d	109b	Askam in Furness to Dunnerholme	ESTUARINE	FRINGING	NON-CLIMBING		X	X							7	86	7	0	7	NET ACCRETION
11d	109c	Hodbarrow	ESTUARINE	FRINGING	NON-CLIMBING		X								8	7	85	0	8	NET STABLE
11d	109d	Haverigg Haws and Kirksanton Haws	ESTUARINE	TRANSGRESSIVE	NON-CLIMBING	X	X	X	X	X	X				23	23	54	0	23	VARIABLE STATUS
11d	110a	Eskmeals Dunes	ESTUARINE	BARRIER SPIT	PAIRED		X		X	X		X			35	0	65	0	35	NET STABLE
11d	110b	Drigg Dunes	ESTUARINE	BARRIER SPIT	PAIRED		X		X	X	X				67	3	29	0	67	NET MARINE EROSION
11d	111	Seascale to Braystones	OPEN COAST	FRINGING	NON-CLIMBING		X								48	25	10	16	65	NET MARINE EROSION & PROTECTED
11e	112	Maryport to Grune Point	OPEN COAST	FRINGING	NON-CLIMBING		X	X						X	35	18	43	4	39	VARIABLE STATUS

Table 3.3 Meteorological stations used in wind regime analysis.

STATION	NGRE	NGRN	DATA RUN	YEARS WITH INCOMPLETE DATA	HEIGHT ABOVE MEAN SEA LEVEL (m)	HEIGHT ABOVE GROUND (m)
Tynemouth	4374	5694	1981-2000		33	10
Donna Nook	5429	3996	1993-2000	1993	8	10
Hemsby	6493	3162	1981-2000		14	13
Manston	6332	1669	1981-2000		44	10
Isle of Portland	3677	0692	1981-2000 (Except 1993)	1992, 1994	52	10
Culdrose	1672	0257	1981-2000	1988	78	21
Chivenor	2496	1344	1981-2000		6	10
Pembrey Sands	2365	2043	1993-2000	1993	3	10
Valley	2308	3758	1981-2000		10	10
Squires Gate	3316	4316	1970-1995		22	12
St. Bees Head	2955	5148	1992-2000		124	10

NGRE = National Grid Reference Easting
NGRE = National Grid Reference Northing

Table 3.4 Annual mean rainfall total and 'rain days' for the period 1961 to 1990, drift potential total and resultant drift potential calculated for the data run of available wind data and Index of Drift Potential including Precipitation and Index of Resultant Drift Potential including Precipitation.

STATION USED FOR WIND DATA	STATION USED FOR RAINFALL DATA	ANNUAL RAINFALL TOTAL (mm)	RAIN DAYS (>1mm)	DRIFT POTENTIAL TOTAL (vector units)	INDEX DPP	RESULTANT DRIFT POTENTIAL (vector units)	INDEX RDPP
Tynemouth	Durham	651	115.8	2996	397	348	46
Donna Nook	Finningley	576	105.8	1672	274	117	19
Hemsby	Lowestoft	584	115.1	787	117	205	30
Manston	Hastings	728	115.2	665	79	239	28
Isle of Portland	Everton	756	116.3	2791	317	1280	146
Culdrose	St Mawgan	1005	151.4	1706	112	543	36
Chivenor	Bude	880	146.5	1060	82	582	45
Pembrey	Dale Fort	829	133.7	1935	175	1435	129
Valley	Valley	843	138.3	2180	187	1466	126
Squires Gate	Squires Gate	853	140.4	1085	91	688	57
St Bees Head	Dumfries	1047	152.3	1891	119	829	52

Table 3.5 Drift Potential total (DP), Resultant Drift Potential (RDP), Resultant Drift Direction (RDD) and classification of the directional variability (RDP/DP and wind regime classification) for selected meteorological stations on the coast of England and Wales. Drift Potentials calculated from Fryberger & Dean (1979) equation using data supplied by the Meteorological Office.

STATION	DP TOTAL (Vector units)	RDP (Vector units)			RDD (Degrees from north)			RDP /DP	EFFECTIVE WIND REGIME CLASSIFICATION
	DATA RUN	DATA RUN	ANNUAL MIN	ANNUAL MAX	DATA RUN	ANNUAL MIN	ANNUAL MAX		
Tynemouth	2996 (1981-2000)	348	128 (1986)	1870 (1996)	118	21 (1997)	257 (1996)	0.12	Complex
Donna Nook	1672 (1994-2000)	117	39 (1997)	661 (1996)	128	27 (1994)	352 (1997)	0.07	Obtuse Bimodal
Hemsby	787 (1981-2000)	205	39 (1985)	628 (1990)	73	48 (1982)	233 (1996)	0.26	Wide Unimodal
Manston	665 (1981-2000)	239	45 (1996)	595 (1998)	56	36 (1982)	126 (1992)	0.36	Wide Unimodal
Isle of Portland	2791 (1981-2000, ex. 1992-94)	1280	397 (1987)	2851 (1998)	82	61 (1985)	96 (1986)	0.46	Wide Unimodal
Culdrose	1706 (1981-2000, ex. 1988)	543	251 (1997)	1214 (1992)	64	33 (1989)	329 (1997)	0.32	Wide Unimodal
Chivenor	1060 (1981-2000)	582	219 (1996)	908 (1998)	77	55 (1996)	97 (1984)	0.55	Wide Unimodal
Pembrey Sands	1935 (1994-2000)	1435	950 (1996)	1903 (2000)	53	45 (2000)	57 (1994)	0.74	Wide Unimodal
Valley	2180 (1981-2000)	1466	714 (1987)	2172 (1986)	33	19 (1989)	52 (1983)	0.67	Wide Unimodal
Squires Gate	1085 (1970-1995)	688	361 (1976)	1364 (1990)	70	55 (1986)	83 (1980)	0.63	Wide Unimodal
St. Bees Head	1891 (1992-2000)	829	673 (1996)	945 (1992)	45	25 (1996)	64 (1998)	0.44	Obtuse Bimodal

Table 3.6 Process regime of coastal sand dune systems in England and Wales

DUNE SYSTEM			REFERENCE	WIND REGIME				ANNUAL	TIDAL RANGE		
SUB-CELL	**SITE**	**SITE NAME**	**METEOROLOGICAL STATION**	**DP (vector units)**	**RDP (vector units)**	**RDP/DP**	**RDD (degrees from north)**	**RAINFALL (mm)**	**PORT**	**SPRING (m)**	**NEAP (m)**
1a	**1**	Cocklawburn to Goswick	Tynemouth	2996	348	0.12	118	651	Berwick	4.1	2.5
1a	**2**	Holy Island	Tynemouth	2996	348	0.12	118	651	Holy Island	4.2	2.2
1a	**3a**	Ross Links and Budle Bay west	Tynemouth	2996	348	0.12	118	651	Holy Island	4.2	2.2
1a	**3b**	Budle Bay east	Tynemouth	2996	348	0.12	118	651	Holy Island	4.2	2.2
1a	**4**	Bamburgh to Seahouses	Tynemouth	2996	348	0.12	118	651	North Sunderland	4.1	2.1
1a	**5**	Annstead Dunes	Tynemouth	2996	348	0.12	118	651	North Sunderland	4.1	2.1
1a	**6**	Beadnell Bay	Tynemouth	2996	348	0.12	118	651	North Sunderland	4.1	2.1
1a	**7**	Embleton Bay	Tynemouth	2996	348	0.12	118	651	North Sunderland	4.1	2.1
1a	**8a+b**	Sugar Sands and Howdiemont Sands	Tynemouth	2996	348	0.12	118	651	Amble	4.2	2.1
1a	**8c**	Boulmer	Tynemouth	2996	348	0.12	118	651	Amble	4.2	2.1
1a	**9a**	Alnmouth	Tynemouth	2996	348	0.12	118	651	Amble	4.2	2.1
1a	**9b**	Buston Links	Tynemouth	2996	348	0.12	118	651	Amble	4.2	2.1
1a	**9c**	Birling Links	Tynemouth	2996	348	0.12	118	651	Amble	4.2	2.1
1a	**10**	Amble to Hauxley	Tynemouth	2996	348	0.12	118	651	Amble	4.2	2.1
1a	**11**	Druridge Bay	Tynemouth	2996	348	0.12	118	651	Amble	4.2	2.1
1a	**12**	Snab Point to Beacon Point	Tynemouth	2996	348	0.12	118	651	Blyth	4.2	2.2
1a	**13**	Beacon Point to Newbiggin Point	Tynemouth	2996	348	0.12	118	651	Blyth	4.2	2.2
1a	**14**	Newbiggin Bay	Tynemouth	2996	348	0.12	118	651	Blyth	4.2	2.2
1a	**15a**	North Seaton	Tynemouth	2996	348	0.12	118	651	Blyth	4.2	2.2
1a	**15b**	Cambois to North Blyth	Tynemouth	2996	348	0.12	118	651	Blyth	4.2	2.2
1a	**16**	South Blyth to Seaton Sluice	Tynemouth	2996	348	0.12	118	651	Blyth	4.2	2.2
1a	**17c**	Long Sands	Tynemouth	2996	348	0.12	118	651	River Tyne, North Shields	4.3	2.1
1b	**18**	South Shields	Tynemouth	2996	348	0.12	118	651	River Tyne, North Shields	4.3	2.1
1b	**19**	Whitburn Bay	Tynemouth	2996	348	0.12	118	651	Sunderland	4.4	2.2
1c	**20**	Hart Warren Dunes	Tynemouth	2996	348	0.12	118	651	Hartlepool	4.6	2.4
1c	**21a**	Carr House Sands and Seaton Dunes	Tynemouth	2996	348	0.12	118	651	River Tees Entrance	4.6	2.3
1c	**21b**	Coatham Sands	Tynemouth	2996	348	0.12	118	651	River Tees Entrance	4.6	2.3
1c	**21c**	Redcar to Marske-by-the-Sea	Tynemouth	2996	348	0.12	118	651	River Tees Entrance	4.6	2.3
2a	**22**	Spurn Peninsula	Donna Nook	1672	117	0.07	128	576	Spurn Head	5.7	2.8
2b	**23**	Cleethorpes and Humberston	Donna Nook	1672	117	0.07	128	576	Grimsby	6.0	3.0
2b	**24**	Horse Shoe Point	Donna Nook	1672	117	0.07	128	576	Grimsby	6.0	3.0
2c	**25**	Somercotes Haven to Mablethorpe	Donna Nook	1672	117	0.07	128	576	Skegness	6.0	2.8
2c	**26**	Sutton on Sea to Chapel St Leonards	Donna Nook	1672	117	0.07	128	576	Skegness	6.0	2.8
2c	**27**	Seathorne to Gibraltar Point	Donna Nook	1672	117	0.07	128	576	Skegness	6.0	2.8
3a	**28**	Old Hunstanton to Holme Dunes	Hemsby	787	205	0.26	73	584	Holme-next-the-Sea	5.5	3.0
3a	**29**	Brancaster Bay	Hemsby	787	205	0.26	73	584	Brancaster	5.5	3.0
3a	**30**	Scolt Head Island	Hemsby	787	205	0.26	73	584	Scolt Head Island	5.4	2.8
3a	**31**	Holkham Bay	Hemsby	787	205	0.26	73	584	Holkham	5.2	2.4
3a	**32**	Wells-next-the-Sea to Morston	Hemsby	787	205	0.26	73	584	Wells	5.0	2.6
3a	**33**	Blakeney Point	Hemsby	787	205	0.26	73	584	Blakeney Point	4.9	2.6
3b	**34a**	Happisburgh to Winterton Ness	Hemsby	787	205	0.26	73	584	Sea Palling	3.6	1.6
3b	**34b**	Winterton Ness to Hemsby	Hemsby	787	205	0.26	73	584	Winterton	3.3	1.5
3b	**34c**	Caister-on-Sea to Great Yarmouth	Hemsby	787	205	0.26	73	584	Great Yarmouth	2.8	1.2
3b	**35a**	Gunton Denes and Lowestoft Denes	Hemsby	787	205	0.26	73	584	Lowestoft	1.9	1.1
3b	**35b**	Kessingland	Hemsby	787	205	0.26	73	584	Lowestoft	1.9	1.1
3b	**35c**	Covehithe Broad	Hemsby	787	205	0.26	73	584	Lowestoft	1.9	1.1
3b	**35d**	Southwold	Hemsby	787	205	0.26	73	584	Lowestoft	1.9	1.1
3b	**35e**	Walberswick	Hemsby	787	205	0.26	73	584	Lowestoft	1.9	1.1
3b	**35f**	Minsmere to Sizewell	Hemsby	787	205	0.26	73	584	Lowestoft	1.9	1.1
3b	**35g**	Thorpeness	Hemsby	787	205	0.26	73	584	Lowestoft	1.9	1.1
4b	**36**	Sandwich Bay	Manston	665	239	0.36	56	728	Ramsgate	4.6	2.6
4c	**37**	Romney Sands	Manston	665	239	0.36	56	728	Dungeness	6.0	3.4
4c	**38**	Camber Sands	Isle of Portland	2791	1280	0.46	82	756	Dungeness	6.0	3.4
4d	**39a**	East Beach, Littlehampton	Isle of Portland	2791	1280	0.46	82	756	Littlehampton (entrance)	5.5	2.7
4d	**39b**	West Beach, Littlehampton	Isle of Portland	2791	1280	0.46	82	756	Littlehampton (entrance)	5.5	2.7
5a	**40**	East Head, West Wittering	Isle of Portland	2791	1280	0.46	82	756	Chichester Harbour Entrance	4.0	2.1
5a	**41**	Sinah Common, Hayling Island	Isle of Portland	2791	1280	0.46	82	756	Portsmouth	3.9	1.9
5f	**42a**	Sandbanks	Isle of Portland	2791	1280	0.46	82	756	Poole Harbour	1.6	0.5
5f	**42b**	Studland	Isle of Portland	2791	1280	0.46	82	756	Poole Harbour	1.6	0.5
6a	**43a**	The Maer, Exmouth	Isle of Portland	2791	1280	0.46	82	756	Exmouth (Approaches)	4.1	1.7
6b	**43b**	Dawlish Warren	Isle of Portland	2791	1280	0.46	82	756	Exmouth (Approaches)	4.1	1.7
6c	**44**	Bigbury Bay	Culdrose	1706	543	0.32	64	1005	Salcombe	4.6	2.0
6d	**45**	Par Sands	Culdrose	1706	543	0.32	64	1005	Par	4.5	2.2
6d	**46**	Kennack Towans	Culdrose	1706	543	0.32	64	1005	Coverack	4.7	2.3
6e	**47**	The Towans, Mullion	Culdrose	1706	543	0.32	64	1005	Porthleven	4.7	2.3
6e	**48**	Praa Sands	Culdrose	1706	543	0.32	64	1005	Porthleven	4.7	2.3
6e	**49**	Marazion	Culdrose	1706	543	0.32	64	1005	Penzance (Newlyn)	4.8	2.4
7a	**50**	Whitesand Bay	Culdrose	1706	543	0.32	64	1005	Cape Cornwall	5.4	2.3
7a	**51a**	Lelant Towans	Chivenor	1060	582	0.55	77	880	St Ives	5.8	2.5
7a	**51b**	Hayle Towans, Upton Towans and Gwithian Towans	Chivenor	1060	582	0.55	77	880	St Ives	5.8	2.5
7a	**51c**	Godrevy Towans	Chivenor	1060	582	0.55	77	880	St Ives	5.8	2.5
7a	**52**	Porth Towan	Chivenor	1060	582	0.55	77	880	Perranporth	6.1	2.7
7a	**53**	Perran Bay	Chivenor	1060	582	0.55	77	880	Perranporth	6.1	2.7
7a	**54**	Holywell Bay	Chivenor	1060	582	0.55	77	880	Newquay	6.4	2.8
7a	**55**	Crantock Bay	Chivenor	1060	582	0.55	77	880	Newquay	6.4	2.8
7a	**56**	Fistral Bay	Chivenor	1060	582	0.55	77	880	Newquay	6.4	2.8
7a	**57a**	Mawgan Porth	Chivenor	1060	582	0.55	77	880	Newquay	6.4	2.8
7a	**57b**	Constantine Bay	Chivenor	1060	582	0.55	77	880	Padstow	6.5	3.0
7b	**58b**	Rock to Daymer Bay	Chivenor	1060	582	0.55	77	880	Padstow	6.5	3.0
7b	**59**	Widemouth Bay	Chivenor	1060	582	0.55	77	880	Boscastle	6.4	2.9

Table 3.6 continued.

DUNE SYSTEM			REFERENCE	WIND REGIME				ANNUAL	TIDAL RANGE		
SUB-CELL	SITE	SITE NAME	METEOROLOGICAL STATION	DP (vector units)	RDP (vector units)	RDP/DP	RDD (degrees from north)	RAINFALL (mm)	PORT	SPRING (m)	NEAP (m)
7b	**60**	Bude	Chivenor	1060	582	0.55	77	880	Boscastle	6.4	2.9
7c	**61a**	Northam Burrows	Chivenor	1060	582	0.55	77	880	Appledore	7.3	3.6
7c	**61b**	Instow Sands	Chivenor	1060	582	0.55	77	880	Yelland Marsh	7.0	3.5
7c	**61c**	Braunton Burrows	Chivenor	1060	582	0.55	77	880	Appledore	7.3	3.6
7c	**62**	Croyde Burrows	Chivenor	1060	582	0.55	77	880	Appledore	7.3	3.6
7c	**63**	Woolacombe Warren	Chivenor	1060	582	0.55	77	880	Appledore	7.3	3.6
7d	**64**	Berrow and Brean	Chivenor	1060	582	0.55	77	880	Burnham-on-Sea	11.0	5.5
7d	**65**	Weston Bay	Chivenor	1060	582	0.55	77	880	Weston-super-Mare	11.2	5.8
7d	**66**	Sand Bay	Chivenor	1060	582	0.55	77	880	Weston-super-Mare	11.2	5.8
8b	**67**	Merthyr-mawr Warren	Pembrey	1935	1435	0.74	53	829	Porthcawl	8.9	5.3
8b	**68a**	Kenfig Burrows	Pembrey	1935	1435	0.74	53	829	Porthcawl	8.9	5.3
8b	**68b**	Margam Burrows	Pembrey	1935	1435	0.74	53	829	Port Talbot	8.4	3.9
8b	**68c**	Baglan Burrows	Pembrey	1935	1435	0.74	53	829	Port Talbot	8.4	3.9
8b	**68d**	Crymlyn Burrows	Pembrey	1935	1435	0.74	53	829	Port Talbot	8.4	3.9
8b	**68e**	Black Pill Burrows	Pembrey	1935	1435	0.74	53	829	Swansea	8.5	4.0
8b	**69a**	Pennard Burrows	Pembrey	1935	1435	0.74	53	829	Mumbles	8.4	3.8
8b	**69b**	Penmaen Burrows	Pembrey	1935	1435	0.74	53	829	Mumbles	8.4	3.8
8b	**69c**	Nicholaston Burrows	Pembrey	1935	1435	0.74	53	829	Mumbles	8.4	3.8
8b	**69d**	Oxwich Burrows	Pembrey	1935	1435	0.74	53	829	Mumbles	8.4	3.8
8b	**70**	Port-Eynon Bay	Pembrey	1935	1435	0.74	53	829	Mumbles	8.4	3.8
8c	**71**	Rhossilli Bay	Pembrey	1935	1435	0.74	53	829	Bury Port	7.5	3.6
8c	**72a**	Broughton Burrows, Delvid Burrows and Hills Burrows	Pembrey	1935	1435	0.74	53	829	Bury Port	7.5	3.6
8c	**72b**	Whiteford Burrows	Pembrey	1935	1435	0.74	53	829	Bury Port	7.5	3.6
8c	**73**	Pembrey Burrows	Pembrey	1935	1435	0.74	53	829	Bury Port	7.5	3.6
8c	**74**	Laugharne Burrows and Pendine Burrows	Pembrey	1935	1435	0.74	53	829	Ferryside	6.6	3.7
8c	**75**	The Burrows, Tenby	Pembrey	1935	1435	0.74	53	829	Tenby	7.5	3.3
8c	**76**	Lydstep Haven	Pembrey	1935	1435	0.74	53	829	Tenby	7.5	3.3
8c	**77**	Manorbier Bay	Pembrey	1935	1435	0.74	53	829	Stackpole Quay	6.9	3.2
8c	**78**	Freshwater East	Pembrey	1935	1435	0.74	53	829	Stackpole Quay	6.9	3.2
8c	**79**	Stackpole Warren	Pembrey	1935	1435	0.74	53	829	Stackpole Quay	6.9	3.2
8d	**80a**	Linney Burrows and Brownslade Burrows	Pembrey	1935	1435	0.74	53	829	Dale Roads	6.4	2.7
8d	**80b**	Gupton Burrows, Broomhill Burrows and Kilpaison Burrows	Pembrey	1935	1435	0.74	53	829	Dale Roads	6.4	2.7
8d	**81**	The Burrows, Whitesands Bay	Pembrey	1935	1435	0.74	53	829	Ramsey Sound	4.4	1.7
9a	**82**	Newport Bay	Valley	2180	1466	0.67	33	843	Fishguard	5.0	1.4
9a	**83a**	Poppit Sands	Valley	2180	1466	0.67	33	843	Port Cardigan	4.0	1.4
9a	**83b**	Towyn Warren	Valley	2180	1466	0.67	33	843	Port Cardigan	4.0	1.4
9a	**84**	Ynyslas	Valley	2180	1466	0.67	33	843	Aberdovey	4.3	1.5
9a	**85**	Aberdovey to Tywyn	Valley	2180	1466	0.67	33	843	Aberdovey	4.3	1.5
9a	**86a**	Fairbourne spit	Valley	2180	1466	0.67	33	843	Barmouth	4.3	1.7
9a	**86b**	Barmouth	Valley	2180	1466	0.67	33	843	Barmouth	4.3	1.7
9a	**87**	Morfa Dyffryn	Valley	2180	1466	0.67	33	843	Barmouth	4.3	1.7
9a	**88a**	Morfa Harlech	Valley	2180	1466	0.67	33	843	Criccieth	4.6	1.6
9b	**88b**	Morfa Bychan	Valley	2180	1466	0.67	33	843	Criccieth	4.6	1.6
9b	**89**	Morfa Abererch	Valley	2180	1466	0.67	33	843	Criccieth	4.6	1.6
9b	**90**	Pwllheli and Traeth Crugan	Valley	2180	1466	0.67	33	843	Pwllheli	4.5	1.5
9b	**91a**	The Warren, Abersoch	Valley	2180	1466	0.67	33	843	St Tudwal's Road	4.3	1.5
9b	**91b**	Morfa Gors	Valley	2180	1466	0.67	33	843	St Tudwal's Road	4.3	1.5
9b	**92**	Tai Morfa	Valley	2180	1466	0.67	33	843	Aberdaron	4.1	1.4
10a	**93**	Morfa Dinlle	Valley	2180	1466	0.67	33	843	Fort Belan	4.0	1.7
10b	**94**	Newborough Warren	Valley	2180	1466	0.67	33	843	Llanddwyn Island	4.2	2.0
10b	**95**	Porth Twyn-mawr	Valley	2180	1466	0.67	33	843	Llanddwyn Island	4.2	2.0
10b	**96**	Tywyn Aberffraw	Valley	2180	1466	0.67	33	843	Porth Trecastell	4.3	1.8
10b	**97a**	Tywyn Fferam	Valley	2180	1466	0.67	33	843	Porth Trecastell	4.3	1.8
10b	**97b**	Tywyn Llyn	Valley	2180	1466	0.67	33	843	Porth Trecastell	4.3	1.8
10b	**98**	Tywyn Trewan	Valley	2180	1466	0.67	33	843	Porth Trecastell	4.3	1.8
10b	**99**	Tywyn-gywyn	Valley	2180	1466	0.67	33	843	Holyhead	4.9	2.4
10b	**100**	Tywyn-mawr	Valley	2180	1466	0.67	33	843	Holyhead	4.9	2.4
10b	**101a**	Dulas Bay	Squires Gate	1085	688	0.63	70	853	Moelfre	6.6	3.3
10b	**101b**	Lligwy Bay	Squires Gate	1085	688	0.63	70	853	Moelfre	6.6	3.3
10b	**102**	Red Wharf Bay	Squires Gate	1085	688	0.63	70	853	Moelfre	6.6	3.3
10c	**103a**	Conwy Morfa	Squires Gate	1085	688	0.63	70	853	Conwy	6.8	3.6
10c	**103b**	Deganwy and Llandudno	Squires Gate	1085	688	0.63	70	853	Llandudno	7.0	3.8
11a	**104a**	Kinmel Dunes	Squires Gate	1085	688	0.63	70	853	Hilbre Island	7.7	4.1
11a	**104b**	Rhyl to Prestatyn	Squires Gate	1085	688	0.63	70	853	Hilbre Island	7.7	4.1
11a	**104c**	Gronant Dunes and The Warren, Talacre	Squires Gate	1085	688	0.63	70	853	Hilbre Island	7.7	4.1
11a	**105**	Wirral Peninsula	Squires Gate	1085	688	0.63	70	853	Hilbre Island	7.7	4.1
11b	**106a**	Seaforth to Hightown	Squires Gate	1085	688	0.63	70	853	Formby	8.0	4.4
11b	**106b**	Hightown to Marshside	Squires Gate	1085	688	0.63	70	853	Formby	8.0	4.4
11b	**107a**	Lytham to Blackpool	Squires Gate	1085	688	0.63	70	853	Blackpool	7.9	4.2
11b	**107b**	Fleetwood to Pilling	Squires Gate	1085	688	0.63	70	853	Fleetwood	8.0	4.3
11d	**108**	Walney Island	St Bees Head	1891	829	0.44	45	1047	Haws Point	8.3	4.1
11d	**109a**	Sandscale Haws	St Bees Head	1891	829	0.44	45	1047	Duddon Bay	7.6	4.0
11d	**109b**	Askam in Furness to Dunnerholme	St Bees Head	1891	829	0.44	45	1047	Duddon Bay	7.6	4.0
11d	**109c**	Hodbarrow	St Bees Head	1891	829	0.44	45	1047	Duddon Bay	7.6	4.0
11d	**109d**	Haverigg Haws and Kirksanton Haws	St Bees Head	1891	829	0.44	45	1047	Duddon Bay	7.6	4.0
11d	**110a**	Eskmeals Dunes	St Bees Head	1891	829	0.44	45	1047	Tarn Point	7.4	3.9
11d	**110b**	Drigg Dunes	St Bees Head	1891	829	0.44	45	1047	Tarn Point	7.4	3.9
11d	**111**	Seascale to Braystones	St Bees Head	1891	829	0.44	45	1047	Tarn Point	7.4	3.9
11e	**112**	Maryport to Grune Point	St Bees Head	1891	829	0.44	45	1047	Silloth	8.4	4.8

Table 3.7 Management status, hinterland use and dune activities at coastal sand dune systems in England and Wales

DUNE SYSTEM			SEA DEFENCES											STABILISATION						ACCESS				VEGETATION		FLOOD DEFENCE SIGNIFICANCE	LAND USE																						
																											HINTERLAND									DUNE													
SUB-CELL	SITE	SITE NAME	SEA WALL	REVETMENT	GABIONS	GROYNES	BREAKWATERS	RUBBLE	ROCK ARMOUR	TIMBER SOLDIERS	FENCING	BEACH REPROFILING	BEACH RECHARGE	FENCING	XMAS TREES	MARRAM PLANTING	CONTOURING	SURFACE THATCHING, BINDING	AFFORESTATION	FENCING	SIGNPOSTS	BOARDWALK	BEACH PARKING	GRAZING	SCRUB CONTROL		INDUSTRIAL	HOUSING	INFRASTRUCTURE	MILITARY	HOLIDAY ACCOMMODATION	GOLF COURSE	AMENITY	NATURAL	AGRICULTURAL	SAND MINING	WATER EXTRACTION	CONSERVATION	HOLIDAY ACCOMODATION (CHALETS, CARAVANS, CAMPING)	VEHICLES (QUAD BIKES, MOTORBIKES, 4 WD-TRAILS)	SUNBATHING / WALKING / CYCLING	GOLF COURSE	CULTIVATION	STOCK GRAZING	AFFORESTATION	MILITARY	INFRASTRUCTURE	HOUSING	INDUSTRIAL
1a	1	Cocklawburn to Goswick																								MEDIUM	X								X			X				X				F			
1a	2	Holy Island																								LOW									X			X											
1a	3a	Ross Links and Budle Bay west																						X		LOW									X			X						X					
1a	3b	Budle Bay east																								NONE						X			X			X											
1a	4	Bamburgh to Seahouses												X												LOW		X							X			X											
1a	5	Annstead Dunes																								LOW		X				X			X			X											
1a	6	Beadnell Bay																		X						LOW		X			X				X			X											
1a	7	Embleton Bay																								LOW		X				X			X			X	X										
1a	8a+b	Sugar Sands and Howdiemont Sands																								NONE									X			X											
1a	8c	Boulmer																								LOW		X							X			X											
1a	9a	Alnmouth			X																					HIGH		X										X				X							
1a	9b	Buston Links																								NONE									X			X											
1a	9c	Birling Links																								NONE									X			X											
1a	10	Amble to Hauxley			X				X					X						X						NONE		X							X			X											
1a	11	Druridge Bay												X						X		X		X		LOW		X							X	X		X						X					
1a	12	Snab Point to Beacon Point												X										X		NONE	X	X	X											X				X					X
1a	13	Beacon Point to Newbiggin Point																						X		LOW		X														X		X					
1a	14	Newbiggin Bay																								NONE		X																					
1a	15a	North Seaton																								NONE								X						X									
1a	15b	Cambois to North Blyth																								HIGH	X																						
1a	16	South Blyth to Seaton Sluice	X			X								X		X		X								HIGH	X	X	X												X								
1a	17c	Long Sands												X												NONE		X	X																				
1b	18	South Shields				X								X												HIGH		X	X		X							X											
1b	19	Whitburn Bay	X																							NONE		X	X									X											
1c	20	Hart Warren Dunes												X	X											LOW	X	X	X									X				X							
1c	21a	Carr House Sands and Seaton Dunes					X							X							X				X	HIGH	X					X						X		X									
1c	21b	Coatham Sands					X							X												HIGH	X	X										X		X		X							X
1c	21c	Redcar to Marske-by-the-Sea	X			X																				HIGH		X	X				X																
2a	22	Spurn Peninsula		X		X																				HIGH												X											
2b	23	Cleethorpes and Humberston	X	X		X								X												HIGH		X	X		X	X						X			X								
2b	24	Horse Shoe Point																								MEDIUM	X											X											
2c	25	Somercotes Haven to Mablethorpe	X											X										X	X	HIGH		X	X		X	X			X			X						X		X			
2c	26	Sutton on Sea to Chapel St Leonards	X	X		X							X	X						X						HIGH		X			X				X			X				X						X	
2c	27	Seathorne to Gibraltar Point	X	X		X			X											X						HIGH		X	X		X				X			X				X							
3a	28	Old Hunstanton to Holme Dunes			X	X					X															HIGH		X			X				X			X	X			X							
3a	29	Brancaster Bay			X			X	X		X															HIGH		X	X						X			X				X							
3a	30	Scolt Head Island																								MEDIUM		X							X			X											
3a	31	Holkham Bay			X	X													X	X		X				MEDIUM		X			X				X			X							X				
3a	32	Wells-next-the-Sea to Morston																								LOW		X							X			X											
3a	33	Blakeney Point																								LOW		X	X						X			X											
3b	34a	Happisburgh to Winterton Ness	X			X							X							X						HIGH		X	X		X				X			X											
3b	34b	Winterton Ness to Hemsby	X			X			X					X												HIGH		X	X		X				X			X											
3b	34c	Caister-on-Sea to Great Yarmouth	X			X																				HIGH		X	X		X	X						X											
3b	35a	Gunton Denes and Lowestoft Denes	X			X														X						NONE		X				X																	
3b	35b	Kessingland																								LOW					X			X					X										
3b	35c	Covehithe Broad																								LOW								X	X			X											
3b	35d	Southwold																								LOW		X	X																				
3b	35e	Walberswick																								MEDIUM		X						X															
3b	35f	Minsmere to Sizewell		X														X		X	X	X				HIGH	X	X						X				X											
3b	35g	Thorpeness																								MEDIUM		X																					
4b	36	Sandwich Bay																								HIGH	X	X	X						X			X				X							
4c	37	Romney Sands												X		X				X	X					HIGH		X							X			X											
4c	38	Camber Sands				X								X												HIGH		X	X		X							X				X							
4d	39a	East Beach, Littlehampton	X			X																				NONE		X	X				X														X	X	
4d	39b	West Beach, Littlehampton												X		X				X	X	X				MEDIUM									X			X				X							
5a	40	East Head, West Wittering												X						X	X	X				LOW		X										X											
5a	41	Sinah Common, Hayling Island																								HIGH		X										X				X							
5f	42a	Sandbanks	X			X																				LOW		X	X																		X	X	
5f	42b	Studland														X				X	X				X	LOW					X							X											
6a	43a	The Maer, Exmouth	X																		X					LOW		X	X				X																
6b	43b	Dawlish Warren			X	X										X				X	X					MEDIUM								X				X				X							
6c	44	Bigbury Bay												X	X					X	X					NONE								X															
6d	45	Par Sands												X						X						HIGH		X	X		X							X											
6d	46	Kennack Towans	X											X												NONE								X				X											
6e	47	The Towans, Mullion	X											X	X						X					NONE								X				X				X							
6e	48	Praa Sands							X																	NONE		X																					
6e	49	Marazion																		X						NONE			X		X			X															
7a	50	Whitesand Bay							X											X		X				NONE		X							X														
7a	51a	Lelant Towans																								NONE		X	X													X							
7a	51b	Hayle Towans, Upton Towans and Gwithian Towans						X						X		X		X		X	X					NONE		X	X						X	X		X	X							F		X	
7a	51c	Godrevy Towans																		X		X				NONE								X															
7a	52	Porth Towan																		X						LOW		X										X											
7a	53	Perran Bay												X		X				X	X					NONE									X			X	X			X				X			
7a	54	Holywell Bay																		X	X					LOW		X										X											
7a	55	Crantock Bay																								NONE									X			X											
7a	56	Fistral Bay			X									X						X	X					NONE						X						X											
7a	57a	Mawgan Porth																								NONE		X				X																	
7a	57b	Constantine Bay												X						X						NONE		X				X						X											
7b	58b	Rock to Daymer Bay																			X					NONE								X	X	F		X				X							
7b	59	Widemouth Bay							X																	NONE		X										X											

Table 3.7 continued.

DUNE SYSTEM			SEA DEFENCES											STABILISATION						ACCESS				VEGETATION		FLOOD DEFENCE FUNCTION	LAND USE																						
																								HINTERLAND									DUNE													
SUB-CELL	SITE	SITE NAME	SEA WALL	REVETMENT	GABIONS	GROYNES	BREAKWATERS	RUBBLE	ROCK ARMOUR	TIMBER SOLDIERS	FENCING	BEACH REPROFILING	BEACH RECHARGE	FENCING	XMAS TREES	MARRAM PLANTING	CONTOURING	SURFACE THATCHING, BINDING	AFFORESTATION	FENCING	SIGNPOSTS	BOARDWALK	BEACH PARKING	GRAZING	SCRUB CONTROL		INDUSTRIAL	HOUSING	INFRASTRUCTURE	MILITARY	HOLIDAY ACCOMMODATION	GOLF COURSE	AMENITY	NATURAL	AGRICULTURAL	SAND MINING	WATER EXTRACTION	CONSERVATION	HOLIDAY ACCOMODATION (CHALETS, CARAVANS, CAMPING)	VEHICLES (QUAD BIKES, MOTORBIKES, 4 WD-TRAILS)	SUNBATHING / WALKING / CYCLING	GOLF COURSE	CULTIVATION	STOCK GRAZING	AFFORESTATION	MILITARY	INFRASTRUCTURE	HOUSING	INDUSTRIAL
7b	60	Bude							X											X						HIGH		X										X										
7c	61a	Northam Burrows																		X			X		MEDIUM									X		X				X		X				
7c	61b	Instow Sands												X											LOW		X	X								X										
7c	61c	Braunton Burrows		X	X	X			X				X		X				X		X		X		MEDIUM									X		X			X	X		X		X		
7c	62	Croyde Burrows																							LOW		X									X	X									
7c	63	Woolacombe Warren	X	X									X		X				X	X				NONE		X						X													
7d	64	Berrow and Brean	X		X			X	X							X						X			HIGH		X			X				X	F		X				X						X
7d	65	Weston Bay																		X						HIGH		X	X			X															
7d	66	Sand Bay	X											X											HIGH		X			X				X														
8b	67	Merthyr-mawr Warren																	X						X	LOW		X							X	X		X							X	F		
8b	68a	Kenfig Burrows																					X	X	MEDIUM	X		X						X			X						X			X		
8b	68b	Margam Burrows																	X								HIGH	X		X							F		X							X		X		X
8b	68c	Baglan Burrows					X							X											HIGH	X	X	X																	X		
8b	68d	Crymlyn Burrows					X		X																HIGH	X		X									X									X		X
8b	68e	Black Pill Burrows		X																						HIGH		X	X			X														X		
8b	69a	Pennard Burrows																				X		X		NONE		X											X			X	X		X				
8b	69b	Penmaen Burrows																		X		X				NONE								X				X										
8b	69c	Nicholaston Burrows																				X				NONE									X			X										
8b	69d	Oxwich Burrows																						X		LOW		X											X						X				
8b	70	Port-Eynon Bay																		X	X						LOW		X			X								X	X							F		
8c	71	Rhossili Bay																							LOW									X			X	X									
8c	72a	Broughton Burrows, Delvid Burrows and Hills Burrows							X																LOW					X				X			X										
8c	72b	Whiteford Burrows																	X				X		NONE								X	X			X						X	X			
8c	73	Pembrey Burrows	X				X		X					X					X	X						HIGH		X	X	X		X					F		X	X		X				X	X		
8c	74	Laugharne Burrows and Pendine Burrows			X				X					X											HIGH		X		X					X			X								X		
8c	75	The Burrows, Tenby			X				X												X				MEDIUM			X	X	X								X				X						
8c	76	Lydstep Haven			X				X																NONE					X							X	X									
8c	77	Manorbier Bay																		X	X				NONE								X				X										
8c	78	Freshwater East	X											X		X					X				LOW		X											X										X	
8c	79	Stackpole Warren																X	X						X		NONE								X				X						X	X			
8d	80a	Linney Burrows and Brownslade Burrows																						X		NONE									X	F		X						X		X		
8d	80b	Gupton Burrows, Broomhill Burrows and Kilpaison Burrows												X									X		NONE									X	X		X						X				
8d	81	The Burrows, Whitesands Bay							X											X						NONE						X						X										
9a	82	Newport Bay																		X	X						LOW		X				X						X				X						
9a	83a	Poppit Sands							X																LOW		X											X										X	
9a	83b	Towyn Warren							X											X						NONE								X				X	X									
9a	84	Ynyslas																		X	X	X					LOW		X			X				X			X								F		
9a	85	Aberdovey to Tywyn											X	X	X												MEDIUM		X	X						X				X			X						
9a	86a	Fairbourne spit																			X						NONE								X				X										
9a	86b	Barmouth	X						X											X						NONE								X													X		
9a	87	Morfa Dyffryn							X					X		X				X		X		X		HIGH		X	X	X	X				X			X						X		X		
9a	88a	Morfa Harlech												X		X				X				X		HIGH		X			X				X			X				X		X				
9b	88b	Morfa Bychan												X						X	X						MEDIUM		X			X	X							X	X									
9b	89	Morfa Abererch												X						X						MEDIUM			X		X				X			X										
9b	90	Pwllheli and Traeth Crugan							X					X						X	X	X		X		HIGH		X	X			X			X			X						X				
9b	91a	The Warren, Abersoch							X					X											LOW					X				X				X									
9b	91b	Morfa Gors	X			X			X					X		X									MEDIUM		X							X				X			X						
9b	92	Tai Morfa																						X		NONE		X							X			X						X				
10a	93	Morfa Dinlle																							LOW									X											F		
10b	94	Newborough Warren							X										X	X				X	X	LOW		X							X	X		X						X	X			
10b	95	Porth Twyn-mawr																						X		NONE									X	F		X						X				
10b	96	Tywyn Aberffraw												X		X				X				X		LOW									X	X		X						X				
10b	97a	Tywyn Fferam																							LOW									X														
10b	97b	Tywyn Llyn												X											LOW		X							X														
10b	98	Tywyn Trewan	X			X							X				X						X		HIGH			X			X			X									X		X		X	
10b	99	Tywyn-gywyn																						X		NONE								X		X		X						X				
10b	100	Tywyn-mawr																							NONE					X				X														
10b	101a	Dulas Bay																						X		NONE									X									X				
10b	101b	Lligwy Bay												X						X						NONE									X														
10b	102	Red Wharf Bay																							NONE		X							X														
10c	103a	Conwy Morfa				X			X						X				X	X						HIGH			X		X											X						
10c	103b	Deganwy and Llandudno	X	X			X		X				X											MEDIUM		X	X			X											X						
11a	104a	Kinmel Dunes	X			X			X										X						HIGH		X	X																	X	X	
11a	104b	Rhyl to Prestatyn	X			X	X						X						X						HIGH		X	X		X											X					X	X	
11a	104c	Gronant Dunes and The Warren, Talacre	X				X	X	X				X						X		X				HIGH	X	X	X		X					F		X			X	X						
11a	105	Wirral Peninsula	X						X				X						X	X	X				MEDIUM		X	X			X							X				X						
11b	106a	Seaforth to Hightown	X					X									X									HIGH		X	X															X						X	
11b	106b	Hightown to Marshside	X									X		X	X				X				X			HIGH		X	X		X				X	X		X				X	X		X	X	X	X	
11b	107a	Lytham to Blackpool																							HIGH	X	X	X		X						X		X				X					X	X	
11b	107b	Fleetwood to Pilling	X			X																			HIGH		X	X			X							X										
11d	108	Walney Island																		X				X		LOW								X				X						X				
11d	109a	Sandscale Haws																		X	X	X		X		NONE									X			X						X				
11d	109b	Askam in Furness to Dunnerholme																							MEDIUM		X	X		X	X			X			X										
11d	109c	Hodbarrow																							LOW	X								X														
11d	109d	Haverigg Haws and Kirksanton Haws							X																MEDIUM	X	X			X				X			X										
11d	110a	Eskmeals Dunes																	X						MEDIUM			X	X									X							X			
11d	110b	Drigg Dunes																							LOW									X			X											X
11d	111	Seascale to Braystones			X																				LOW		X	X			X																	
11e	112	Maryport to Grune Point			X						X								X						HIGH		X	X		X	X			X	X		X										

Table 3.8 Conservation status of coastal sand dune systems in England and Wales (X: whole or part of the site is designated, A: adjacent area alongshore is designated, B: adjacent area to seaward or landward is designated)

DUNE SYSTEM			CONSERVATION DESIGNATIONS														
SUB-CELL	SITE	SITE NAME	BIOSPHERE RESERVE	NATIONAL NATURE RESERVE	LOCAL NATURE RESERVE	AREA OF OUTSTANDING NATURAL BEAUTY	HERITAGE COAST	SITE OF SPECIAL SCIENTIFIC INTEREST	RAMSAR SITE	SPECIAL PROTECTION AREA	SPECIAL AREA OF CONSERVATION	ENVIRONMENTALLY SENSITIVE AREA	GEOLOGICAL CONSERVATION REVIEW SITE	NATIONAL PARK	NATIONAL TRUST OWNERSHIP	WILDLIFE TRUST RESERVE	RSPB RESERVE
1a	1	Cocklawburn to Goswick		X		X	X	X	X	X	X		X			X	
1a	2	Holy Island		X		X	X	X	X	X	X		X				
1a	3a	Ross Links and Budle Bay west		X		X	X	X	X	X	X		X				
1a	3b	Budle Bay east		X		X	X	X	X	X	X		X				
1a	4	Bamburgh to Seahouses				X	X	X	A	A	X				X		
1a	5	Annstead Dunes				X	X	X	X	X	X				X	X	
1a	6	Beadnell Bay				X	X	X	X	X	X				X		
1a	7	Embleton Bay				X	X	X	X	X	X				X		
1a	8a+b	Sugar Sands and Howdiemont Sands				X	X	X	X	X	X						
1a	8c	Boulmer				X	X	X	X	X	X						
1a	9a	Alnmouth				X	X	X	B	B	A						
1a	9b	Buston Links				X	X	X	B	B	X				X		
1a	9c	Birling Links				X	X	X	B	B	X						
1a	10	Amble to Hauxley			X		X	X	X	X						X	
1a	11	Druridge Bay			X		X	X	B	B					X	X	
1a	12	Snab Point to Beacon Point			X			X	B	B							
1a	13	Beacon Point to Newbiggin Point						X	X	X							
1a	14	Newbiggin Bay						X	B	B							
1a	15a	North Seaton						X									
1a	15b	Cambois to North Blyth						X	X	X							
1a	16	South Blyth to Seaton Sluice			X			X									
1a	17c	Long Sands						X	B	B							
1b	18	South Shields						A	B	B							
1b	19	Whitburn Bay						X	X	X							
1c	20	Hart Warren Dunes		X	X		X	X	X	X	B						
1c	21a	Carr House Sands and Seaton Dunes		X	X			X	X	X							
1c	21b	Coatham Sands						X	X	X						X	
1c	21c	Redcar to Marske-by-the-Sea						B	B		B						
2a	22	Spurn Peninsula		X			X	X	X	X			X			X	
2b	23	Cleethorpes and Humberston			X			X	X	X							
2b	24	Horse Shoe Point						X	X	X							
2c	25	Somercotes Haven to Mablethorpe		X				X	X	X	X					X	
2c	26	Sutton on Sea to Chapel St Leonards						X								A	
2c	27	Seathorne to Gibraltar Point		X				X	X	X	X		X				
3a	28	Old Hunstanton to Holme Dunes		X		X	X	X	X	X	X		X			X	
3a	29	Brancaster Bay				X	X	X	X	X	X		X		X		X
3a	30	Scolt Head Island	X	X		X	X	X	X	X	X		X		X		
3a	31	Holkham Bay	X	X		X	X	X	X	X	X		X				
3a	32	Wells-next-the-Sea to Morston	X	X		X	X	X	X	X	X		X				
3a	33	Blakeney Point	X	X		X	X	X	X	X	X		X		X		
3b	34a	Happisburgh to Winterton Ness				X		X		A	X	X		X			
3b	34b	Winterton Ness to Hemsby		X				X		A	X		X				
3b	34c	Caister-on-Sea to Great Yarmouth						X		X							X
3b	35a	Gunton Denes and Lowestoft Denes			X			B									
3b	35b	Kessingland		X		X	X	X		X	X	B					
3b	35c	Covehithe Broad		X		X	X	X		X	X						
3b	35d	Southwold				X	X	B				B					
3b	35e	Walberswick				X	X	A	A	A	A	A				A	
3b	35f	Minsmere to Sizewell				X	X	X	X	X	X	X					X
3b	35g	Thorpeness			A	X	X	X				B				X	X
4b	36	Sandwich Bay		X	X			X	X	X	X				X	X	
4c	37	Romney Sands						X			X						
4c	38	Camber Sands						X		A	A						
4d	39b	West Beach, Littlehampton			X			X									
5a	40	East Head, West Wittering				X		X	X	X	X		X		X		
5a	41	Sinah Common, Hayling Island						X	A	A	A						X
5f	42a	Sandbanks						B	B	B							
5f	42b	Studland		X			X	X	X	X	X		X		X		
6a	43a	The Maer, Exmouth			X	A		X	X	X							
6b	43b	Dawlish Warren		X	X			X	X	X	X		X			X	
6c	44	Bigbury Bay				X	X										
6d	45	Par Sands			X												
6d	46	Kennack Towans		X		X		X			X						
6e	47	The Towans, Mullion				X	X	X			X				X		
6e	48	Praa Sands				X											
6e	49	Marazion				X		A		A							A
7a	50	Whitesand Bay				X	X										
7a	51a	Lelant Towans						X									X
7a	51b	Hayle Towans, Upton Towans and Gwithian Towans			X			X					X			X	B
7a	51c	Godrevy Towans			X			B							X		
7a	52	Porth Towan						X									
7a	53	Perran Bay						X			X						
7a	54	Holywell Bay						X			B				X		
7a	55	Crantock Bay													X		
7a	56	Fistral Bay															
7a	57a	Mawgan Porth															
7a	57b	Constantine Bay				X		X									
7b	58b	Rock to Daymer Bay						X									
7b	59	Widemouth Bay						A									

Table 3.8 continued.

DUNE SYSTEM			CONSERVATION DESIGNATIONS														
SUB-CELL	SITE	SITE NAME	BIOSPHERE RESERVE	NATIONAL NATURE RESERVE	LOCAL NATURE RESERVE	AREA OF OUTSTANDING NATURAL BEAUTY	HERITAGE COAST	SITE OF SPECIAL SCIENTIFIC INTEREST	RAMSAR SITE	SPECIAL PROTECTION AREA	SPECIAL AREA OF CONSERVATION	ENVIRONMENTALLY SENSITIVE AREA	GEOLOGICAL CONSERVATION REVIEW SITE	NATIONAL PARK	NATIONAL TRUST OWNERSHIP	WILDLIFE TRUST RESERVE	RSPB RESERVE
7b	60	Bude						A			A						
7c	61a	Northam Burrows				X		X									
7c	61b	Instow Sands						X									
7c	61c	Braunton Burrows	X			X	X	X			X		X				
7c	62	Croyde Burrows				X	X	X									
7c	63	Woolacombe Warren				X	X	B							X		
7d	64	Berrow and Brean		A	X			X	A	A							
7d	65	Weston Bay						X	X	X							
7d	66	Sand Bay						X	X	X							
8b	67	Merthyr-mawr Warren		X			X	X			X						
8b	68a	Kenfig Burrows		X	X			X			X						
8b	68b	Margam Burrows		B	B			B			B						
8b	68c	Baglan Burrows						B									
8b	68d	Crymlyn Burrows						X									
8b	68e	Black Pill Burrows				B		A									
8b	69a	Pennard Burrows				X	X	X							X		
8b	69b	Penmaen Burrows		B		X	X	X							X		
8b	69c	Nicholaston Burrows		X		X	X	X			B		X		X		
8b	69d	Oxwich Burrows		X		X	X	X			B		X		B		
8b	70	Port-Eynon Bay				X	X	B			A				B	X	
8c	71	Rhossilli Bay				X	X	B		A	A		X		A		
8c	72a	Broughton Burrows, Delvid Burrows and Hills Burrows		X		X	X	X	A	A	X		X				
8c	72b	Whiteford Burrows		X		X	X	X	X	X	X		X		X		
8c	73	Pembrey Burrows			X			X	X	X	X		X				
8c	74	Laugharne Burrows and Pendine Burrows						X		A	X		X				
8c	75	The Burrows, Tenby					X	X			B			X			
8c	76	Lydstep Haven					X	X			B			X	B		
8c	77	Manorbier Bay					X	X			X			X			
8c	78	Freshwater East					X	X			X			X	B		
8c	79	Stackpole Warren		X			X	X		X	X			X	X		
8d	80a	Linney Burrows and Brownslade Burrows					X	X		X	X			X	B		
8d	80b	Gupton Burrows, Broomhill Burrows and Kilpaison Burrows					X	X		X	X			X	X		
8d	81	The Burrows, Whitesands Bay					X	X		X	X	X		X			
9a	82	Newport Bay						B				X		X			
9a	83a	Poppit Sands					X	X			X	X		X			
9a	83b	Towyn Warren						X			X						
9a	84	Ynyslas	X	X				X	X	A	X		X				
9a	85	Aberdovey to Tywyn						X	A	A	X			X			
9a	86	Mawddach Estuary						X			X						
9a	87a	Morfa Dyffryn		X				X			X		X	X			
9a	87b	Llandanwg						X			X		X	X	X		
9a	88a	Morfa Harlech		X				X			X		X	X			
9b	88b	Morfa Bychan						X			X	X			B	X	
9b	89	Morfa Abererch						X			A	X					
9b	90	Pwllheli and Traeth Crugan				B		X			X	X					
9b	91a	The Warren, Abersoch				X		B			A	X			X		
9b	91b	Morfa Gors				X		B			A	X					
9b	92	Tai Morfa				X	X	X		X	X	X					
10a	93	Morfa Dinlle			B			X			X		X				
10b	94	Newborough Warren		X		X		X			X	X	X				
10b	95	Porth Twyn-mawr				X	X	X				X					
10b	96	Tywyn Aberffraw				X	X	X			X	X	X				
10b	97a	Tywyn Fferam				X						X					
10b	97b	Tywyn Llyn				X		B				X					
10b	98	Tywyn Trewan				B		B		B		X					
10b	99	Tywyn-gywyn				X		X				X					
10b	100	Tywyn-mawr				X						X					
10b	101a	Dulas Bay				X		X				X					
10b	101b	Lligwy Bay				X		X				X					
10b	102	Red Wharf Bay				X		B			A	X					
10c	103a	Conwy Morfa									A						
10c	103b	Deganwy and Llandudno									A						
11a	104a	Kinmel Dunes			X												
11a	104b	Rhyl to Prestatyn						B									
11a	104c	Gronant Dunes and The Warren, Talacre			X			X	X	X							X
11a	105	Wirral Peninsula						X	X	X						X	
11b	106a	Seaforth to Hightown						X	X	X	X					X	
11b	106b	Hightown to Marshside		X	X			X	X	X	X		X		X	X	X
11b	107a	Lytham to Blackpool			X			X	X	X							
11b	107b	Fleetwood to Pilling						X	X	X	X					X	
11d	108	Walney Island		X				X	X	X	X		X			X	
11d	109a	Sandscale Haws		X				X	X	X	X				X		
11d	109b	Askam in Furness to Dunnerholme						X	X	X	X						
11d	109c	Hodbarrow						X	X	X	X						X
11d	109d	Haverigg Haws and Kirksanton Haws						X	X	X	X						
11d	110a	Eskmeals Dunes						X			X			X		X	
11d	110b	Drigg Dunes			X			X			X			X			
11d	111	Seascale to Braystones															
11e	112	Maryport to Grune Point				X		X	X	X	X						

Table 3.9 Dune habitats expressed as area values and a percentage of the total area for dune systems in England and Wales and in each coastal cell. Mobility based on strandline, mobile dune, semi-fixed dune and bare sand. Stability based on fixed dune grassland, other grassland, sand sedge, dry heath, dry scrub/woodland and plantation woodland. Index of mobility/stability is the ratio of these two groups. Based on datafrom Radley (1994) and Dargie (1995).

HABITAT	TOTAL		CELL 1		CELL 2		CELL 3		CELL 4 & 5		CELL 6 & 7		CELL 8		CELL 9		CELL 10		CELL 11	
	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%	ha	%
STRANDLINE	86.6	0.4	1.7	0.1	4.5	0.3	27.9	2.5	11.8	1.5	3.1	0.1	3.4	0.1	8.5	0.7	4.2	0.2	21.5	0.5
MOBILE DUNE	1522.6	7.7	201.8	11.8	82.4	6.0	154.9	13.6	37.6	4.7	200.0	6.9	261.7	5.5	150.9	13.0	111.2	5.9	319.3	8.1
SEMI-FIXED DUNE	2992.1	15.2	198.4	11.6	51.2	3.7	197.5	17.4	37.8	4.8	380.4	13.0	814.7	17.1	205.8	17.7	309.5	16.6	792.2	20.2
FIXED DUNE GRASSLAND	4089.1	20.8	552.7	32.4	107.8	7.8	77.3	6.8	267.7	33.8	843.6	28.9	940.9	19.8	303.9	26.1	283.5	15.2	707.9	18.0
OTHER GRASSLAND	860.3	4.4	83.3	4.9	18.7	1.4	29.1	2.6	99.5	12.6	110.9	3.8	208.9	4.4	42.8	3.7	52.8	2.8	214.2	5.5
SAND SEDGE	350.7	1.8	11.5	0.7	1.0	0.1	213.0	18.7	14.6	1.8	3.5	0.1	4.8	0.1	1.9	0.2	11.3	0.6	85.5	2.2
DRY HEATH	208.1	1.1	1.8	0.1	0.0	0.0	28.3	2.5	8.9	1.1	66.1	2.3	27.2	0.6	4.2	0.4	4.9	0.3	66.8	1.7
DRY SCRUB/ WOODLAND	974.8	4.9	49.5	2.9	236.1	17.2	39.1	3.4	23.4	3.0	128.5	4.4	296.3	6.2	58.6	5.0	59.2	3.2	83.9	2.1
DUNE WETLAND	1600.5	8.1	94.6	5.6	51.9	3.8	68.2	6.0	16.9	2.1	236.4	8.1	395.9	8.3	144.5	12.4	181.3	9.7	408.6	10.4
PLANTATION WOODLAND	2144.9	10.9	13.7	0.8	0.0	0.0	98.1	8.6	3.6	0.5	1.2	0.0	1037.3	21.8	1.4	0.1	733.9	39.3	255.9	6.5
BARE SAND	385.2	2.0	18.8	1.1	13.2	1.0	32.7	2.9	6.8	0.9	104.2	3.6	56.0	1.2	50.9	4.4	19.2	1.0	83.0	2.1
OTHER	4482.1	22.8	476.1	27.9	809.2	58.8	170.1	15.0	262.5	33.2	840.2	28.8	716.6	15.0	191.3	16.4	97.9	5.2	885.6	22.6
TOTAL AREA	19697.1		1704.0		1376.0		1136.0		791.0		2918.0		4763.8		1164.6		1868.8		3924.4	
MOBILE	4986.5	25.3	420.7	24.7	151.3	11.0	413.0	36.4	94.0	11.9	687.7	23.6	1135.9	23.8	416.1	35.7	444.1	23.8	1216.0	31.0
STABLE	8628.1	43.8	712.6	41.8	363.7	26.4	484.8	42.7	417.6	52.8	1153.7	39.5	2515.3	52.8	412.8	35.4	1145.5	61.3	1414.3	36.0
INDEX of MOBILITY/ STABILITY	0.58		0.59		0.42		0.85		0.23		0.60		0.45		1.01		0.39		0.86	

Table 3.10 Sedimentological properties of coastal sand dune systems in England and Wales

DUNE SYSTEM			GRAIN SIZE				CALCIUM OXIDE			
SUB-CELL	**SITE**	**SITE NAME**	**AVERAGE (µm)**	**MIN (µm)**	**MAX (µm)**	**N**	**AVERAGE (%)**	**MIN (%)**	**MAX (%)**	**N**
1a	**1**	Cocklawburn to Goswick	345	259	420	12	0.71	0.48	1.00	4
1a	**2**	Holy Island	279	224	491	13	0.93	0.69	1.15	5
1a	**3a**	Ross Links and Budle Bay west	285	234	380	13	1.29	0.78	2.31	5
1a	**3b**	Budle Bay east	295	243	324	5	1.22	0.70	1.60	3
1a	**4**	Bamburgh to Seahouses	258	234	296	10	1.23	0.89	1.61	4
1a	**5**	Annstead Dunes	282	229	401	7	1.40	1.31	1.51	3
1a	**6**	Beadnell Bay	277	200	476	8	2.33	1.62	3.35	3
1a	**7**	Embleton Bay	348	242	483	5	2.61	1.91	3.20	3
1a	**8a+b**	Sugar Sands and Howdiemont Sands	394	343	440	7	4.01	3.38	5.00	3
1a	**8c**	Boulmer	285	213	370	4	2.77	2.31	3.02	3
1a	**9a**	Alnmouth	237	224	249	3	2.54	2.09	2.86	3
1a	**9b**	Buston Links	272	240	295	4	2.21	1.77	2.53	3
1a	**9c**	Birling Links	399	311	481	6	2.70	2.13	3.84	3
1a	**10**	Amble to Hauxley	266	214	347	5	1.50	1.11	1.79	3
1a	**11**	Druridge Bay	312	213	421	10	1.62	1.10	1.96	4
1a	**12**	Snab Point to Beacon Point	368	327	421	6	2.00	1.78	2.42	3
1a	**13**	Beacon Point to Newbiggin Point	358	346	368	3	3.07	2.12	3.63	3
1a	**14**	Newbiggin Bay	405	369	441	2	3.39	2.67	4.11	2
1a	**15a**	North Seaton	256	238	281	5	2.48	1.85	3.67	3
1a	**15b**	Cambois to North Blyth	326	265	367	4	2.21	1.09	3.25	3
1a	**16**	South Blyth to Seaton Sluice	404	289	602	8	1.38	0.78	1.74	3
1a	**17c**	Long Sands	304	278	322	4	1.30	1.09	1.50	3
1b	**18**	South Shields	366	322	431	5	1.51	1.01	1.98	3
1b	**19**	Whitburn Bay	279	262	292	3	3.33	2.13	4.15	3
1c	**20**	Hart Warren Dunes	324	263	397	9	6.53	4.29	8.30	4
1c	**21a**	Carr House Sands and Seaton Dunes	235	206	276	8	2.51	2.07	3.08	4
1c	**21b**	Coatham Sands	243	210	301	13	2.91	2.41	3.55	5
1c	**21c**	Redcar to Marske-by-the-Sea	233	185	268	6	2.96	2.48	3.75	3
2a	**22**	Spurn Peninsula	412	321	656	8	2.02	1.89	2.19	5
2b	**23**	Cleethorpes and Humberston	214	172	226	8	2.95	2.81	3.13	3
2b	**24**	Horse Shoe Point	267	264	270	2	2.53	2.33	2.72	2
2c	**25**	Somercotes Haven to Mablethorpe	249	211	352	27	2.17	1.01	2.92	8
2c	**26**	Sutton on Sea to Chapel St Leonards	364	172	538	20	2.21	1.90	2.75	4
2c	**27**	Seathorne to Gibraltar Point	320	249	493	19	2.68	2.23	3.53	7
3a	**28**	Old Hunstanton to Holme Dunes	317	244	442	9	2.13	1.45	2.79	4
3a	**29**	Brancaster Bay	256	215	277	8	1.24	1.15	1.40	4
3a	**30**	Scolt Head Island	316	211	455	7	1.20	1.18	1.22	3
3a	**31**	Holkham Bay	268	244	334	13	0.49	0.20	1.18	6
3a	**32**	Wells-next-the-Sea to Morston	261	151	320	9	0.13	0.04	0.36	4
3a	**33**	Blakeney Point	277	254	304	11	0.20	0.03	0.39	5
3b	**34a**	Happisburgh to Winterton Ness	366	320	491	10	0.41	0.21	0.54	4
3b	**34b**	Winterton Ness to Hemsby	380	302	477	12	0.87	0.05	3.76	5
3b	**34c**	Caister-on-Sea to Great Yarmouth	382	333	432	15	0.25	0.02	0.78	6
3b	**35a**	Gunton Denes and Lowestoft Denes	377	278	478	9	0.04	0.01	0.08	4
4b	**36**	Sandwich Bay	311	204	423	4	5.20	4.03	6.49	3
4c	**37**	Romney Sands	207	193	219	8	2.00	1.49	2.94	3
4c	**38**	Camber Sands	222	204	257	11	1.65	1.06	2.11	3
4d	**39b**	West Beach, Littlehampton	202	183	221	8	0.73	0.20	1.40	3
5a	**40**	East Head, West Wittering	191	117	222	9	0.16	0.10	0.19	3
5a	**41**	Sinah Common, Hayling Island	204	185	214	9	0.02	0.01	0.02	3
5f	**42b**	Studland	236	206	314	18	0.06	0.05	0.06	7
6b	**43b**	Dawlish Warren	285	222	382	16	0.21	0.04	0.41	5
6c	**44**	Bigbury Bay	500	229	863	30	13.80	11.59	15.79	7
6d	**45**	Par Sands	443	248	686	8	0.99	0.37	1.79	4
6d	**46**	Kennack Towans	381	288	524	6	17.26	15.66	18.19	3
6e	**47**	The Towans, Mullion	560	395	739	15	27.94	23.36	31.20	5
6e	**48**	Praa Sands	529	459	594	7	13.56	7.57	19.80	3
6e	**49**	Marazion	551	457	672	6	3.86	2.41	6.19	3
7a	**50**	Whitesand Bay	524	435	616	15	14.67	11.54	17.70	4
7a	**51a**	Lelant Towans	334	293	412	10	18.47	3.69	27.14	3
7a	**51b**	Hayle Towans, Upton Towans and Gwithian Towans	366	286	499	39	27.23	19.38	35.53	9
7a	**51c**	Godrevy Towans	320	265	381	5	33.74	30.97	36.61	3
7a	**52**	Porth Towan	412	381	481	6	22.91	21.43	25.08	3
7a	**53**	Perran Bay	303	249	365	25	25.47	19.99	29.16	7
7a	**54**	Holywell Bay	427	326	596	11	33.46	31.57	35.26	3
7a	**55**	Crantock Bay	295	261	354	11	27.71	26.53	28.74	3
7a	**56**	Fistral Bay	549	466	612	6	31.61	30.73	32.69	3
7a	**57b**	Constantine Bay	565	393	740	12	36.04	34.86	36.69	4
7b	**58b**	Rock to Daymer Bay	300	243	399	29	32.49	29.26	33.80	9
7b	**59**	Widemouth Bay	468	401	550	6	16.40	14.16	18.24	3
7b	**60**	Bude	360	337	389	4	20.17	19.56	21.59	3
7c	**61a**	Northam Burrows	218	192	254	16	8.15	7.12	9.88	4
7c	**61b**	Instow Sands	217	199	233	10	8.35	7.91	8.81	3
7c	**61c**	Braunton Burrows	227	159	421	33	7.67	6.12	10.50	8

Table 3.10 continued.

DUNE SYSTEM			GRAIN SIZE				CALCIUM OXIDE			
SUB-CELL	SITE	SITE NAME	AVERAGE (µm)	MIN (µm)	MAX (µm)	N	AVERAGE (%)	MIN (%)	MAX (%)	N
7c	**62**	Croyde Burrows	322	292	355	9	5.24	5.17	5.32	3
7c	**63**	Woolacombe Warren	271	252	292	11	4.45	3.17	6.48	3
7d	**64**	Berrow and Brean	184	164	203	13	5.78	4.84	6.91	5
7d	**65**	Weston Bay	175	170	184	3	5.58	5.02	6.36	3
7d	**66**	Sand Bay	265	195	350	6	5.14	3.96	6.88	3
8b	**67**	Merthyr-mawr Warren	265	206	347	11	3.45	2.39	4.83	3
8b	**68a**	Kenfig Burrows	362	227	675	15	2.75	1.93	3.67	5
8b	**68b**	Margam Burrows	242	234	256	5	2.70	2.26	3.03	3
8b	**68c**	Baglan Burrows	261	232	291	10	3.29	2.36	4.01	4
8b	**68d**	Crymlyn Burrows	270	242	301	9	3.33	3.19	3.55	3
8b	**68e**	Black Pill Burrows	280	225	300	5	3.68	3.37	3.89	3
8b	**69a**	Pennard Burrows	290	251	319	9	1.61	0.29	3.79	4
8b	**69b**	Penmaen Burrows	281	270	292	7	2.47	1.54	4.12	3
8b	**69c**	Nicholaston Burrows	272	250	289	8	2.30	1.49	3.21	3
8b	**69d**	Oxwich Burrows	252	234	309	9	5.30	4.77	5.80	4
8b	**70**	Port-Eynon Bay	309	257	368	5	3.93	3.13	4.78	3
8c	**71**	Rhossilli Bay	246	197	293	12	5.22	4.06	6.50	5
8c	**72a**	Broughton Burrows, Delvid Burrows and Hills Burrows	237	231	244	5	5.54	5.29	6.00	3
8c	**72b**	Whiteford Burrows	238	211	282	11	4.26	3.08	5.21	5
8c	**73**	Pembrey Burrows	178	150	225	21	5.38	3.95	6.22	6
8c	**74**	Laugharne Burrows and Pendine Burrows	182	171	201	17	4.88	4.24	6.13	5
8c	**75**	The Burrows, Tenby	253	227	296	7	6.02	5.06	6.60	3
8c	**76**	Lydstep Haven	225	215	236	3	10.25	8.75	12.48	3
8c	**77**	Manorbier Bay	392	308	574	5	8.16	6.80	9.81	3
8c	**78**	Freshwater East	313	253	368	9	11.42	7.83	13.69	4
8c	**79**	Stackpole Warren	329	257	380	15	11.91	8.21	18.33	9
8d	**80a**	Linney Burrows and Brownslade Burrows	478	278	1066	21	9.47	6.50	12.21	7
8d	**80b**	Gupton Burrows, Broomhill Burrows and Kilpaison Burrows	282	252	298	7	11.20	10.59	11.55	3
8d	**81**	The Burrows, Whitesands Bay	254	224	295	7	4.19	3.51	4.60	3
9a	**82**	Newport Bay	204	183	232	8	1.01	0.37	1.37	3
9a	**83a**	Poppit Sands	186	172	199	4	1.24	0.97	1.39	3
9a	**83b**	Towyn Warren	210	200	224	3	0.86	0.68	1.06	3
9a	**84**	Ynyslas	210	193	235	7	1.69	1.45	1.83	3
9a	**85**	Aberdovey to Tywyn	254	227	312	8	1.03	0.86	1.17	3
9a	**86b**	Barmouth	220	205	231	4	0.91	0.51	1.33	3
9a	**87**	Morfa Dyffryn	238	210	283	15	1.20	0.93	1.49	4
9a	**88a**	Morfa Harlech	206	172	246	17	1.34	1.11	1.70	5
9b	**88b**	Morfa Bychan	175	159	196	12	0.59	0.31	0.87	3
9b	**89**	Morfa Abererch	373	202	476	13	0.36	0.15	0.51	3
9b	**90**	Pwllheli and Traeth Crugan	438	387	513	12	0.44	0.32	0.55	3
9b	**91a**	The Warren, Abersoch	261	236	302	8	1.82	1.71	1.93	3
9b	**91b**	Morfa Gors	256	240	272	6	2.38	1.63	3.33	3
9b	**92**	Tai Morfa	323	274	420	8	0.85	0.16	1.24	3
10a	**93**	Morfa Dinlle	225	173	311	18	1.41	1.12	1.68	5
10b	**94**	Newborough Warren	215	175	332	58	1.85	1.24	3.09	11
10b	**95**	Porth Twyn-mawr	402	183	492	9	2.25	1.12	3.23	4
10b	**96**	Tywyn Aberffraw	191	171	229	16	2.09	1.86	2.55	4
10b	**97a**	Tywyn Fferam	401	257	583	6	1.98	1.58	2.68	3
10b	**97b**	Tywyn Llyn	307	245	379	8	2.04	1.33	2.48	3
10b	**98**	Tywyn Trewan	254	167	437	14	1.95	1.38	2.31	4
10b	**99**	Tywyn-gywyn	238	186	378	9	0.66	0.27	1.13	4
10b	**100**	Tywyn-mawr	248	220	304	7	4.30	2.71	6.25	3
10b	**101a**	Dulas Bay	435	322	616	5	1.88	0.58	2.59	3
10b	**101b**	Lligwy Bay	323	297	379	6	1.58	1.19	2.11	3
10b	**102**	Red Wharf Bay	247	194	356	9	3.49	0.57	0.71	3
10c	**103a**	Conwy Morfa	273	257	296	8	0.65	0.57	0.71	3
10c	**103b**	Deganwy and Llandudno	256	225	334	9	1.64	1.06	2.39	3
11a	**104a**	Kinmel Dunes	287	279	305	10	3.72	3.34	4.20	3
11a	**104b**	Rhyl to Prestatyn	291	278	312	7	2.52	2.32	2.71	3
11a	**104c**	Gronant Dunes and The Warren, Talacre	309	248	357	21	3.08	2.64	3.94	5
11a	**105**	Wirral Peninsula	223	177	279	24	1.90	1.52	2.35	7
11b	**106a**	Seaforth to Hightown	232	213	257	10	1.36	1.25	1.45	3
11b	**106b**	Hightown to Marshside	254	198	352	17	1.80	1.36	2.41	6
11b	**107a**	Lytham to Blackpool	245	215	276	12	1.53	1.07	1.94	4
11b	**107b**	Fleetwood to Pilling	340	322	363	4	1.66	0.17	2.23	4
11d	**108**	Walney Island	241	207	282	14	0.80	0.24	1.89	6
11d	**109a**	Sandscale Haws	228	196	274	15	0.65	0.37	1.05	5
11d	**109b**	Askam in Furness to Dunnerholme	230	204	263	7	0.61	0.34	1.08	3
11d	**109c**	Hodbarrow	257	241	275	4	0.65	0.48	0.75	3
11d	**109d**	Haverigg Haws and Kirksanton Haws	239	219	284	9	0.65	0.51	0.75	3
11d	**110a**	Eskmeals Dunes	255	214	291	7	0.74	0.33	1.20	3
11d	**110b**	Drigg Dunes	296	253	337	12	0.48	0.22	0.74	5
11d	**111**	Seascale to Braystones	399	263	485	5	0.48	0.14	0.72	3
11e	**112**	Maryport to Grune Point	412	243	800	16	1.47	0.44	4.07	5

Figures

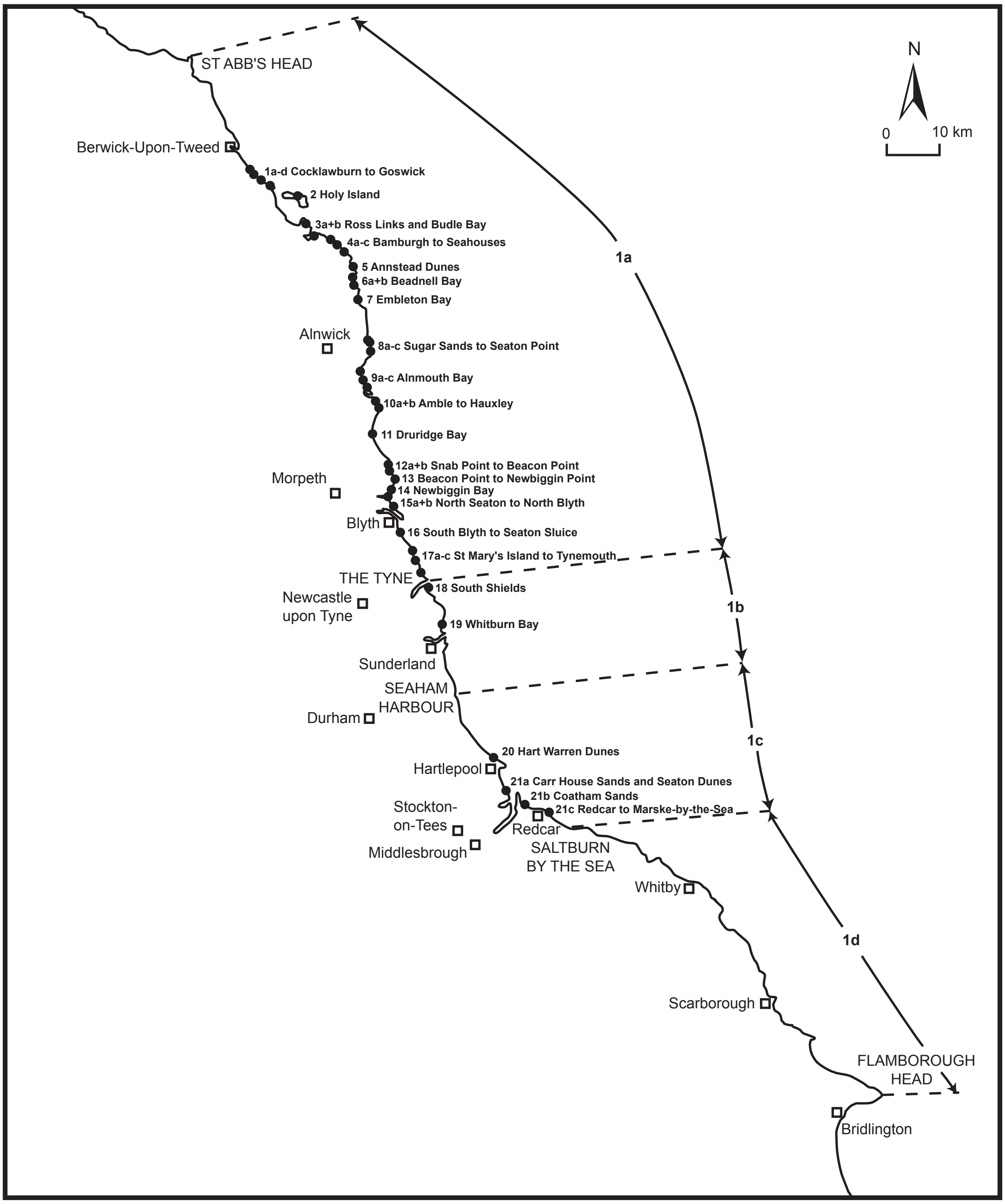


Figure 3.1 Location of the sand dune sites in Cell 1 (St Abb's Head to Flamborough Head)

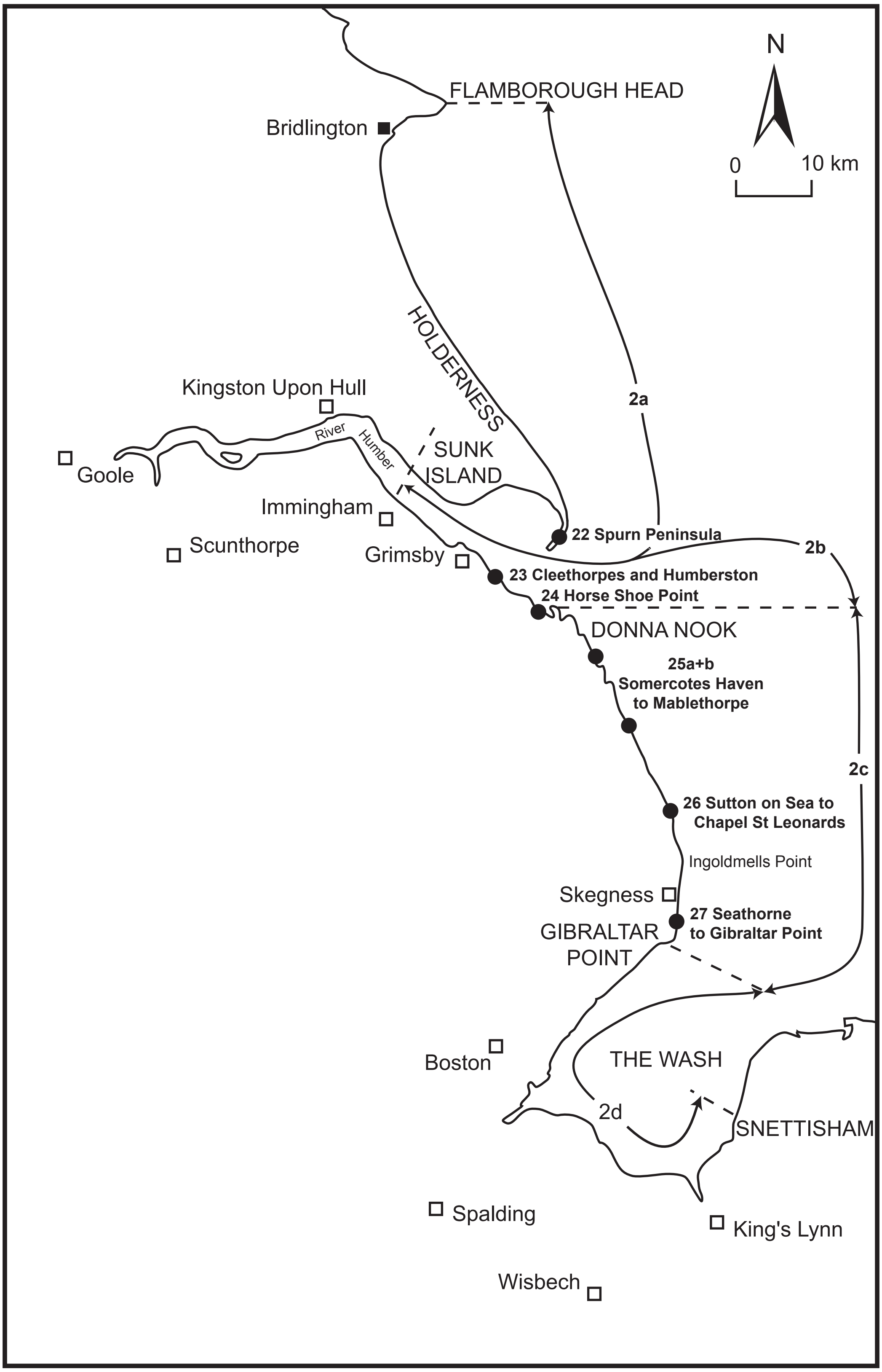


Figure 3.2 Location of the sand dune sites in Cell 2 (Flamborough Head to The Wash)

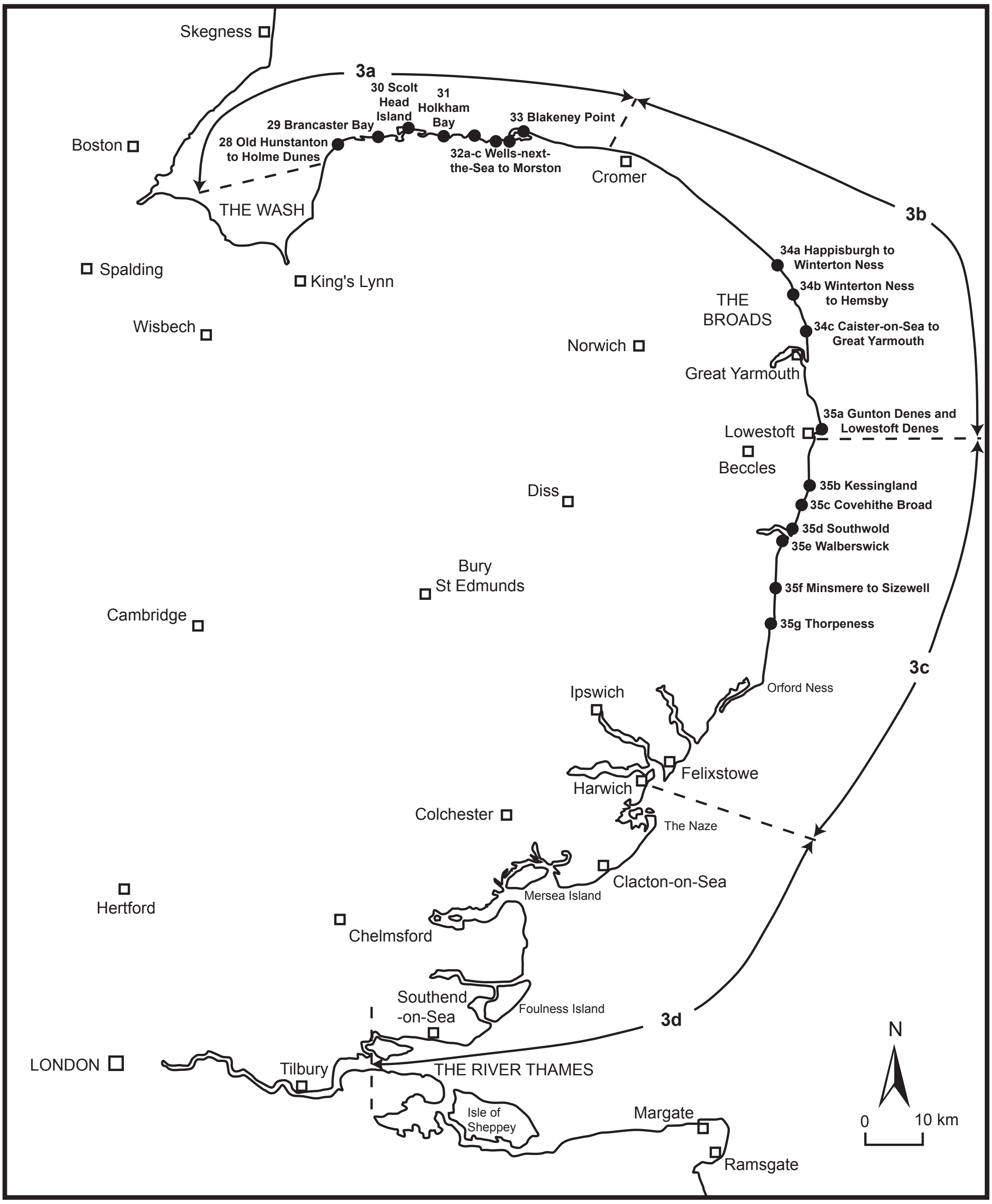


Figure 3.3 Location of the sand dune sites in Cell 3 (The Wash to The Thames)

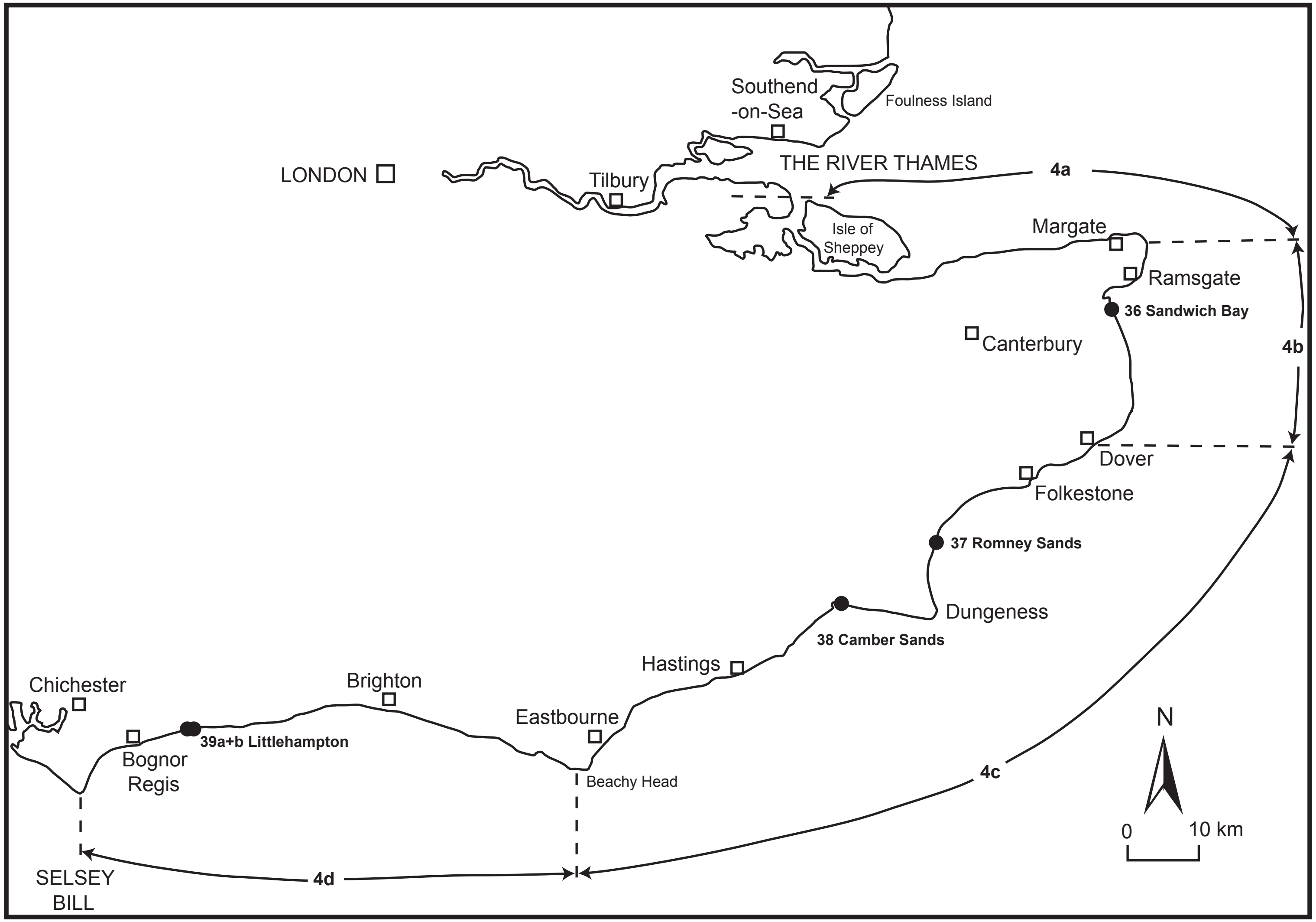


Figure 3.4 Location of the sand dune sites in Cell 4 (The Thames to Selsey Bill)

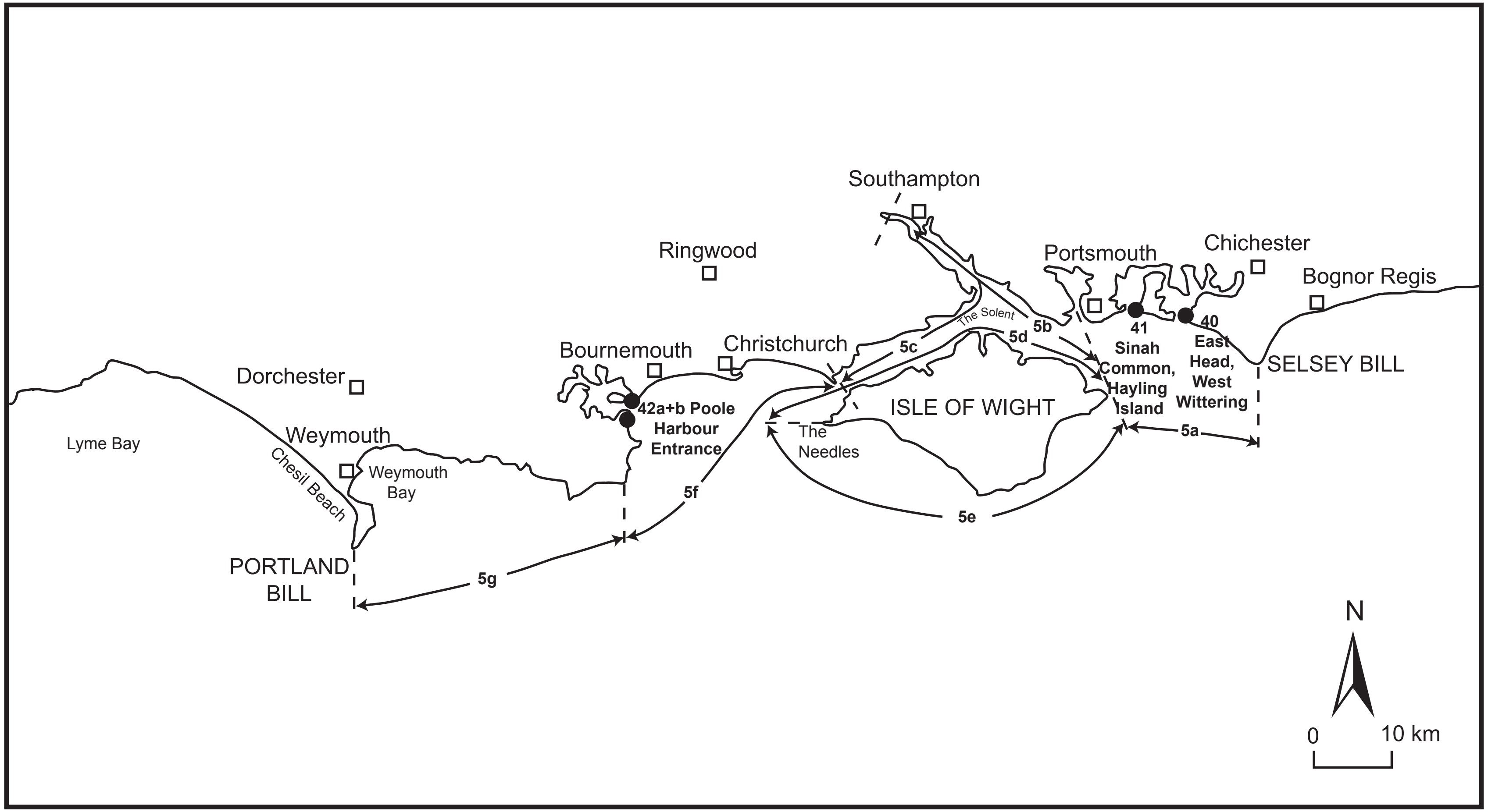


Figure 3.5 Location of the sand dune sites in Cell 5 (Selsey Bill to Portland Bill)

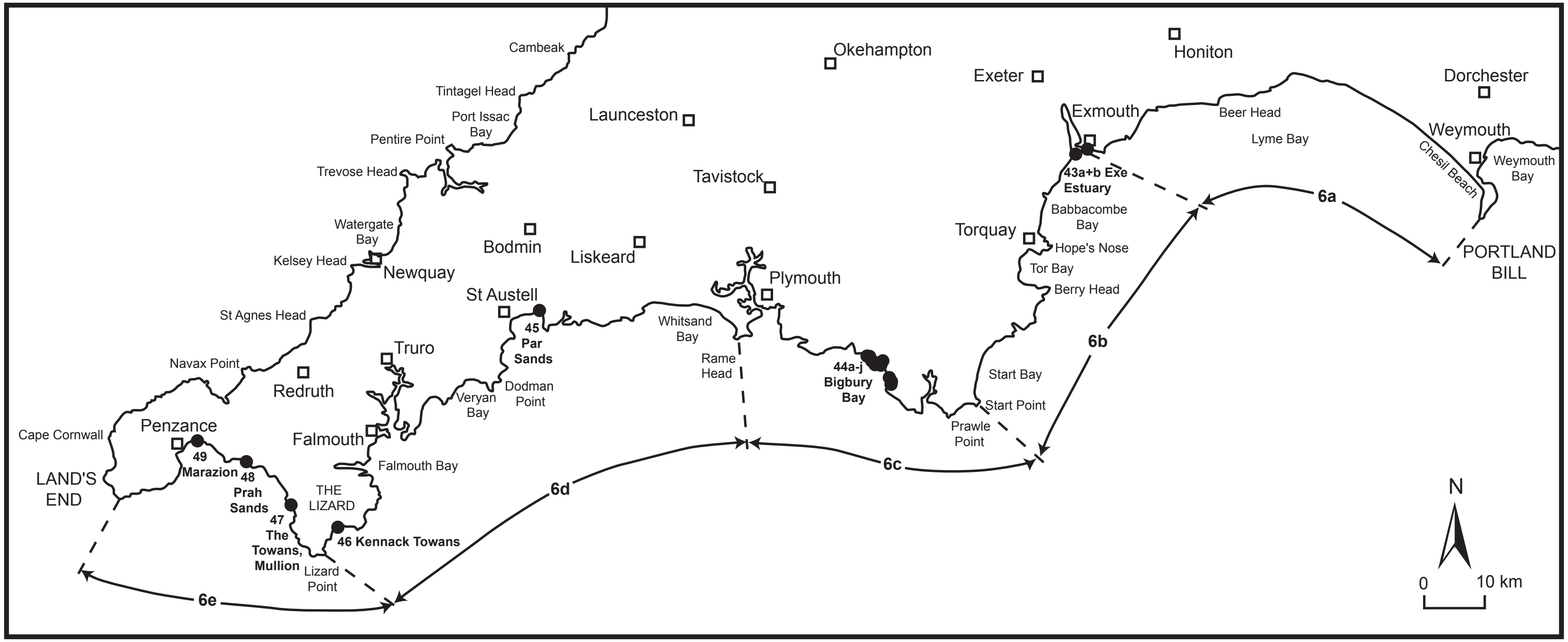


Figure 3.6 Location of the sand dune sites in Cell 6 (Portland Bill to Land's End)

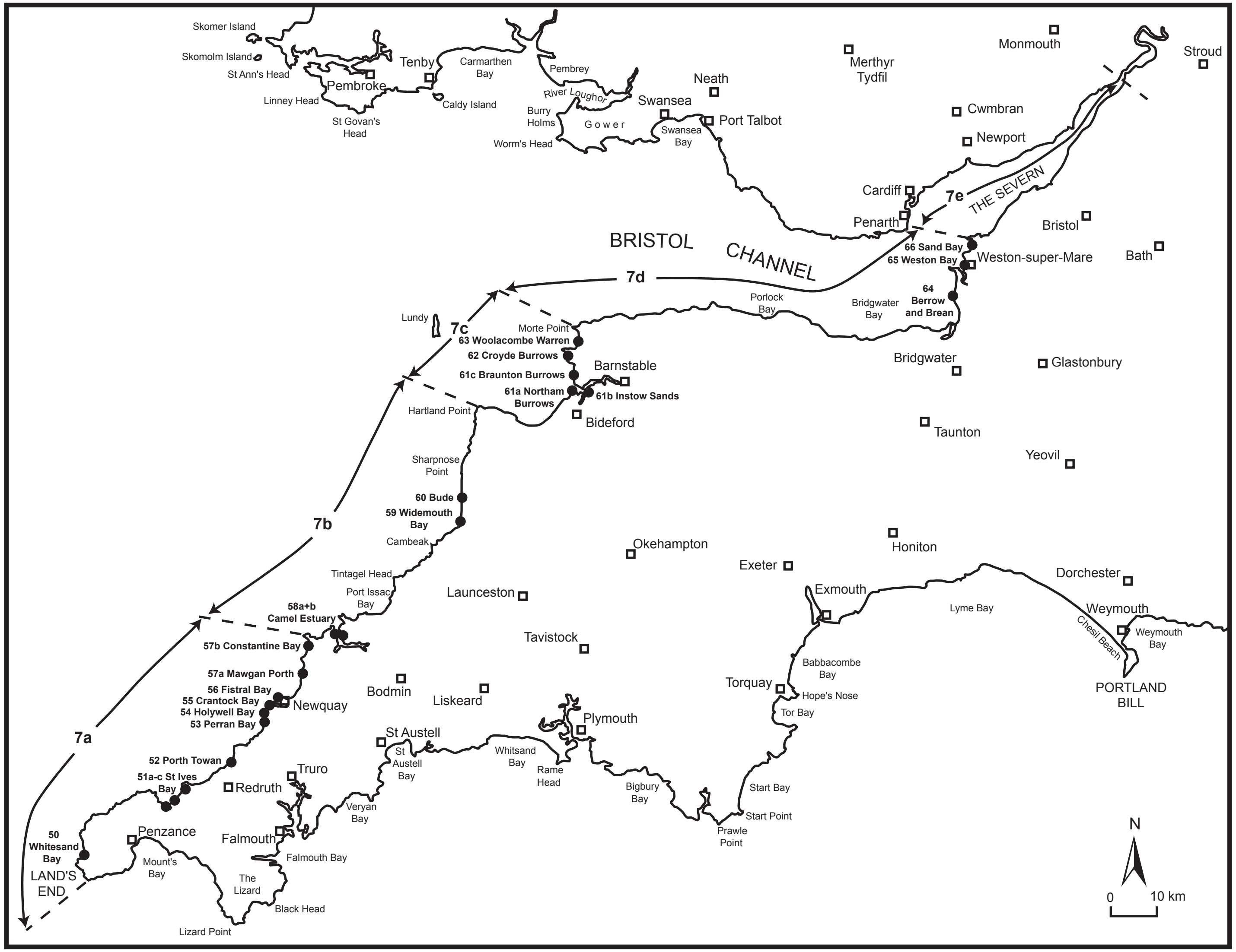


Figure 3.7 Location of the sand dune sites in Cell 7 (Land's End to The Severn)

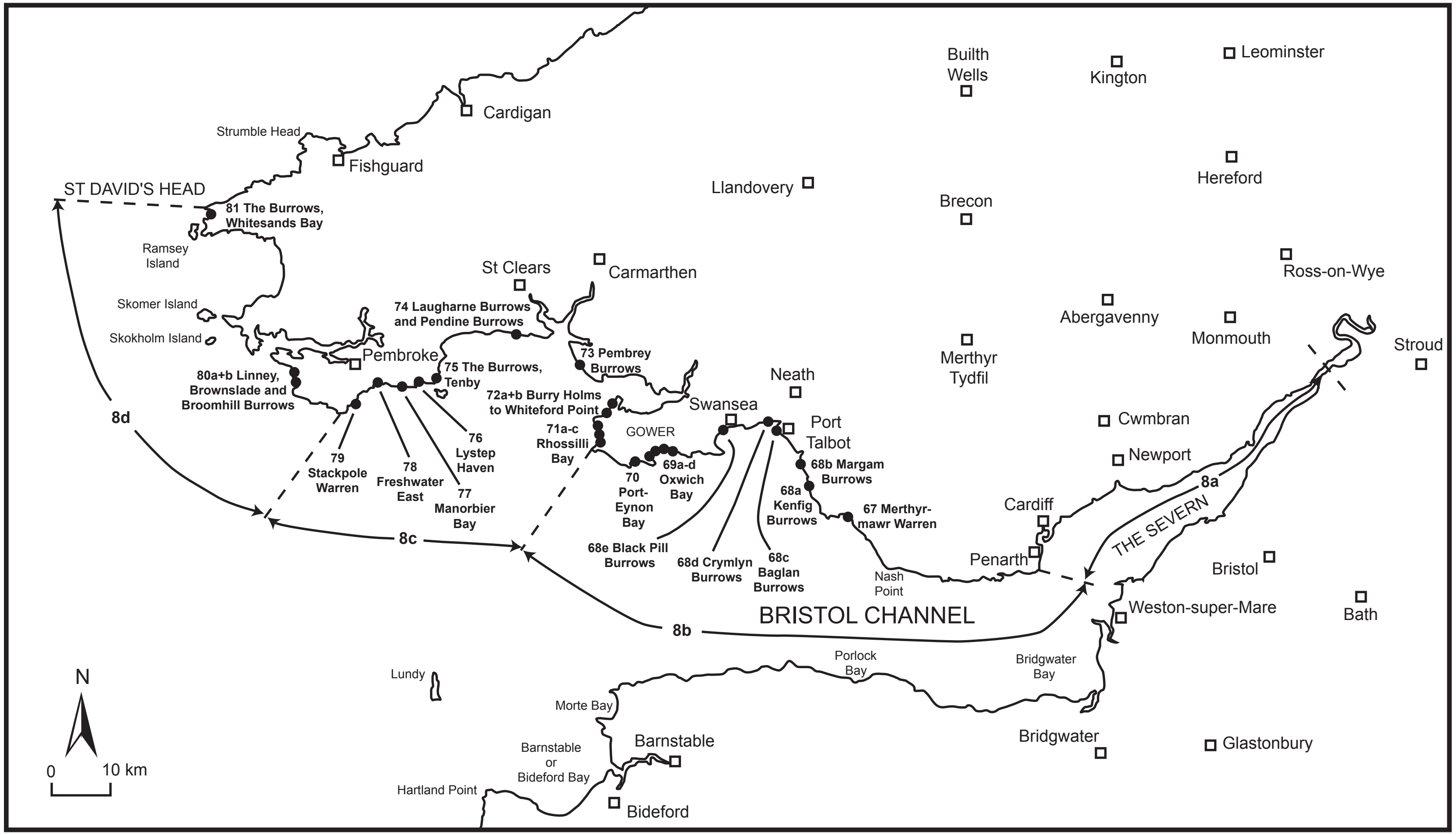


Figure 3.8 Location of the sand dune sites in Cell 8 (The Severn to St David's Head)

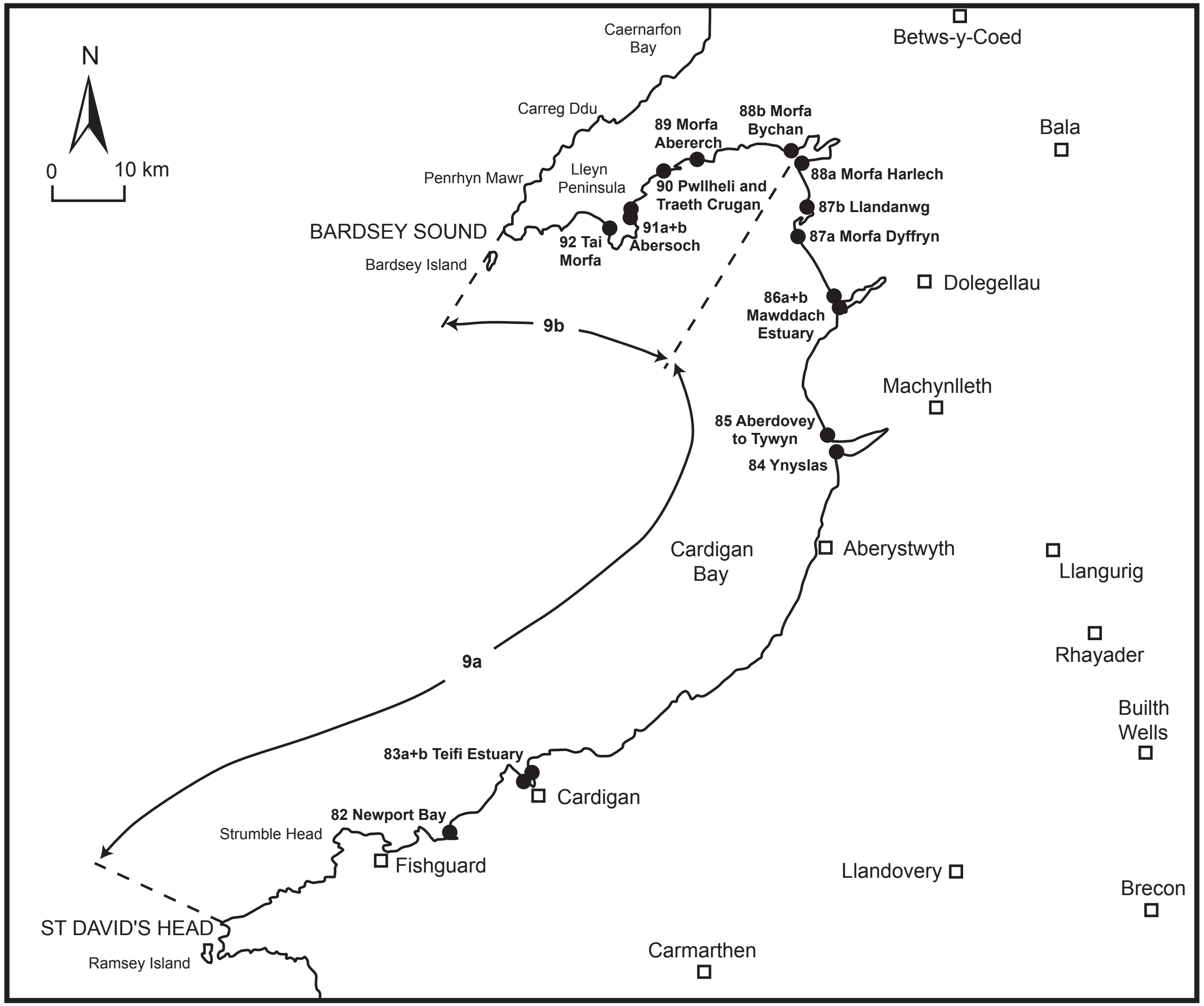


Figure 3.9 Location of the sand dune sites in Cell 9 (St David's Head to Bardsey Sound)

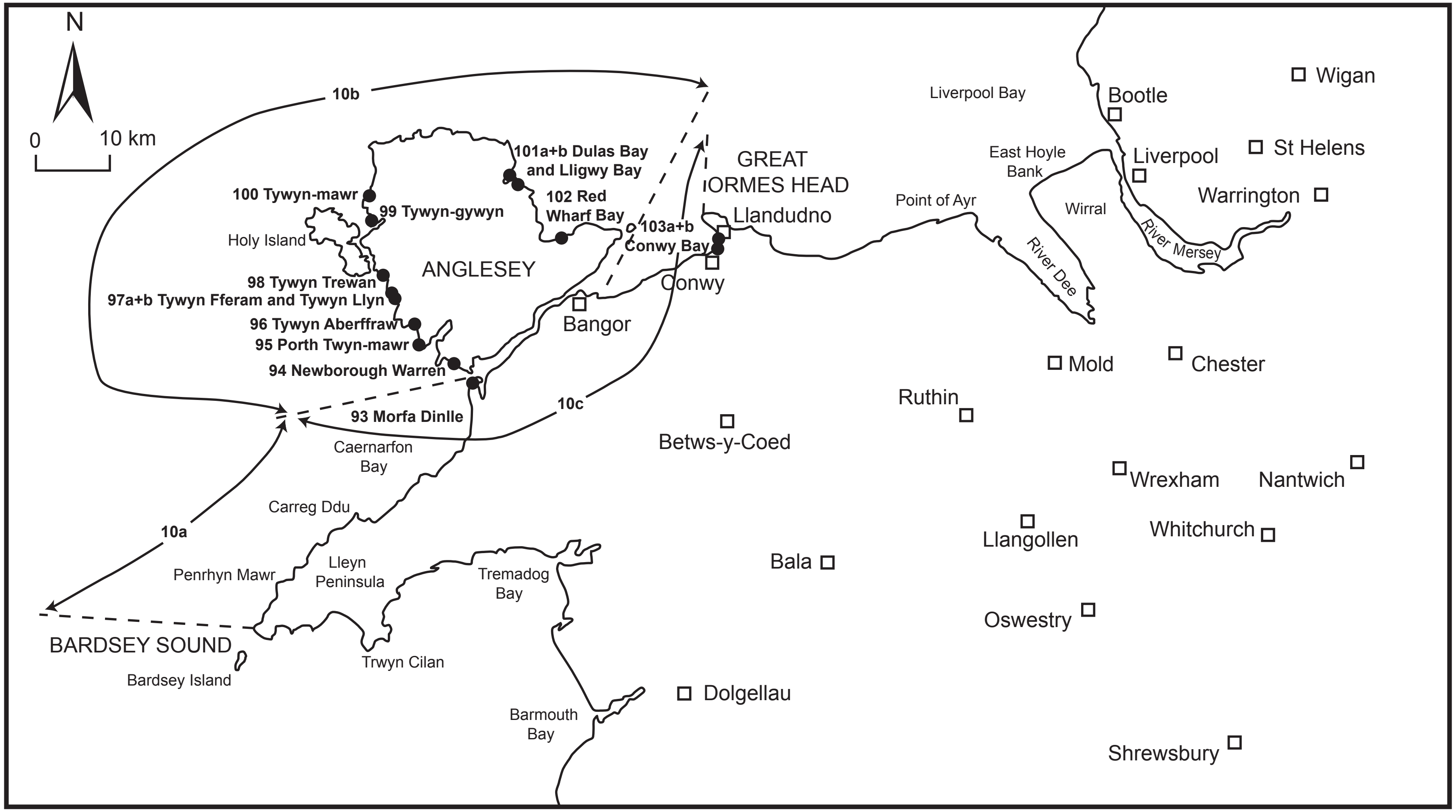


Figure 3.10 Location of the sand dune sites in Cell 10 (Bardsey Sound to Great Ormes Head)

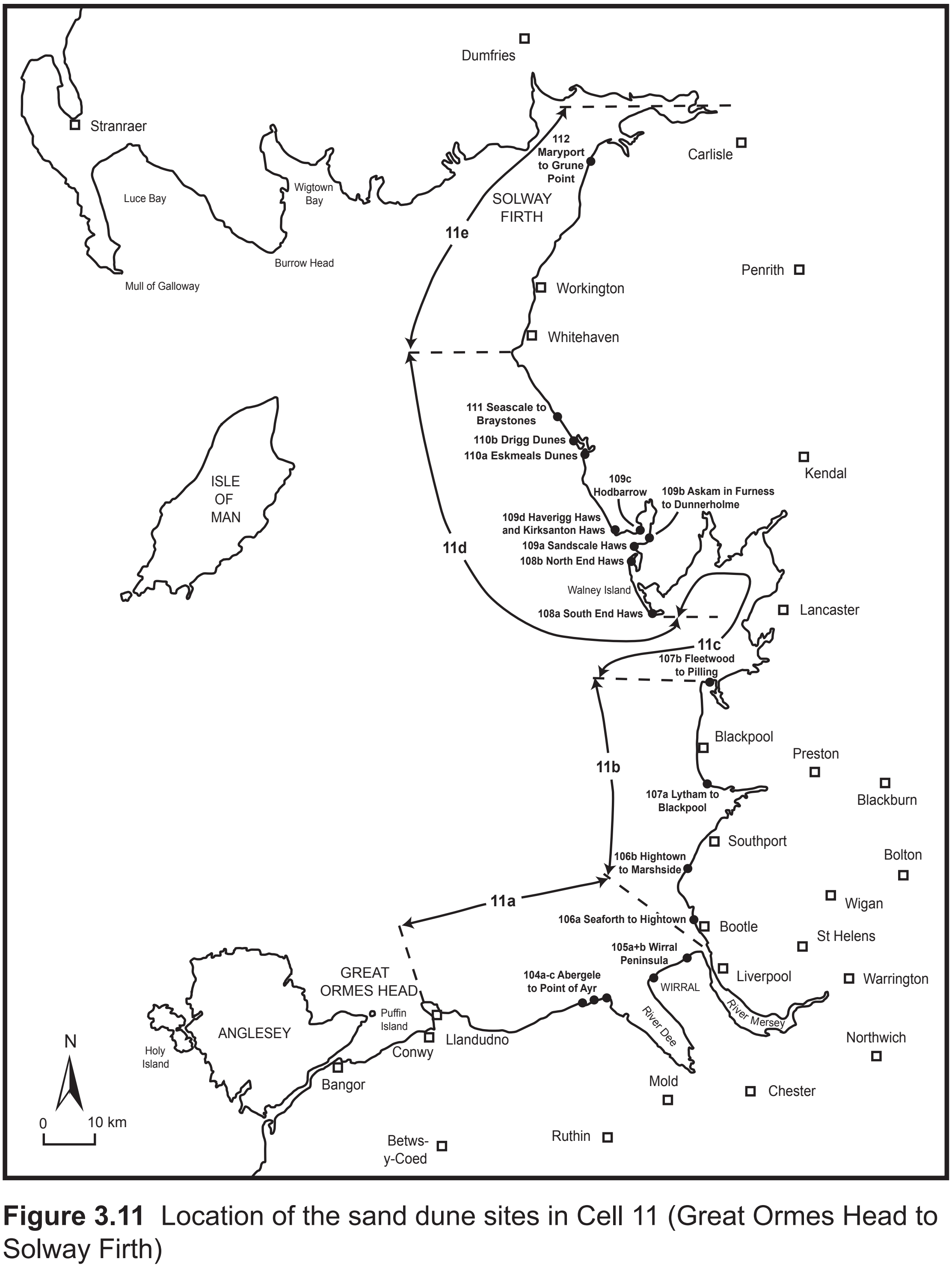


Figure 3.11 Location of the sand dune sites in Cell 11 (Great Ormes Head to Solway Firth)

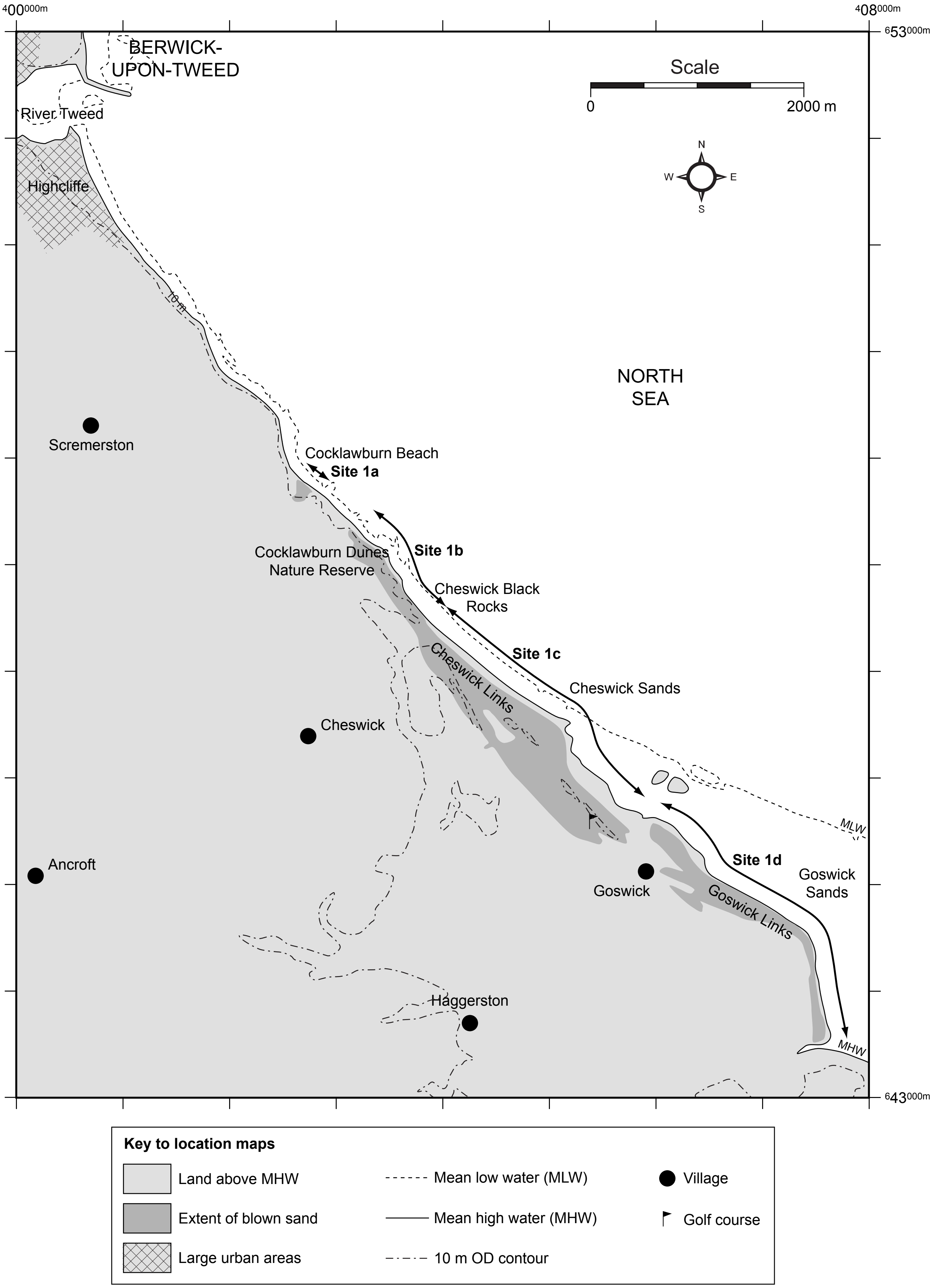


Figure 3.12 Site 1 (Cocklawburn to Goswick): Site 1a (Cocklawburn Beach), Site 1b (Cocklawburn Dunes), Site 1c (Cheswick Links) and Site 1d (Goswick Links)

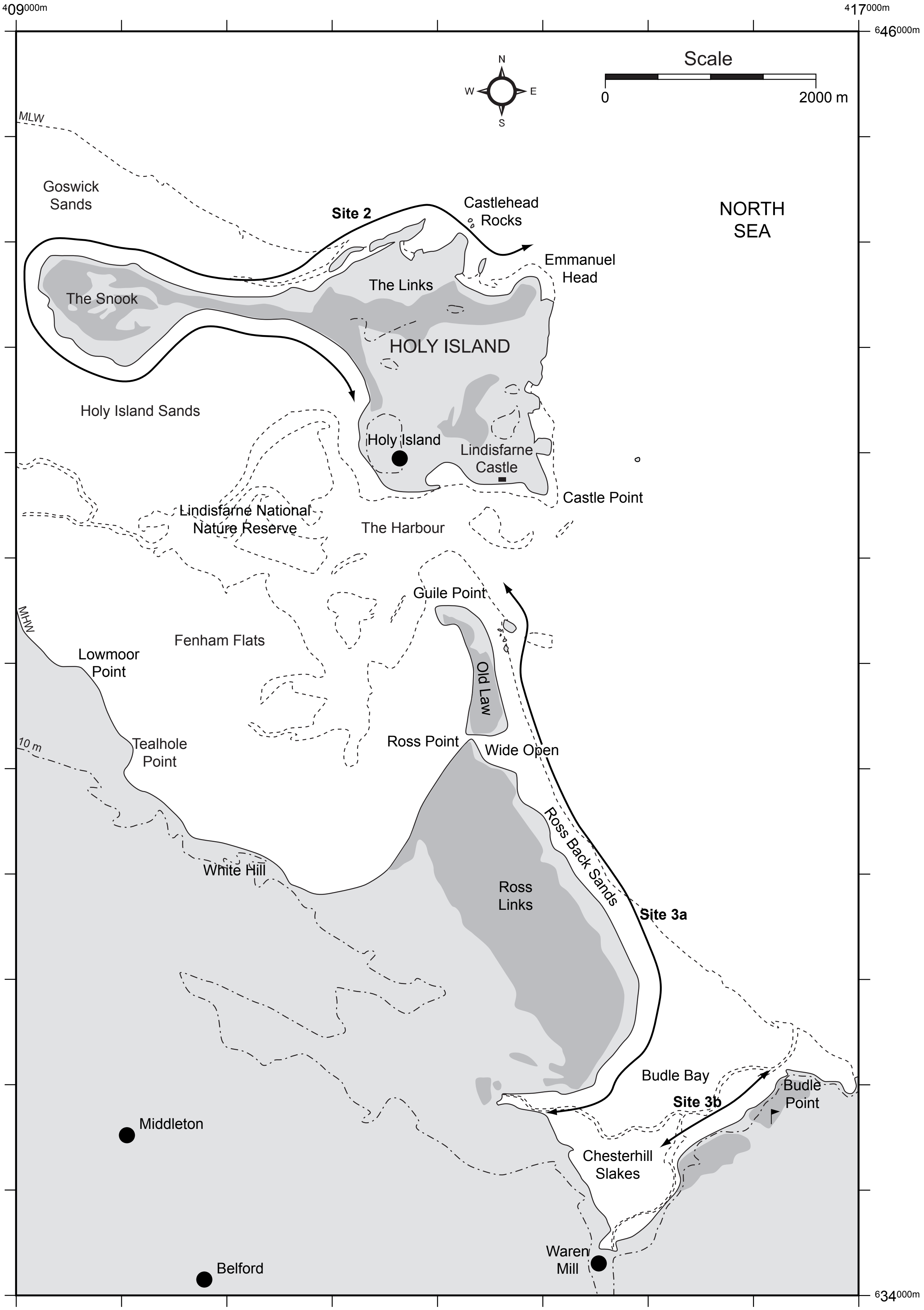


Figure 3.13 Site 2 (Holy Island) and Site 3 (Ross Links and Budle Bay): Site 3a (Ross Links and Budle Bay West) and Site 3b (Budle Bay East)

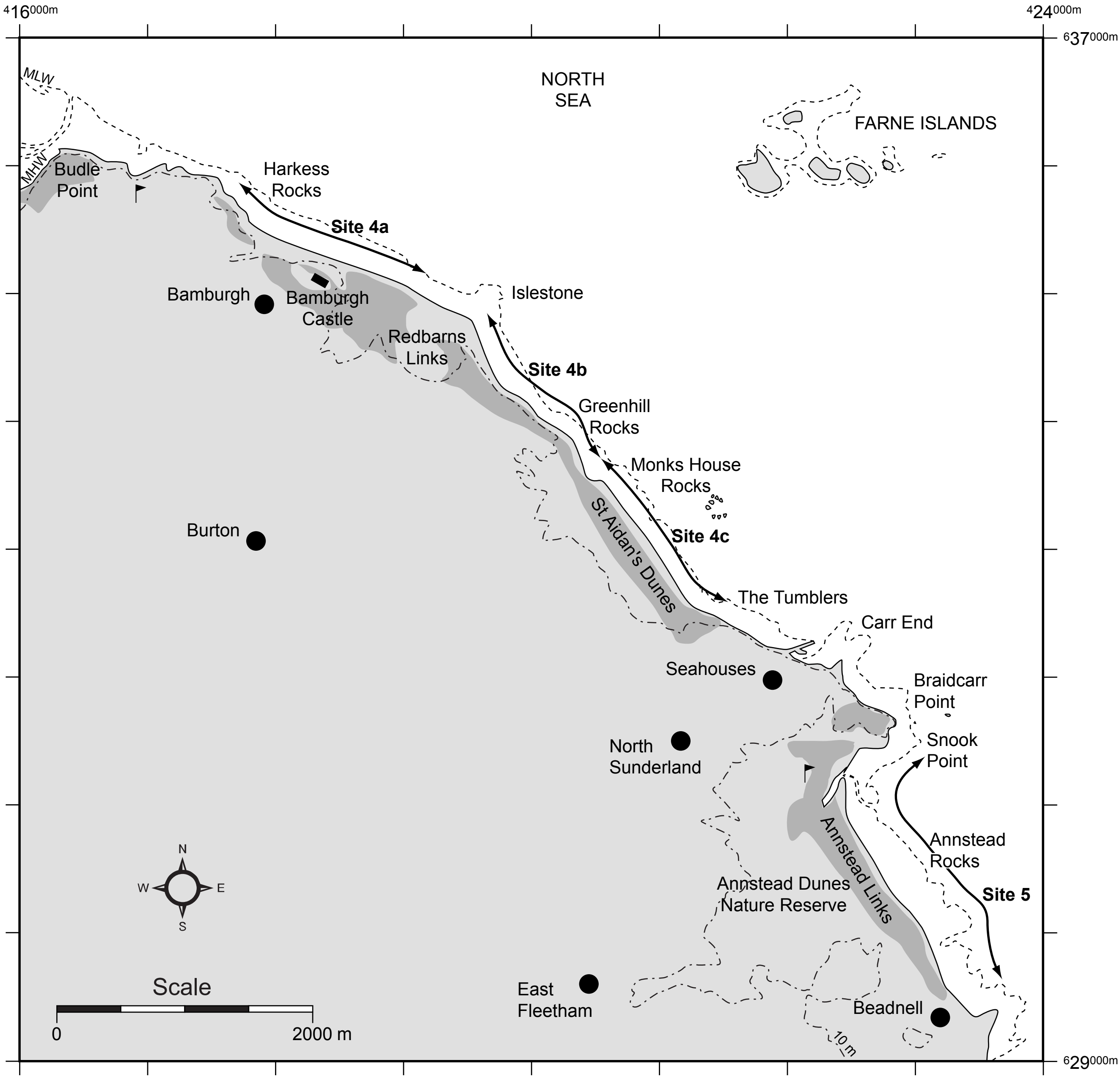


Figure 3.14 Site 4 (Bamburgh to Seahouses): Site 4a (Bamburgh), Site 4b (Redbarns Links) and Site 4c (St Aidan's Dunes), and Site 5 (Annstead Dunes)

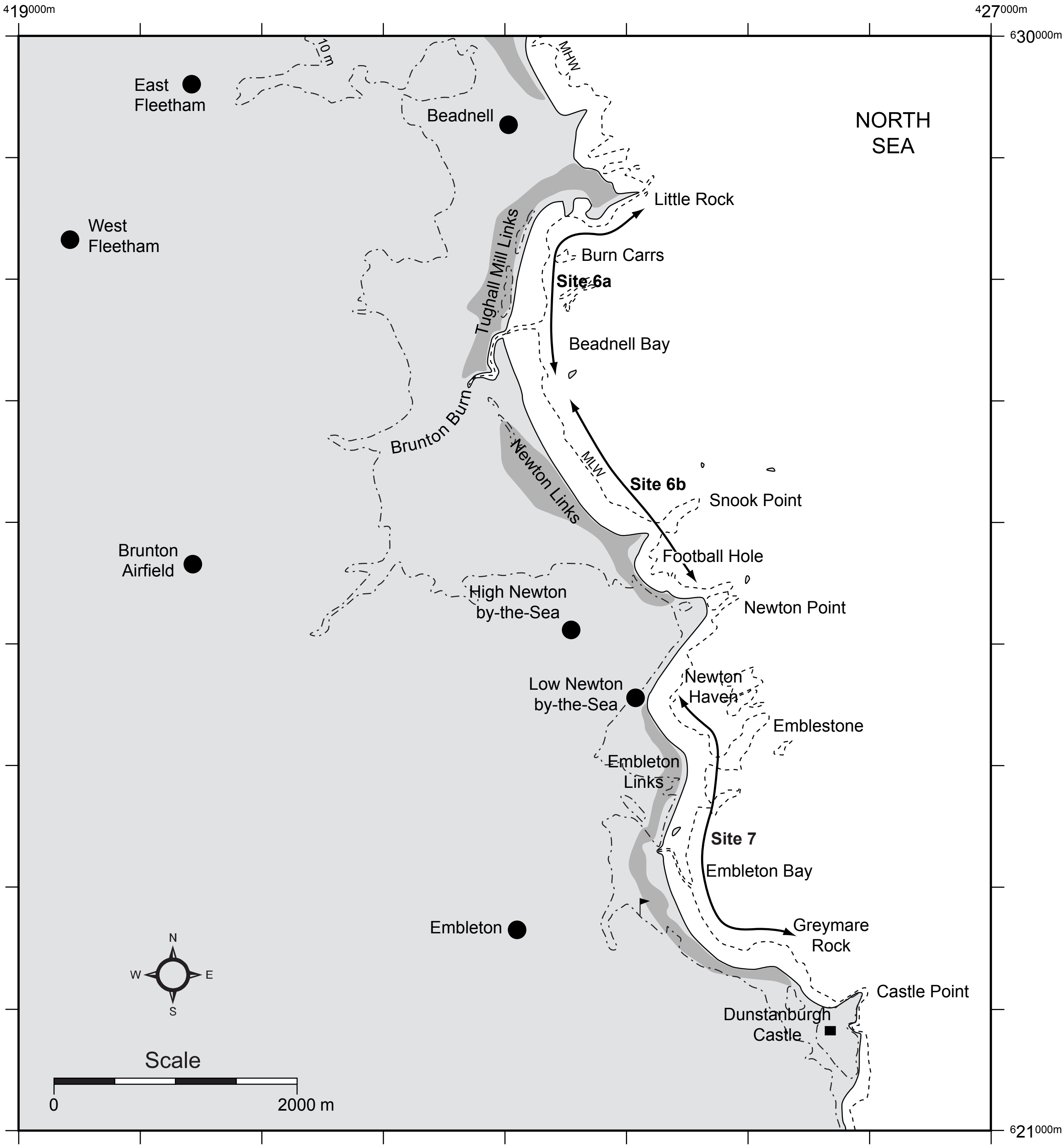


Figure 3.15 Site 6 (Beadnell Bay): Site 6a (Tughall Mill Links) and Site 6b (Newton Links), and Site 7 (Embleton Bay)

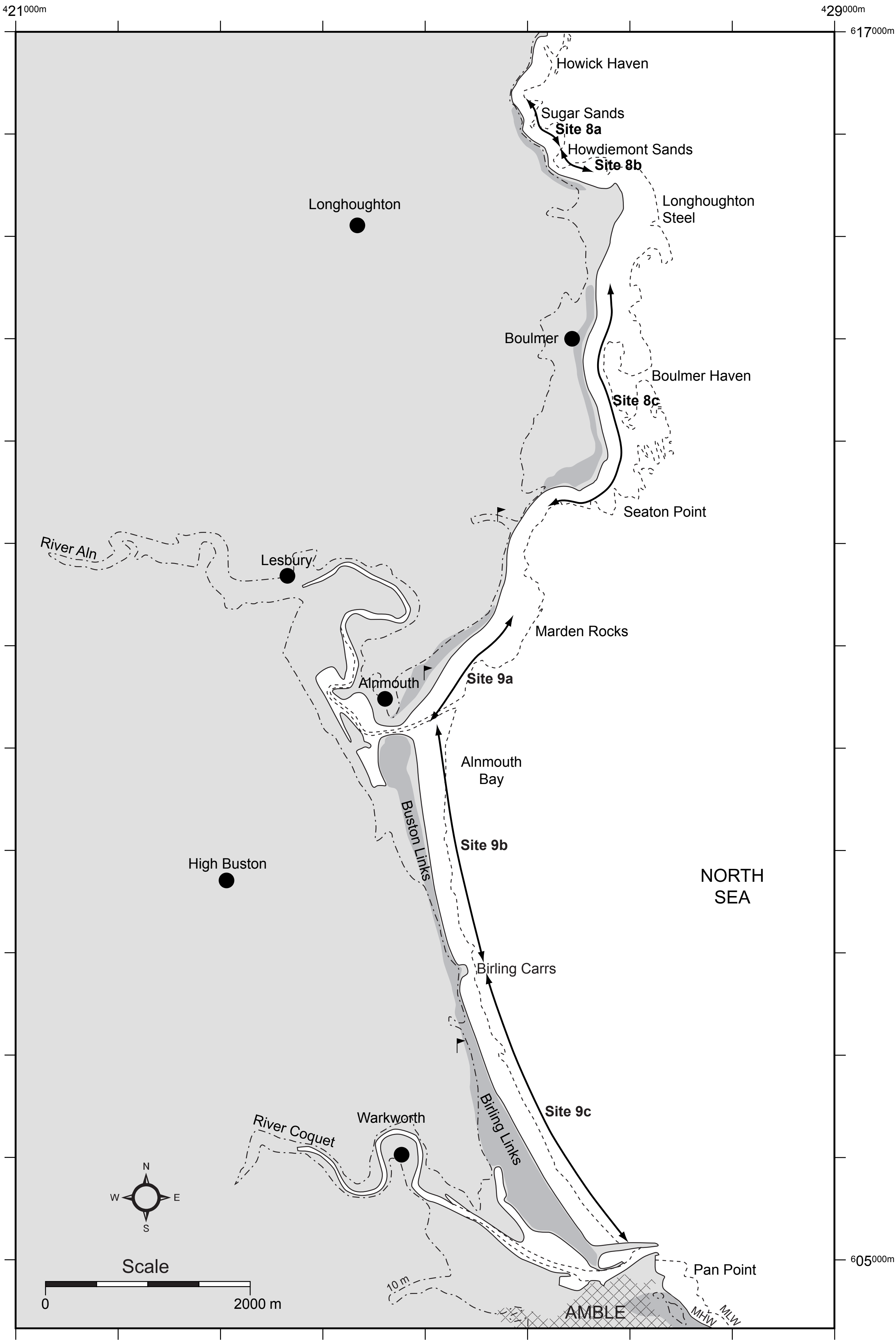


Figure 3.16 Site 8 (Sugar Sands to Seaton Point): Site 8a (Sugar Sands), Site 8b (Howdiemont Sands) and Site 8c (Boulmer), and Site 9 (Alnmouth Bay): Site 9a (Alnmouth), Site 9b (Buston Links) and Site 9c (Birling Links)

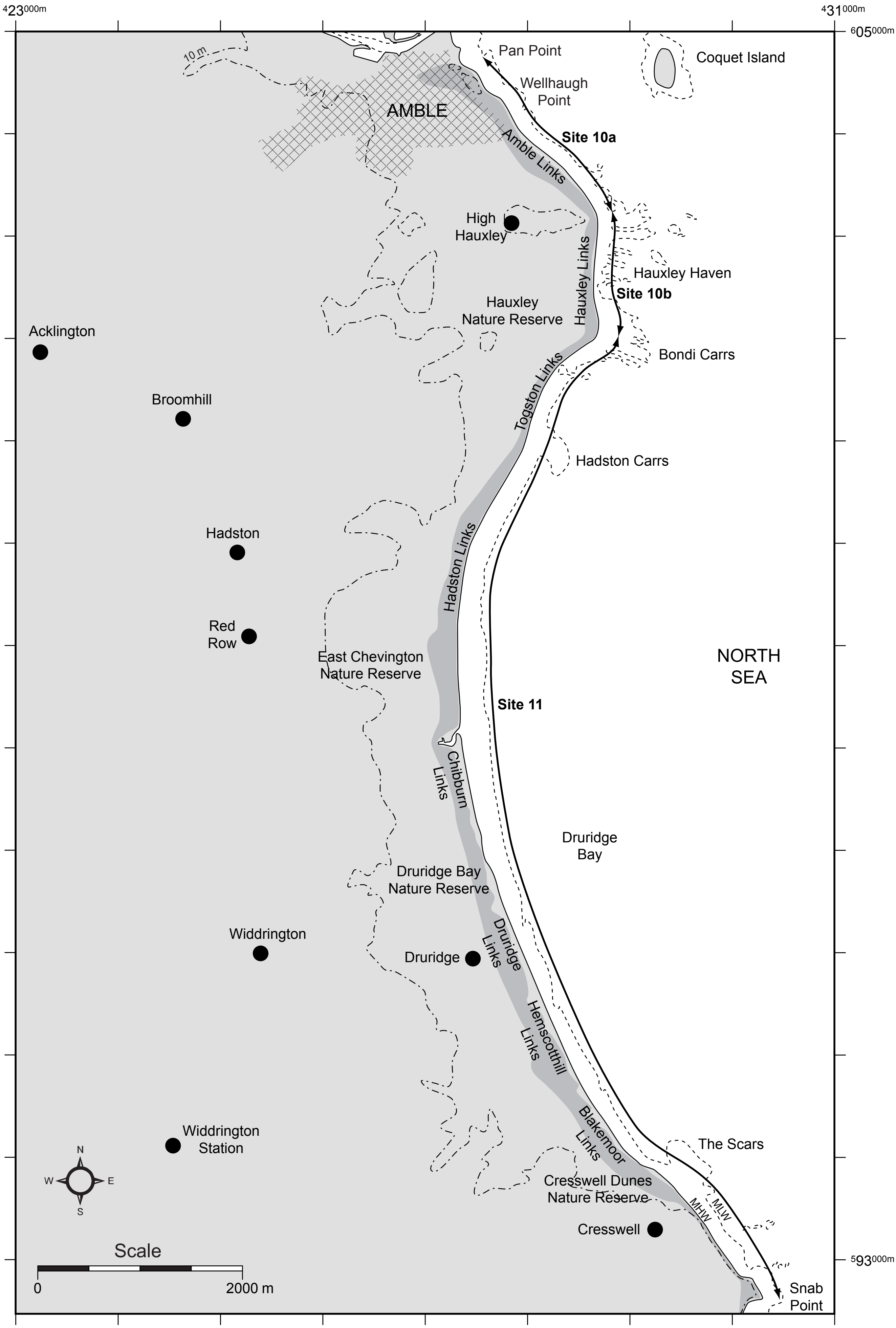


Figure 3.17 Site 10 (Amble to Hauxley): Site 10a (Amble Links) and Site 10b (Hauxley Links), and Site 11 (Druridge Bay)

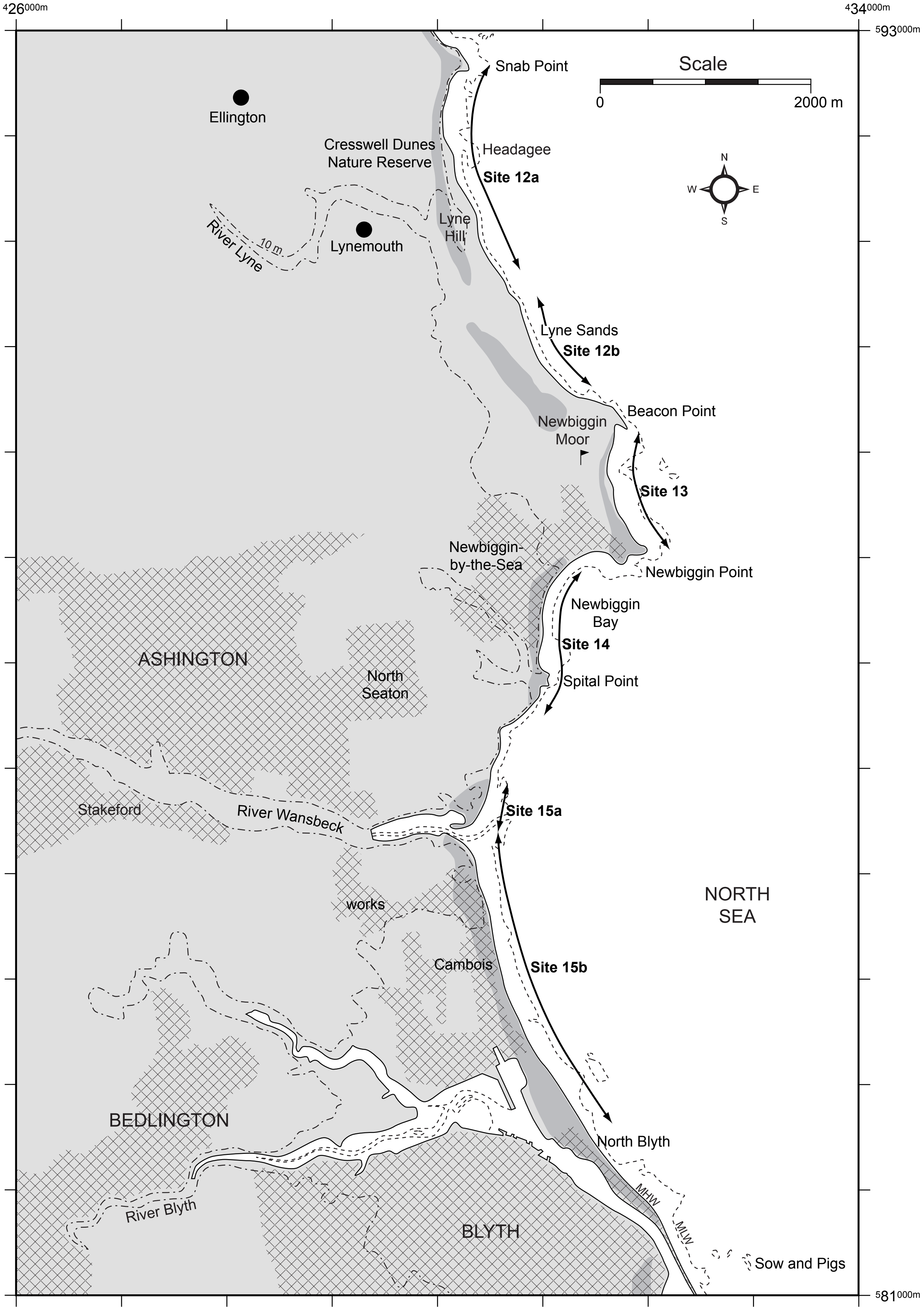


Figure 3.18 Site 12 (Snab Point to Beacon Point): Site 12a (Cresswell Dunes) and Site 12b (Lyne Sands), Site 13 (Beacon Point to Newbiggin Point), Site 14 (Newbiggin Bay), and Site 15 (North Seaton to North Blyth): Site 15a (North Seaton) and Site 15b (Cambois to North Blyth)

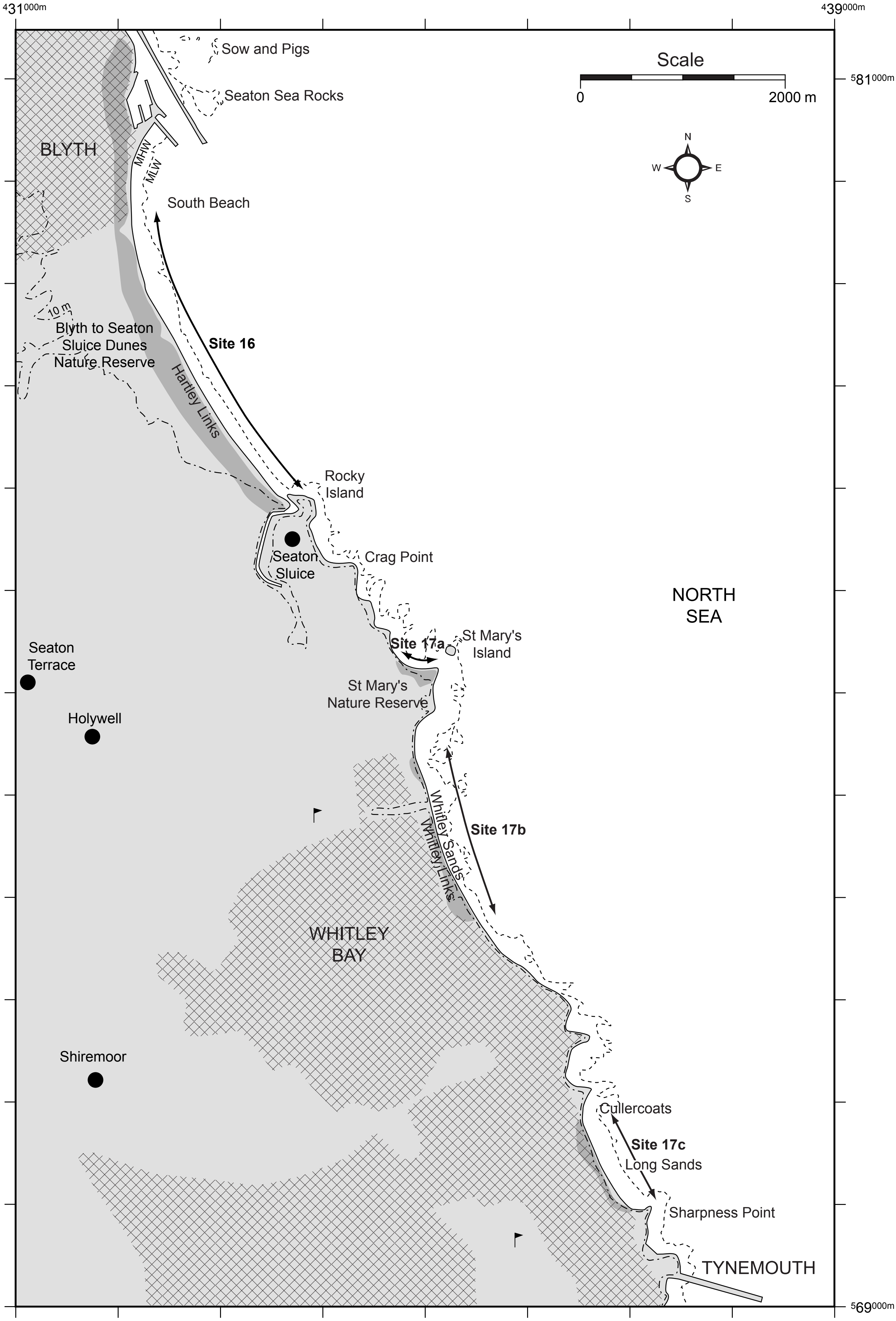


Figure 3.19 Site 16 (Blyth to Seaton Sluice) and Site 17 (St Mary's Island to Tynemouth): Site 17a (St Mary's Island), Site 17b (Whitley Links) and Site 17c (Long Sands)

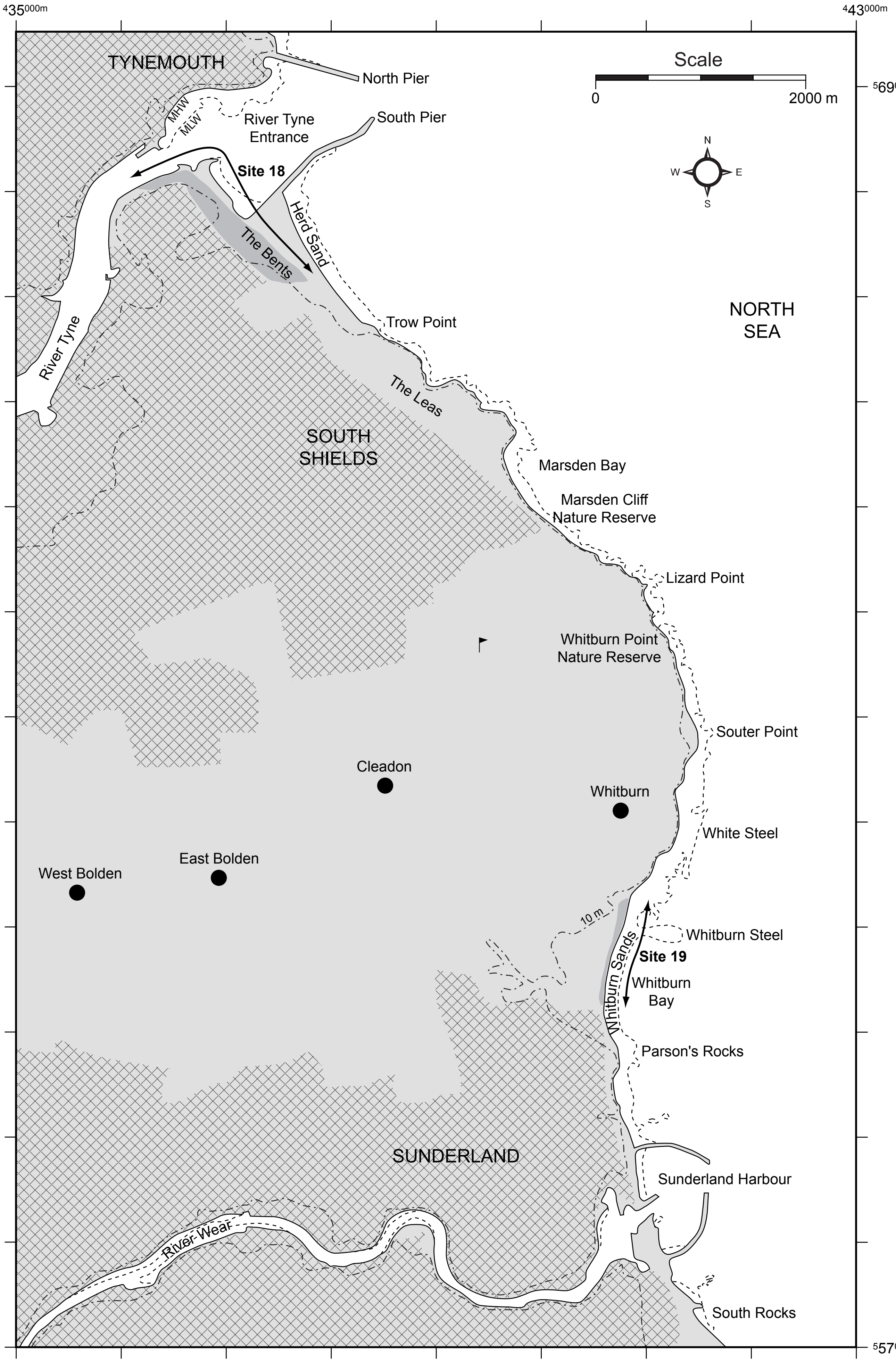


Figure 3.20 Site 18 (South Shields) and Site 19 (Whitburn Bay)

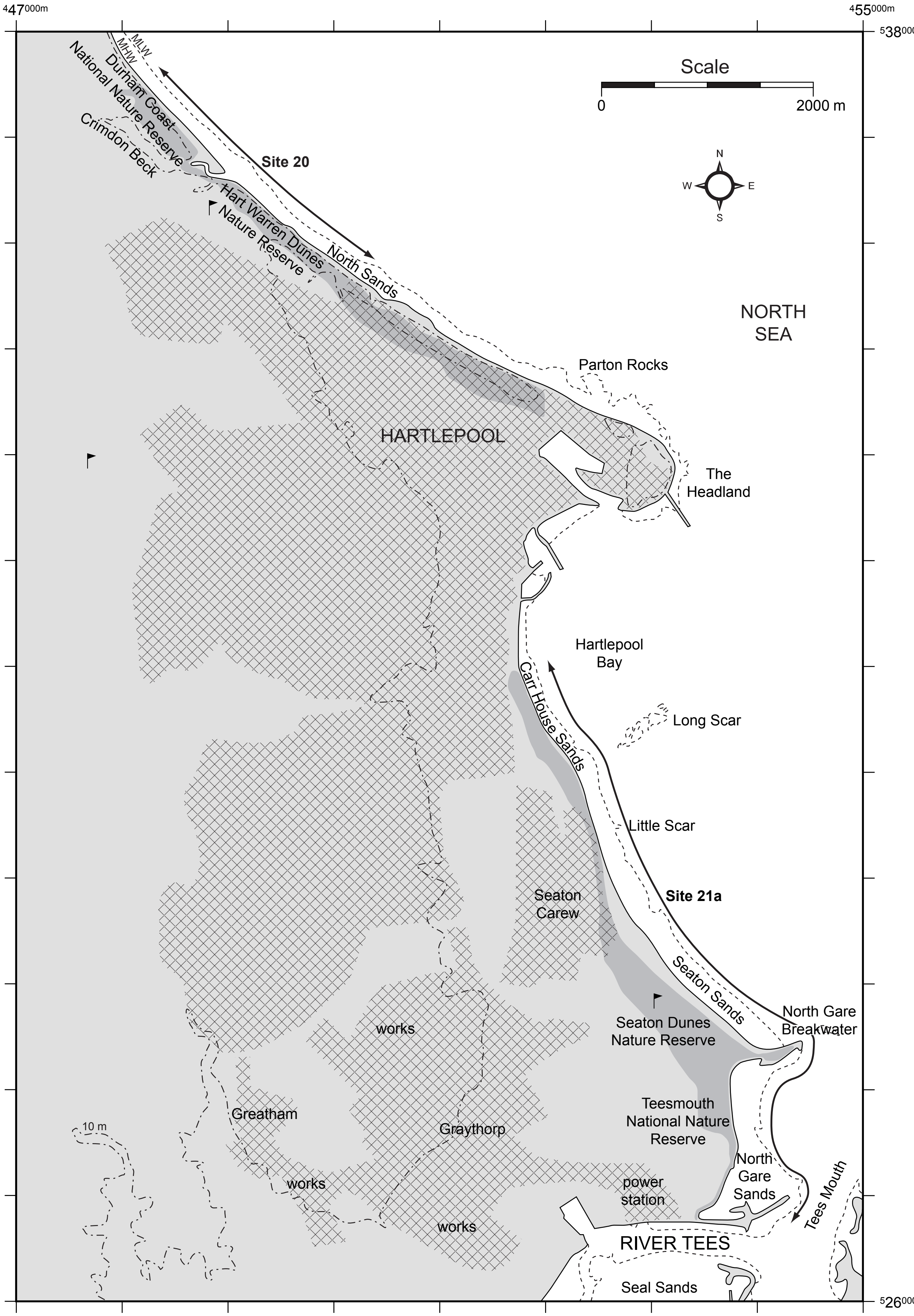


Figure 3.21 Site 20 (Hart Warren Dunes) and Site 21 (Hartlepool to Marske-by-the-Sea): Site 21a (Carr House Sands and Seaton Dunes)

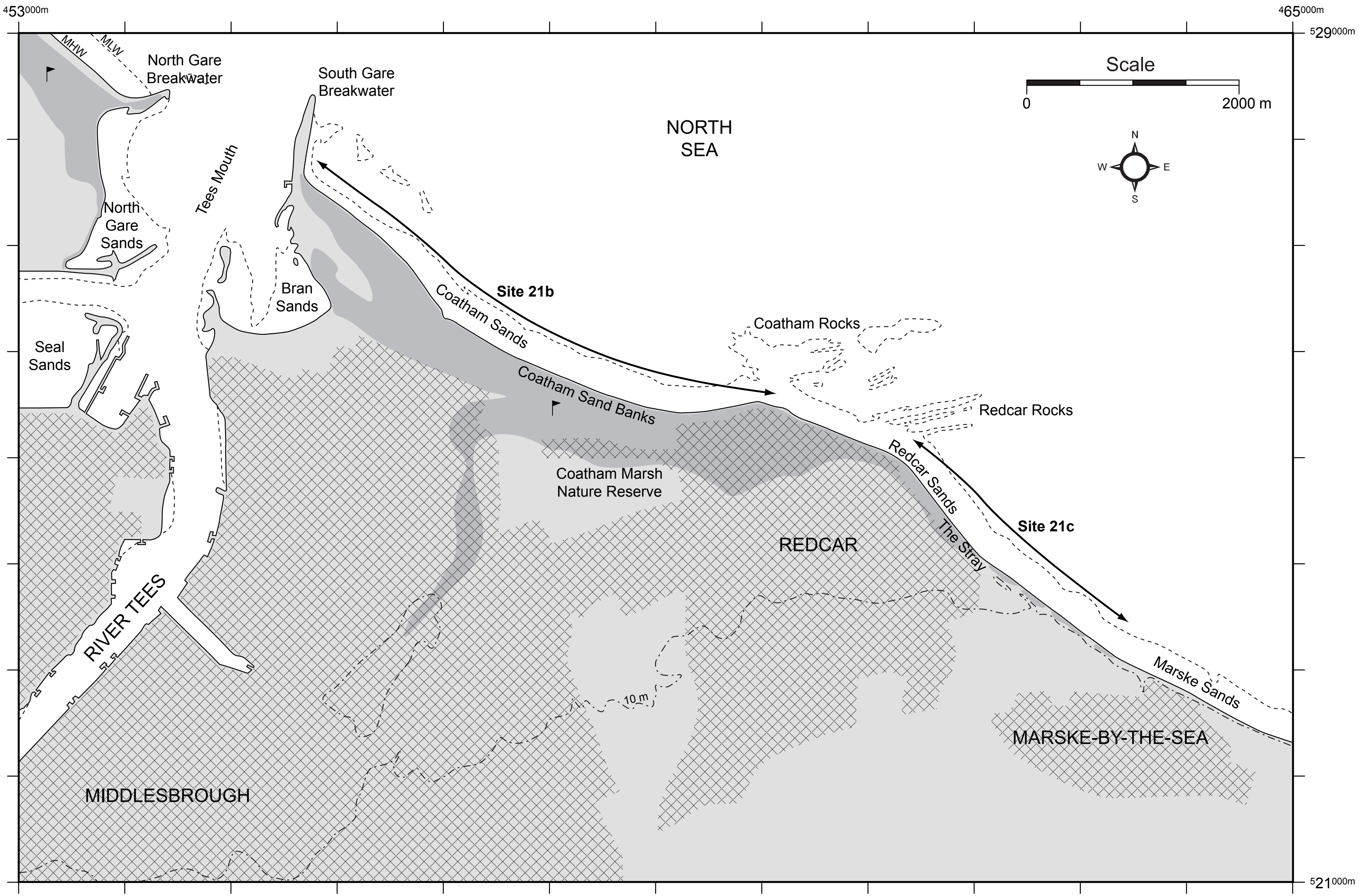


Figure 3.22 Site 21 (Hartlepool to Marske-by-the-Sea): Site 21b (Coatham Sands) and Site 21c (Redcar to Marske-by-the-Sea)

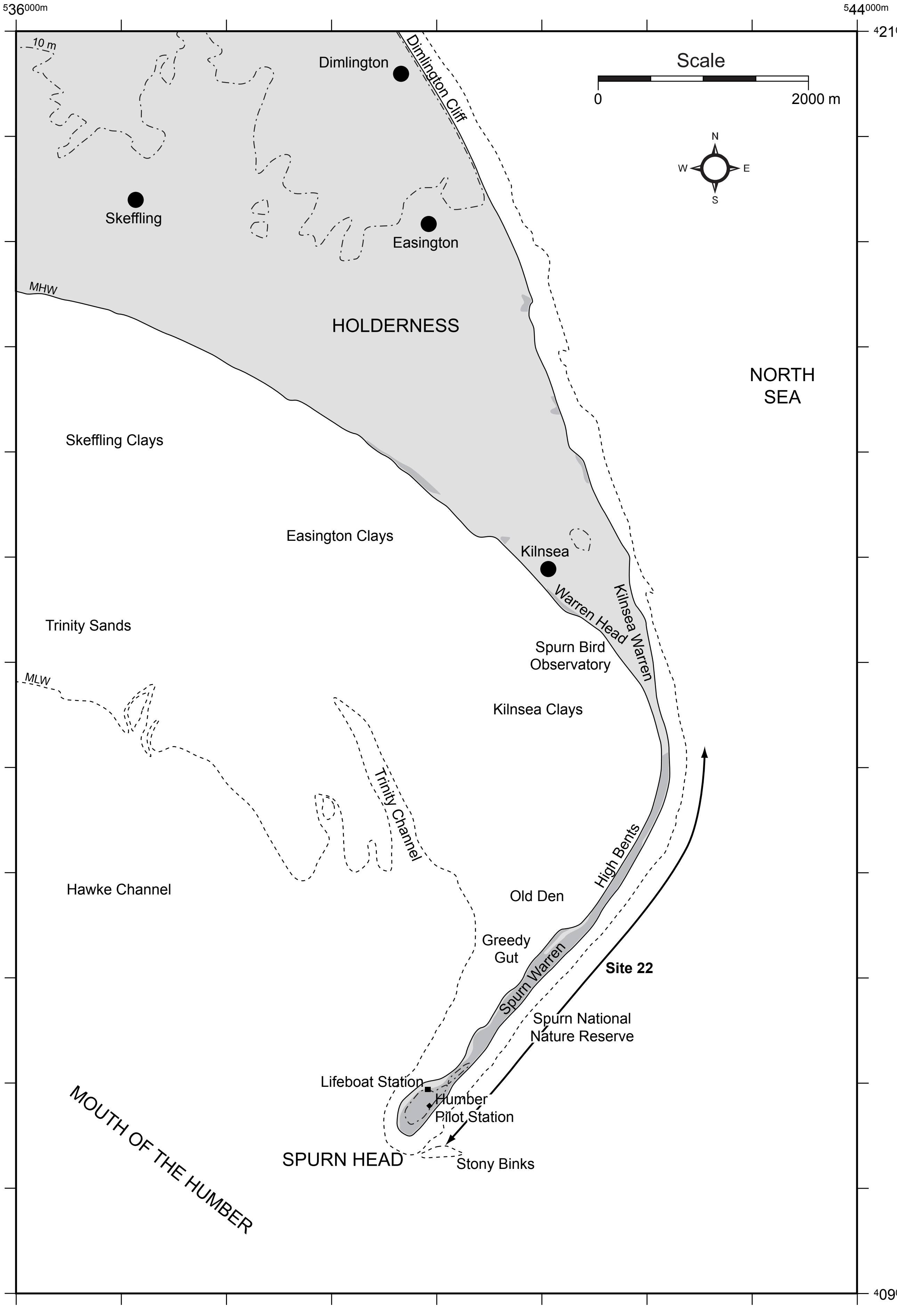


Figure 3.23 Site 22 (Spurn Peninsula)

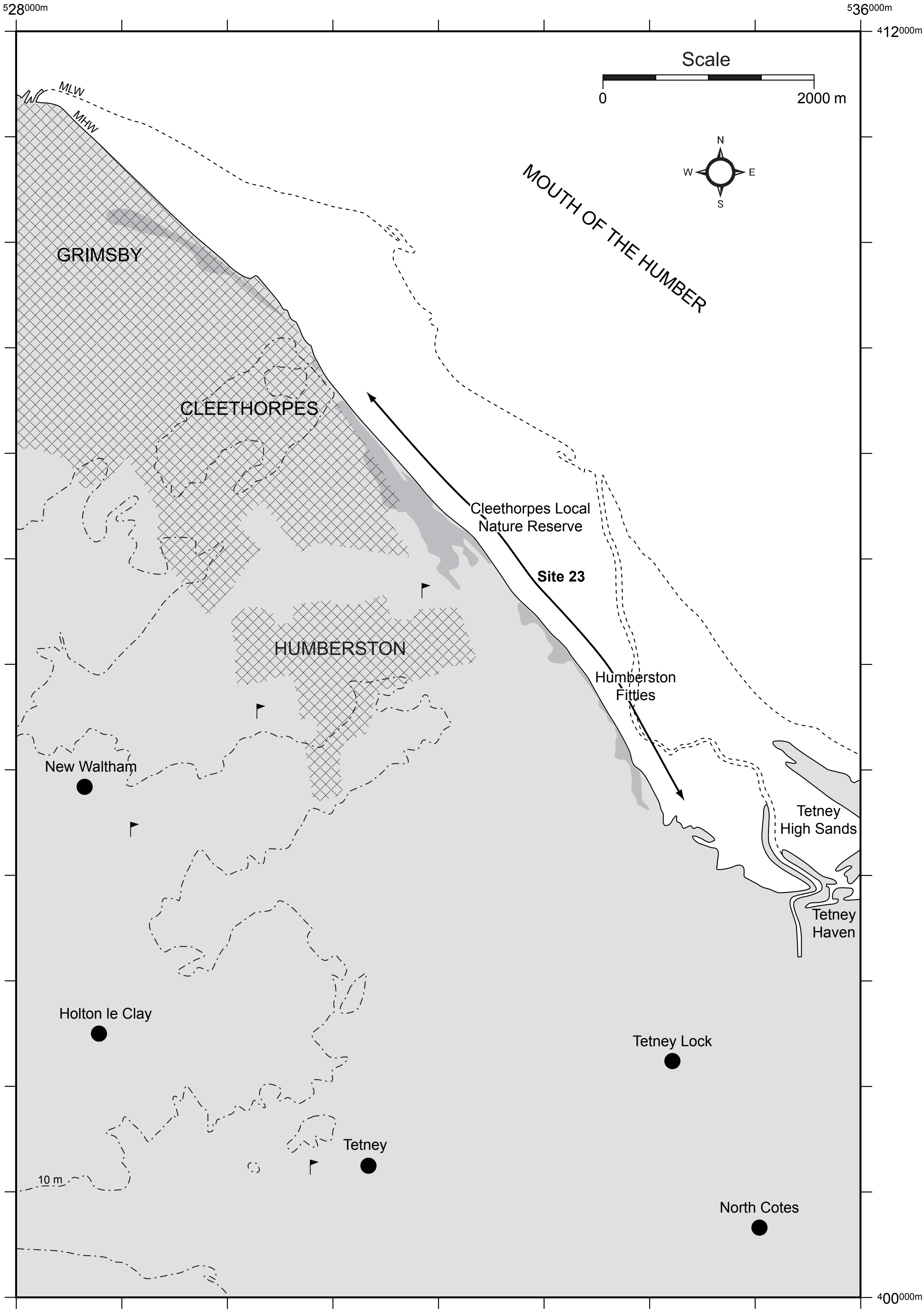


Figure 3.24 Site 23 (Cleethorpes and Humberston)

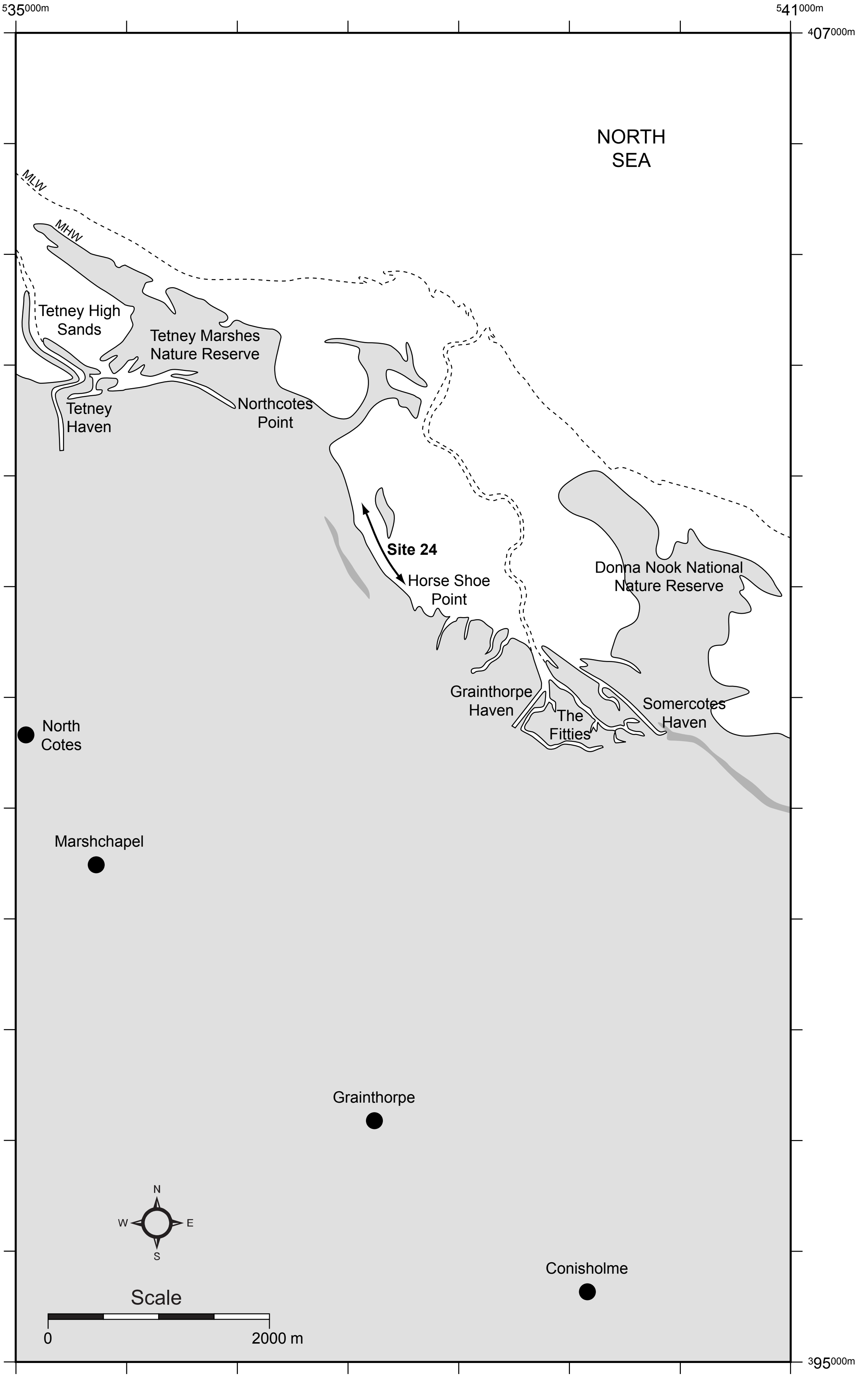


Figure 3.25 Site 24 (Horse Shoe Point)

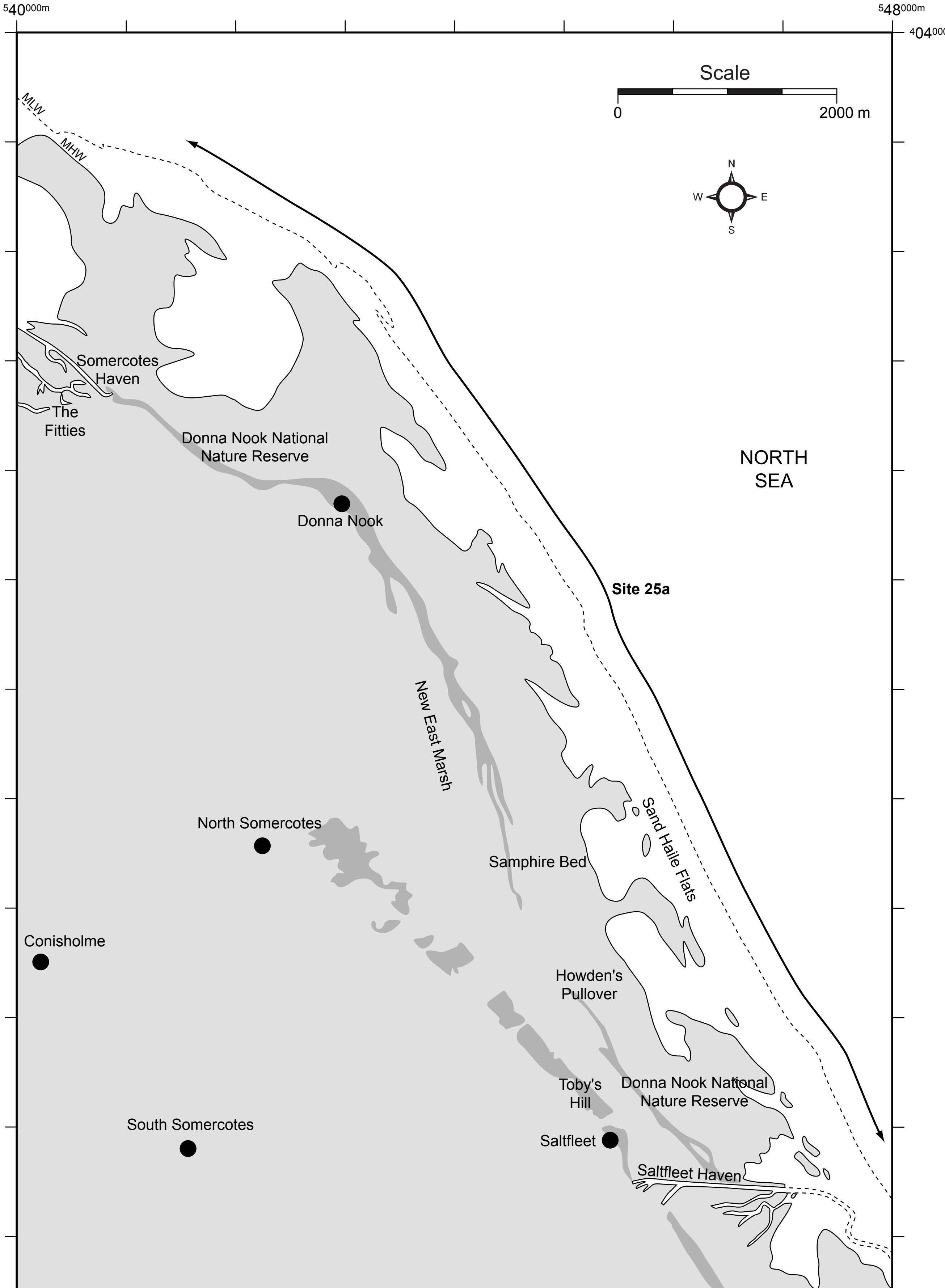


Figure 3.26 Site 25 (Somercotes Haven to Mablethorpe): Site 25a (Somercotes Haven to Saltfleet Haven)

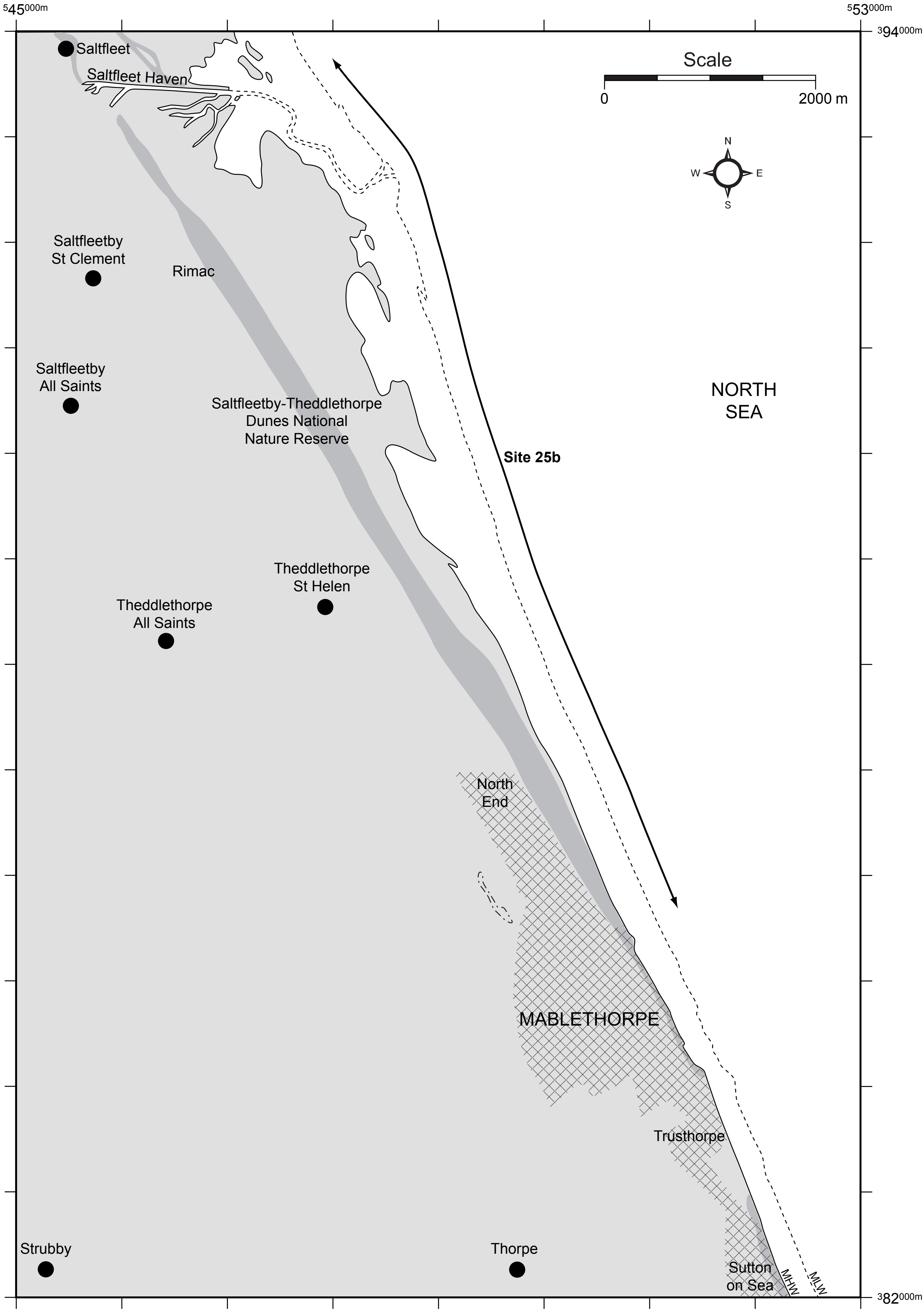


Figure 3.27 Site 25 (Somercotes Haven to Mablethorpe): Site 25b (Saltfleet Haven to Mablethorpe)

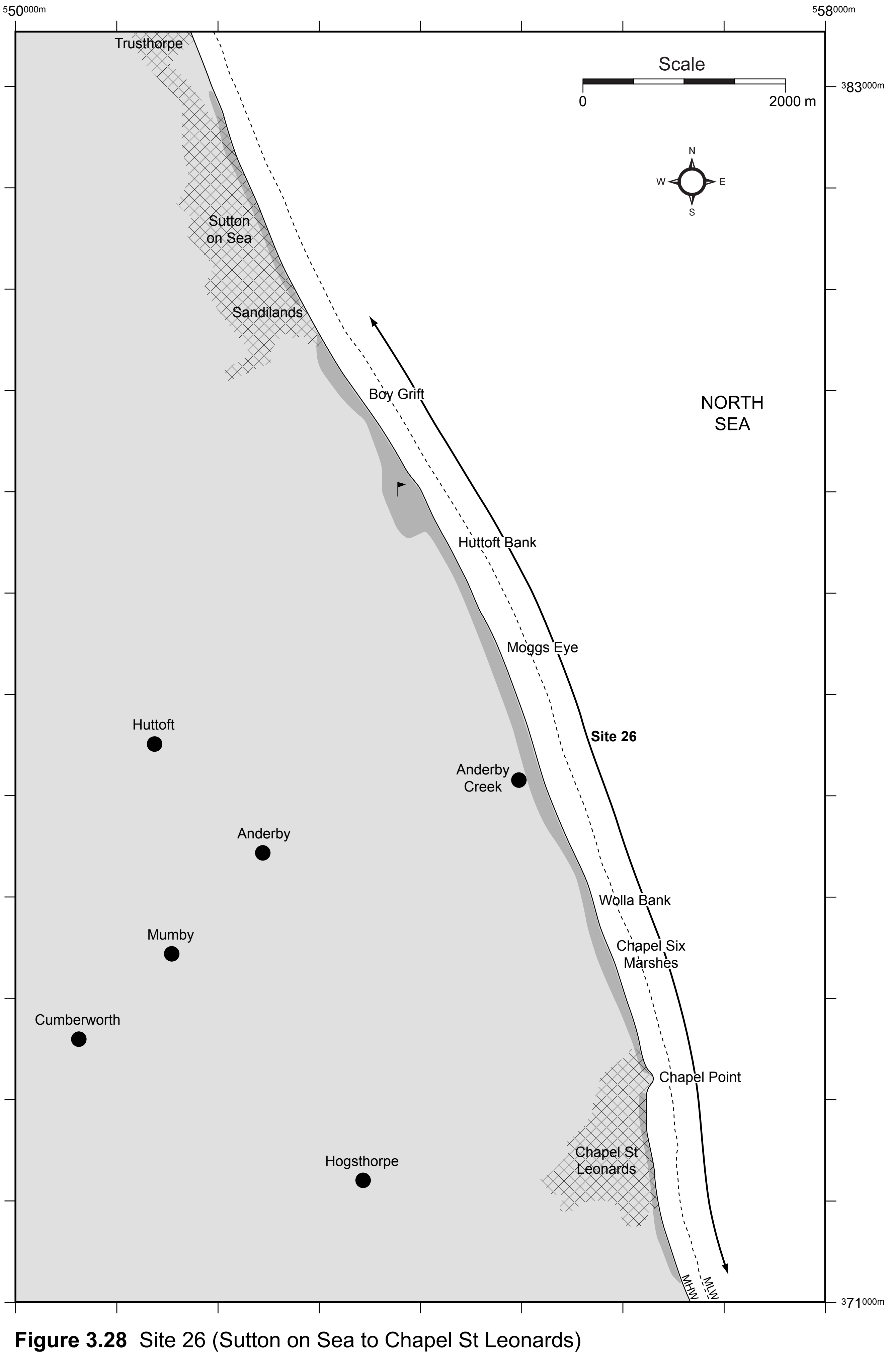


Figure 3.28 Site 26 (Sutton on Sea to Chapel St Leonards)

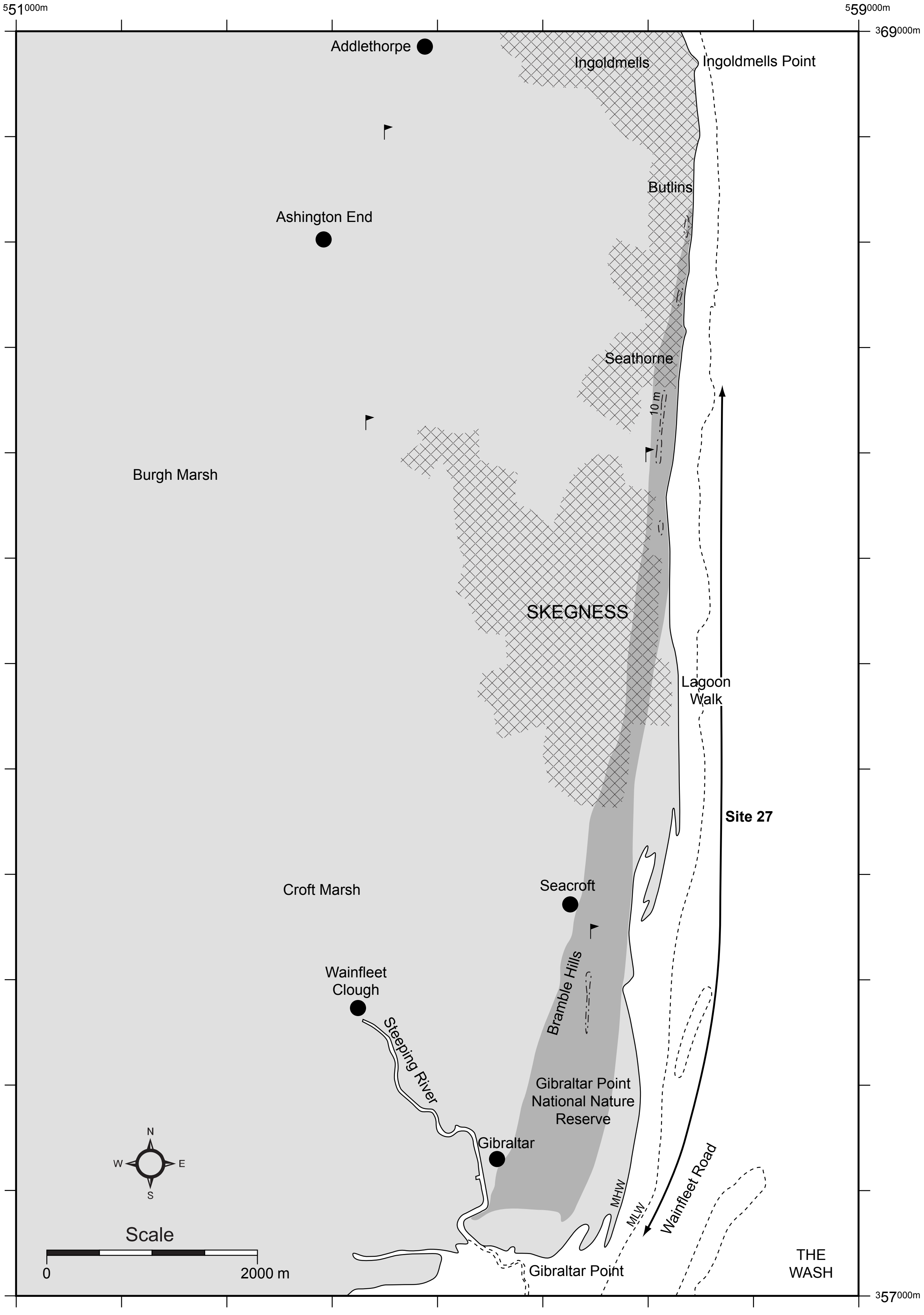


Figure 3.29 Site 27 (Seathorne to Gibraltar Point)

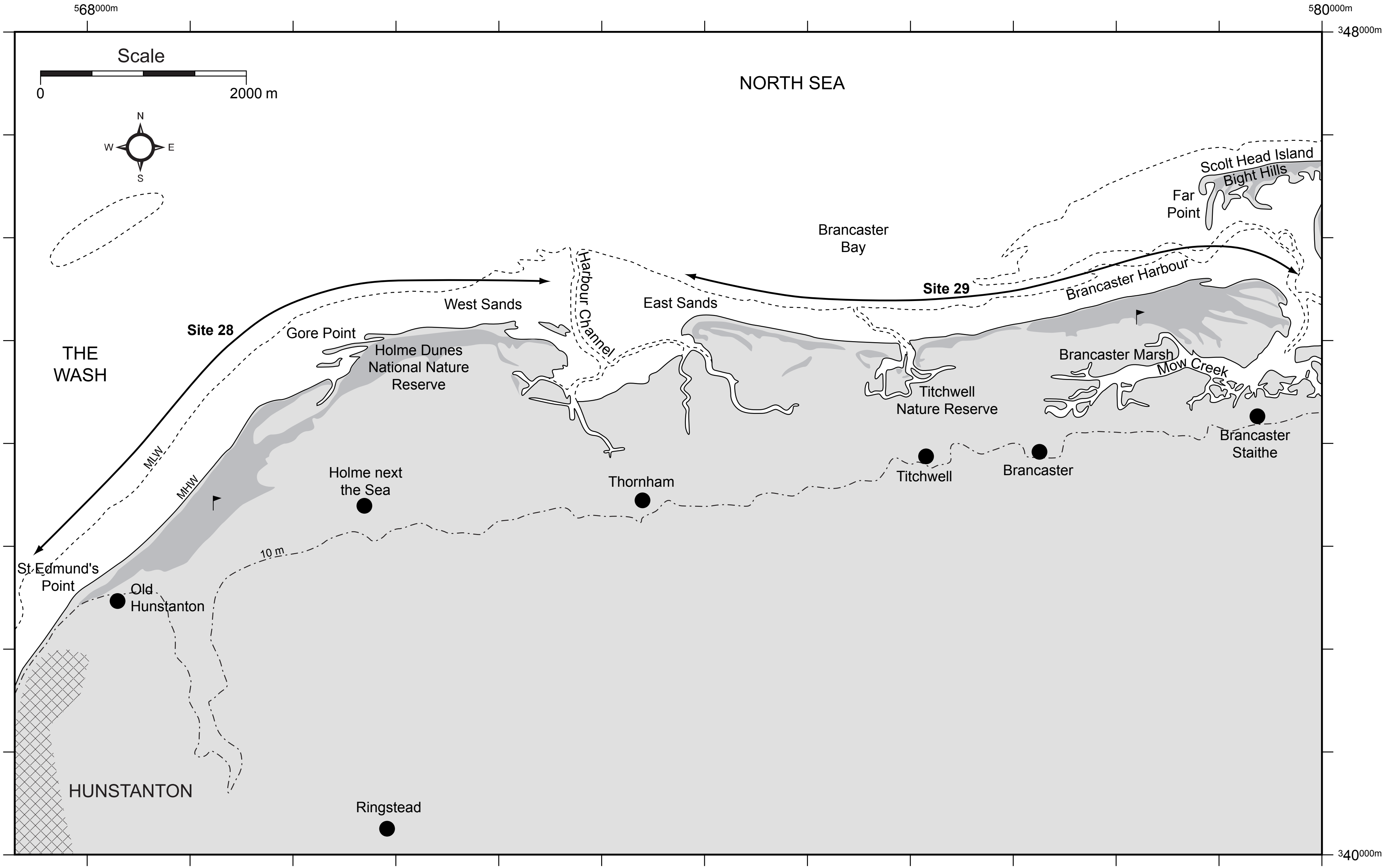


Figure 3.30 Site 28 (Old Hunstanton to Holme Dunes) and Site 29 (Brancaster Bay)

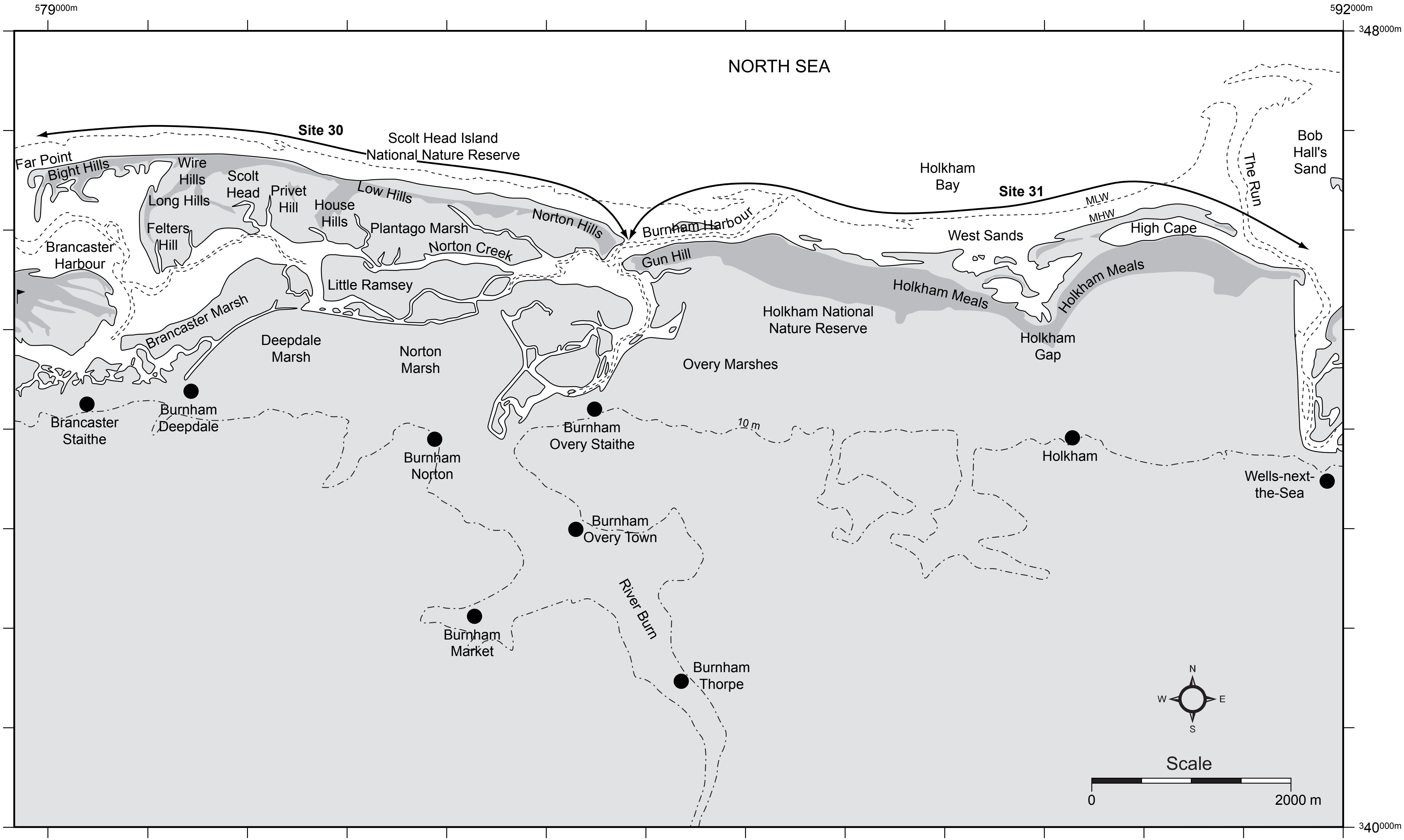


Figure 3.31 Site 30 (Scolt Head Island) and Site 31 (Holkham Bay)

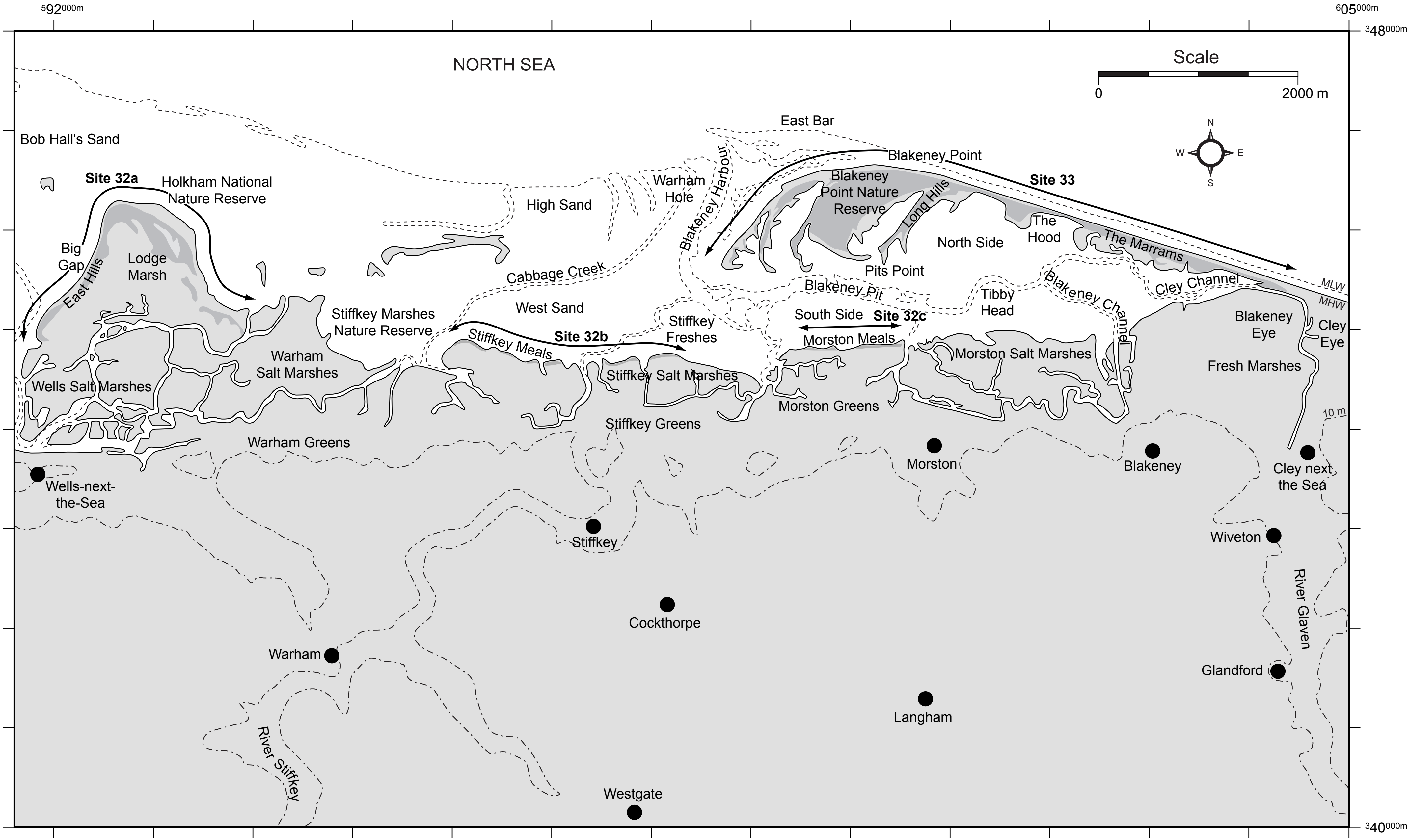


Figure 3.32 Site 32 (Wells-next-the-Sea to Morston): Site 32a (East Hills), Site 32b (Stiffkey Meals) and Site 32c (Morston Meals), and Site 33 (Blakeney Point)

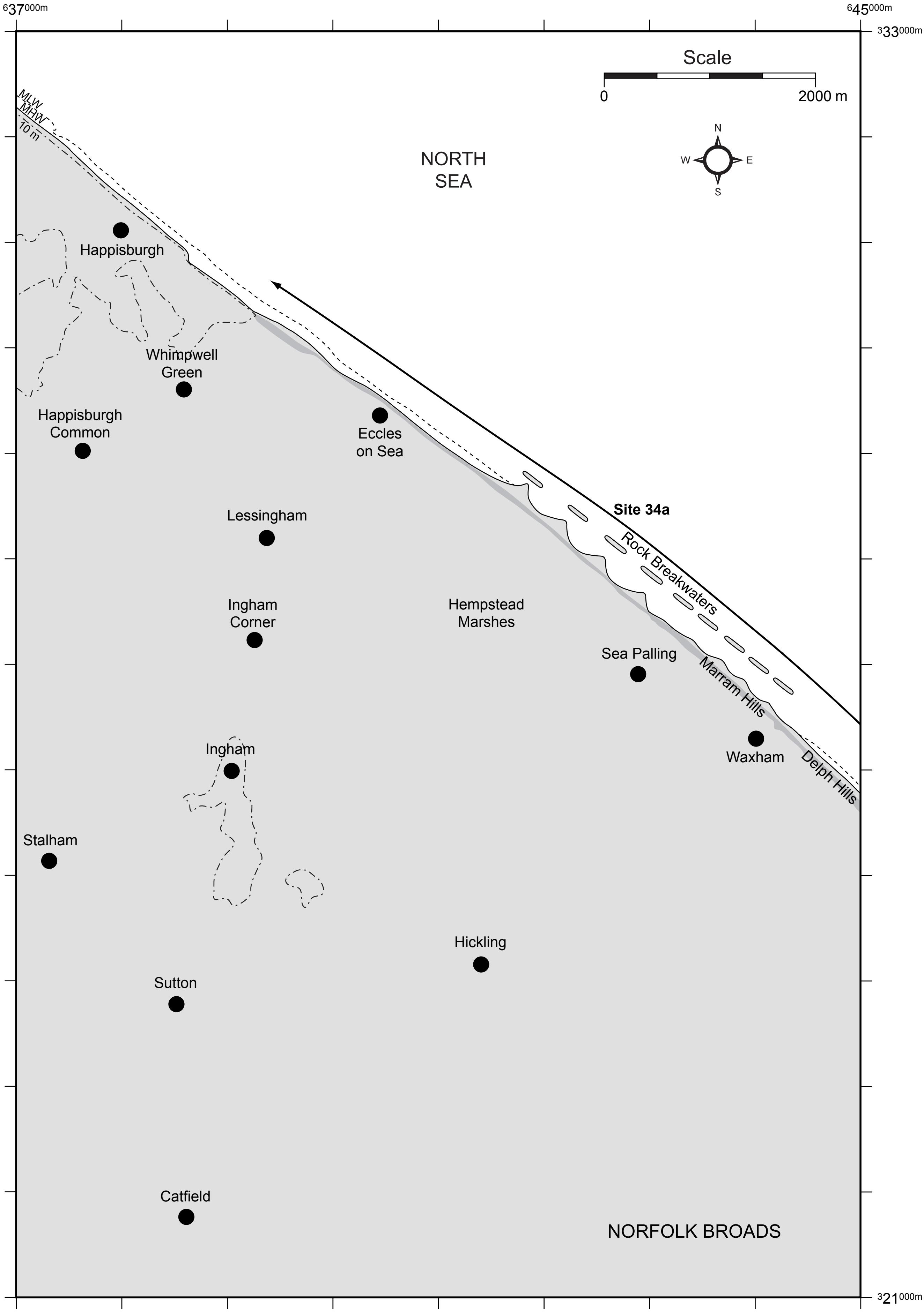


Figure 3.33 Site 34 (Northeast Norfolk Coast): Site 34a (Happisburgh to Winterton Ness, northern part)

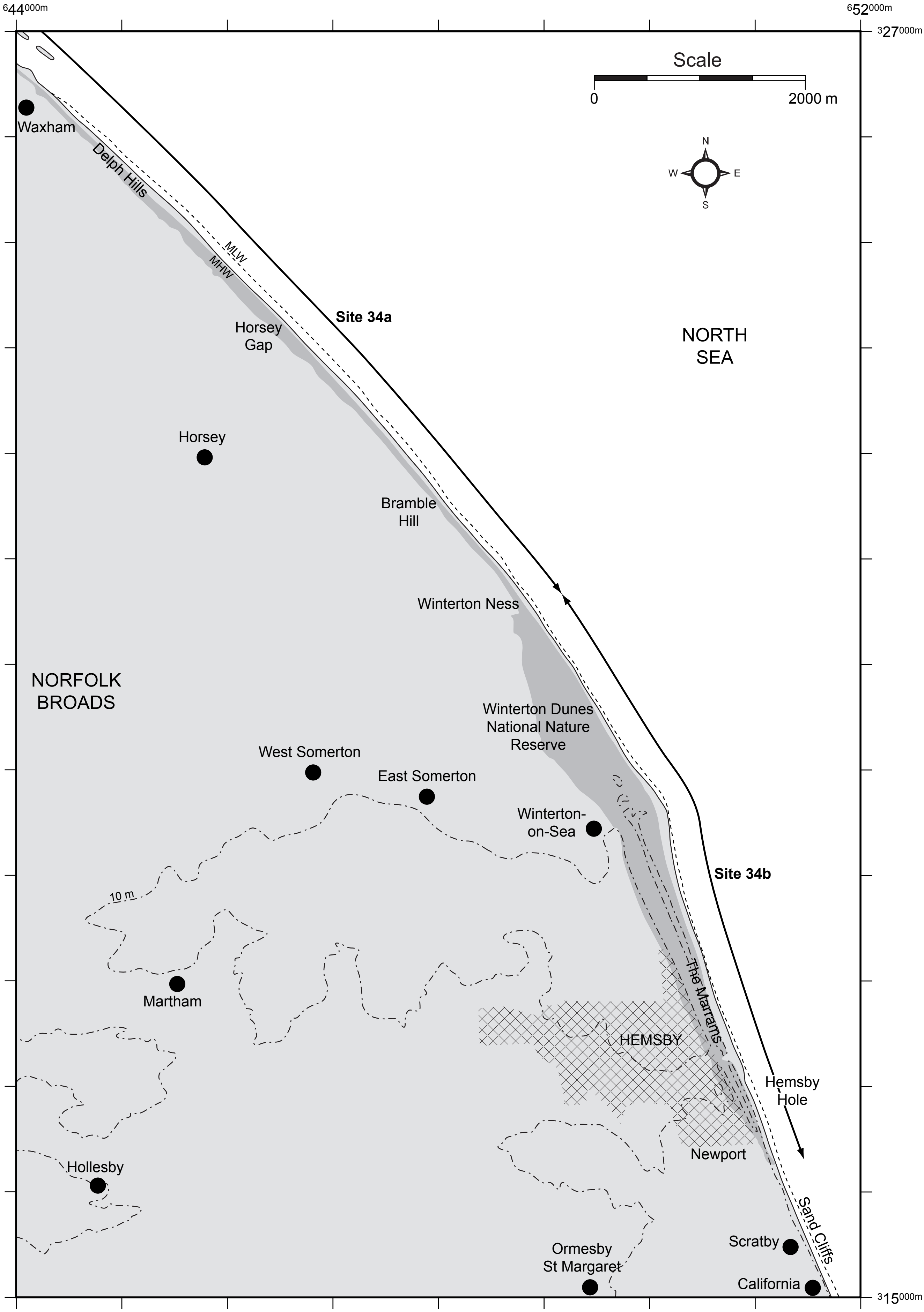


Figure 3.34 Site 34 (Northeast Norfolk Coast): Site 34a (Happisburgh to Winterton Ness, southern part) and Site 34b (Winterton Ness to Hemsby)

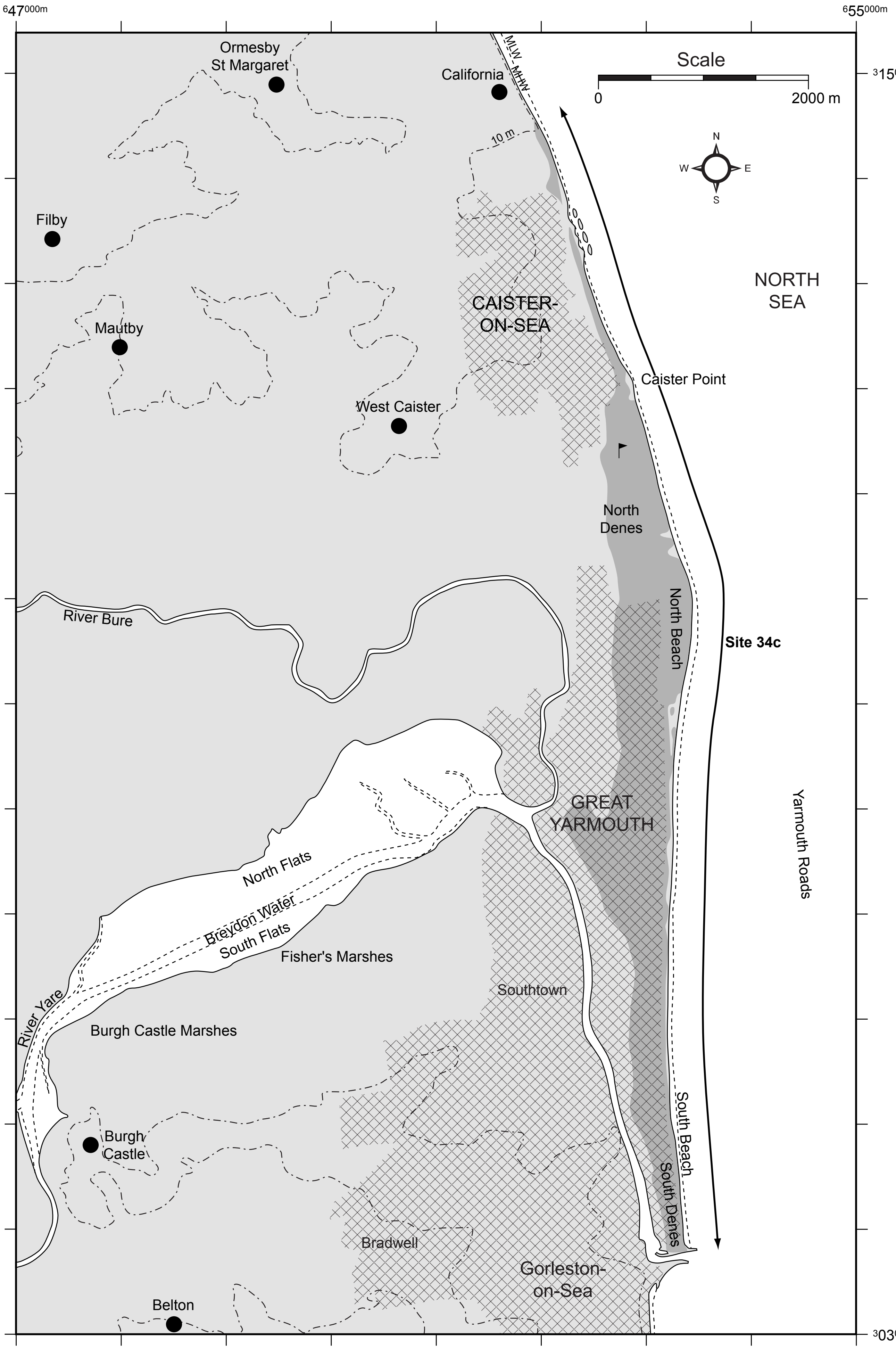


Figure 3.35 Site 34 (Northeast Norfolk Coast): Site 34c (Caister-on-Sea to Great Yarmouth)

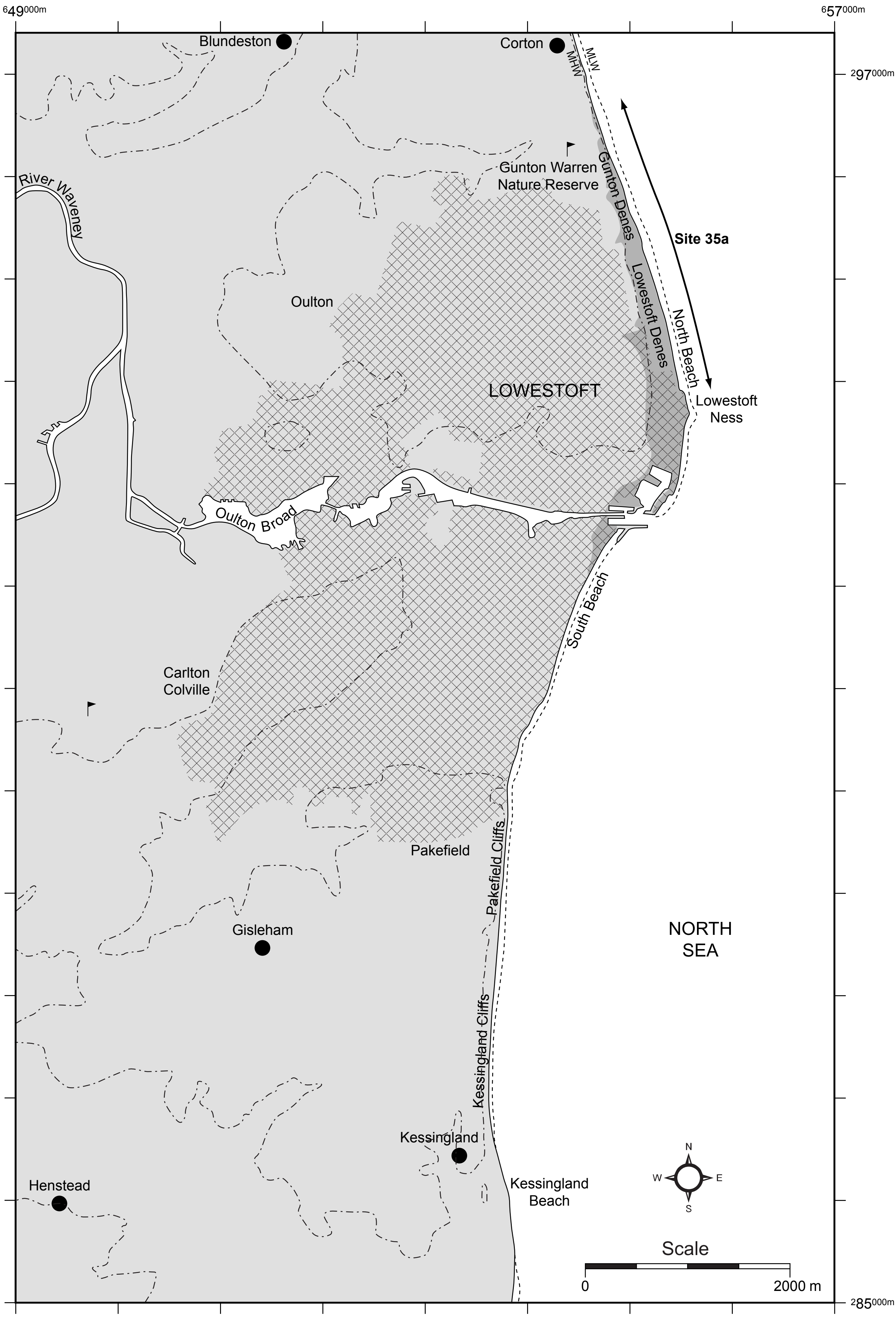


Figure 3.36 Site 35 (Suffolk Coast): Site 35a (Gunton Denes and Lowestoft Denes)

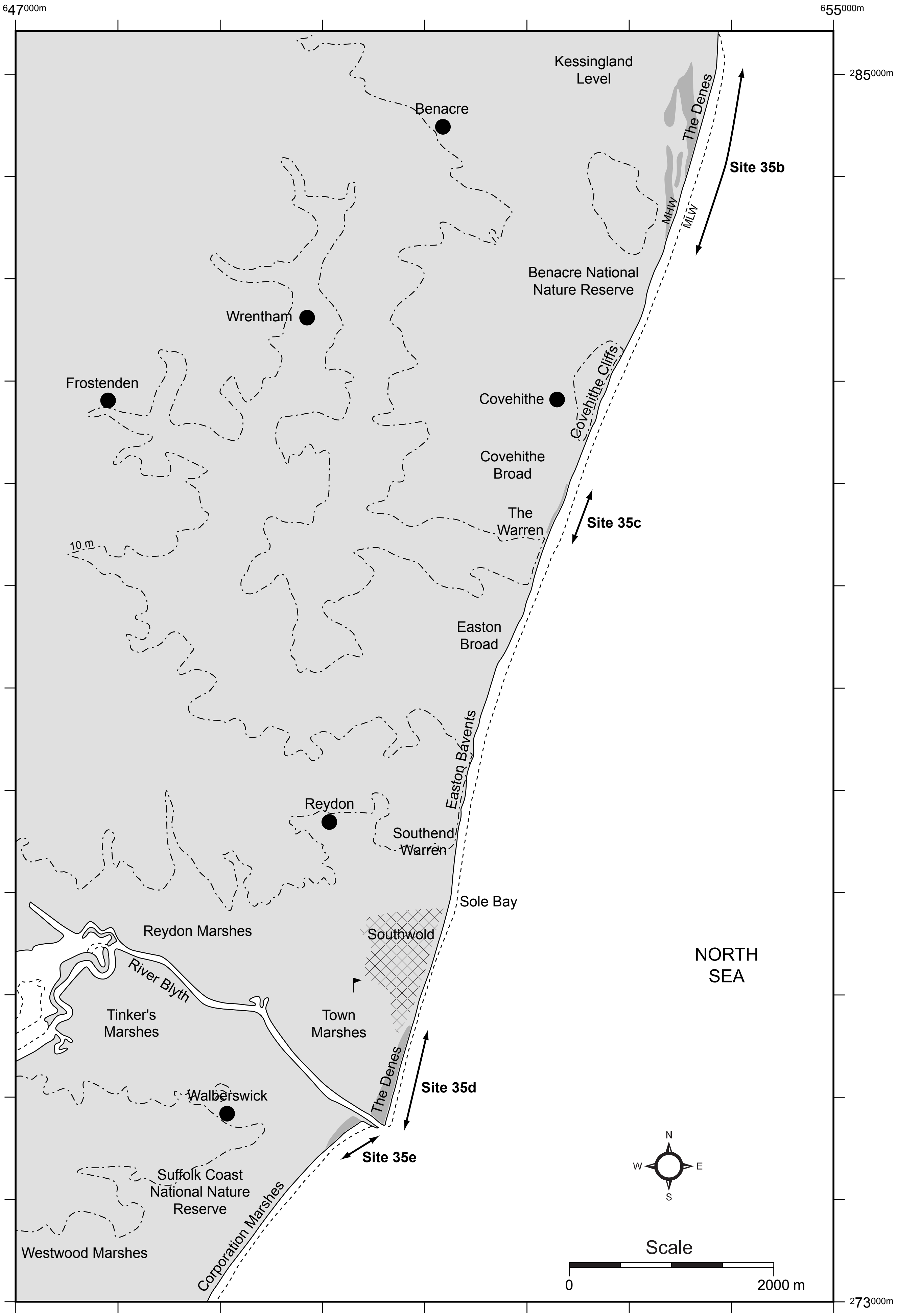


Figure 3.37 Site 35 (Suffolk Coast): Site 35b (Kessingland), Site 35c (Covehithe Broad), Site 35d (Southwold) and Site 35e (Walberswick)

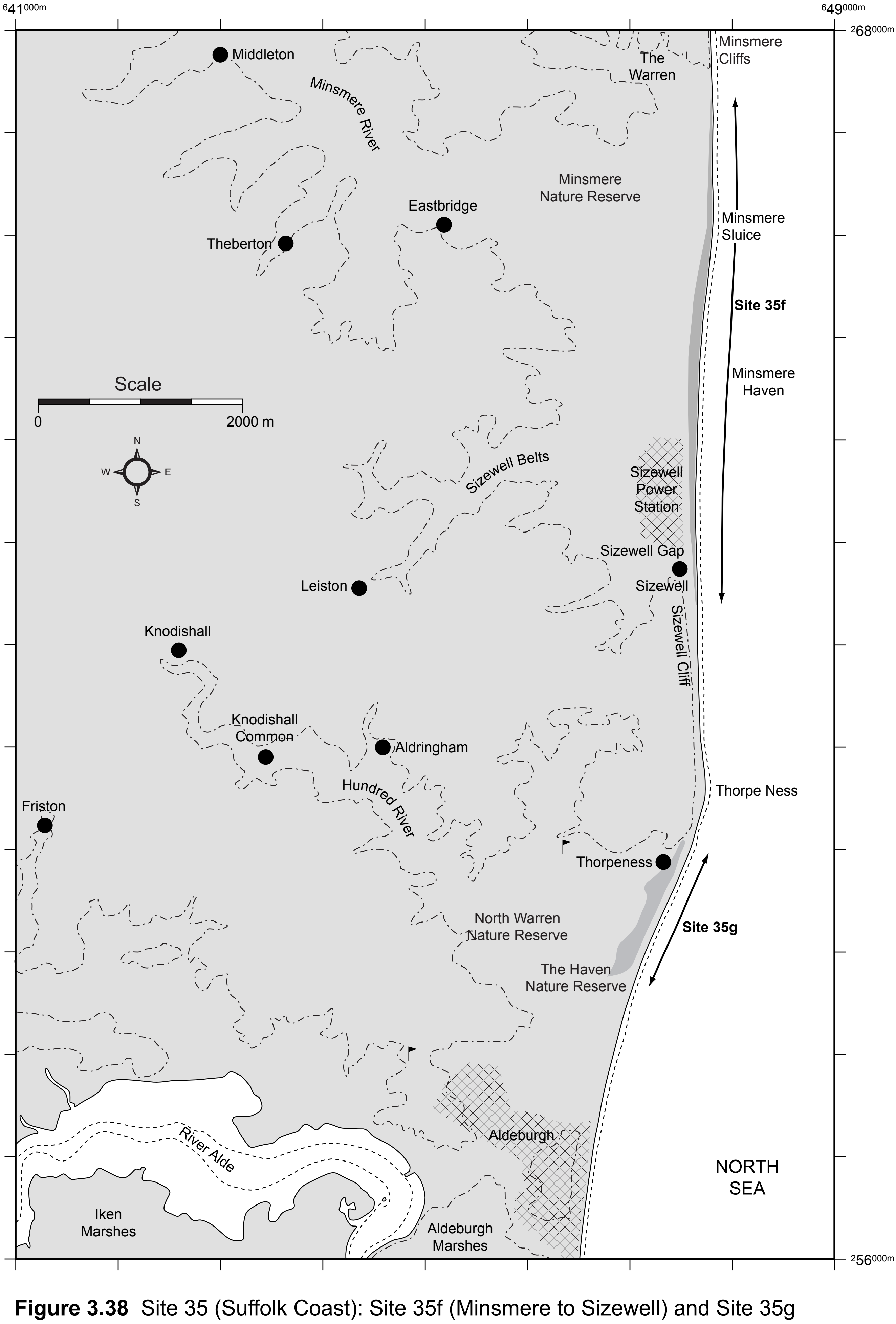


Figure 3.38 Site 35 (Suffolk Coast): Site 35f (Minsmere to Sizewell) and Site 35g (Thorpeness)

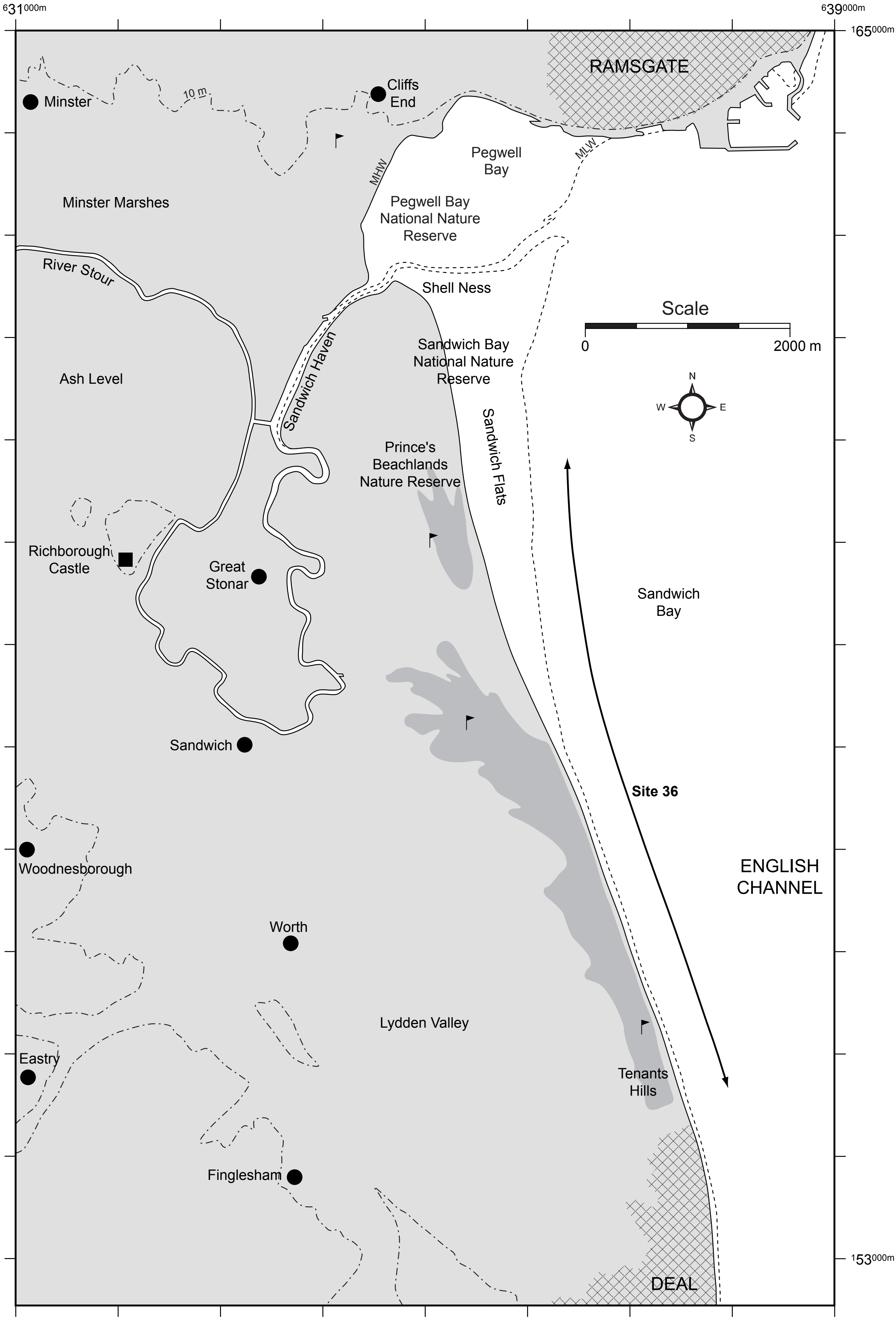


Figure 3.39 Site 36 (Sandwich Bay)

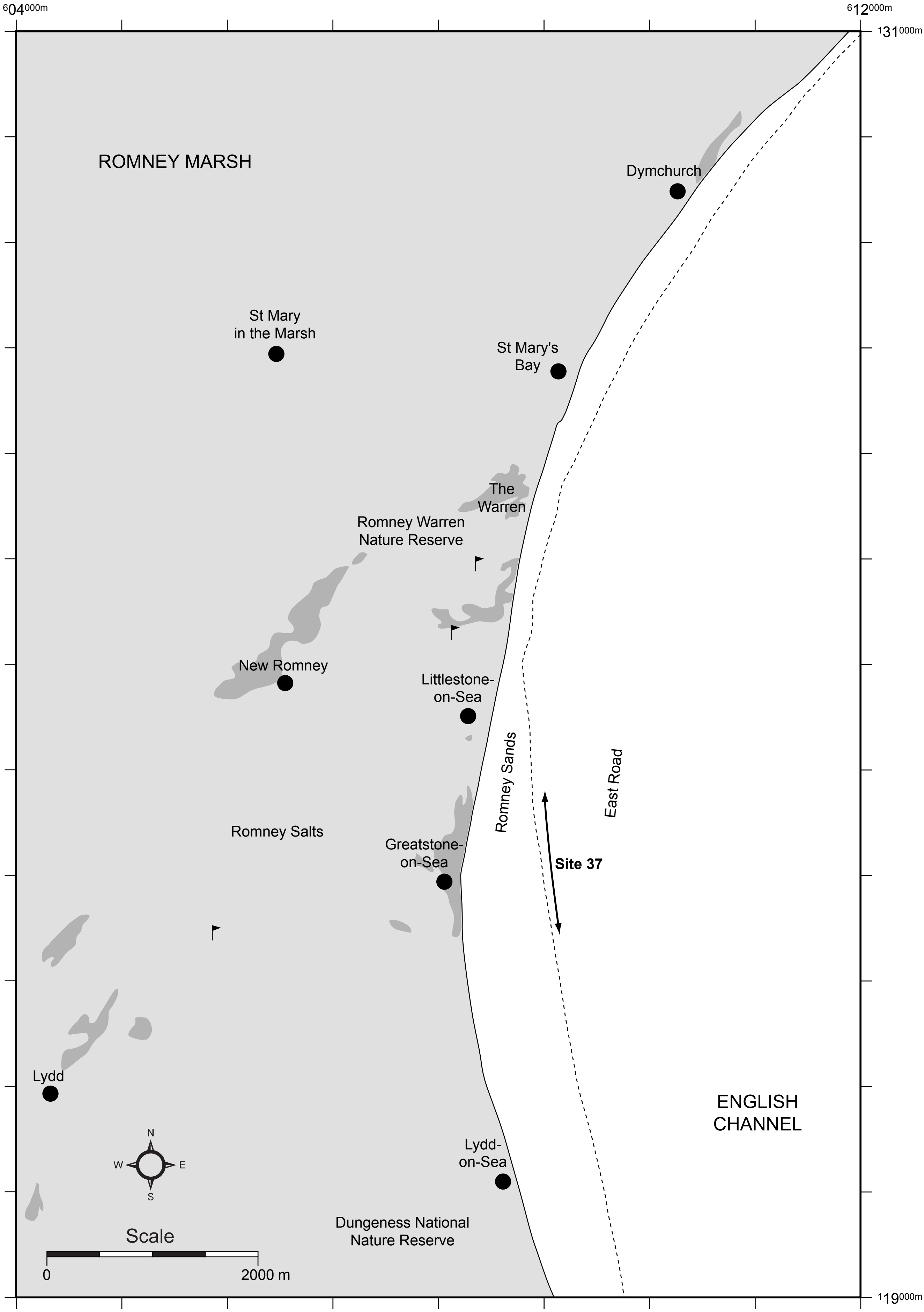


Figure 3.40 Site 37 (Romney Sands)

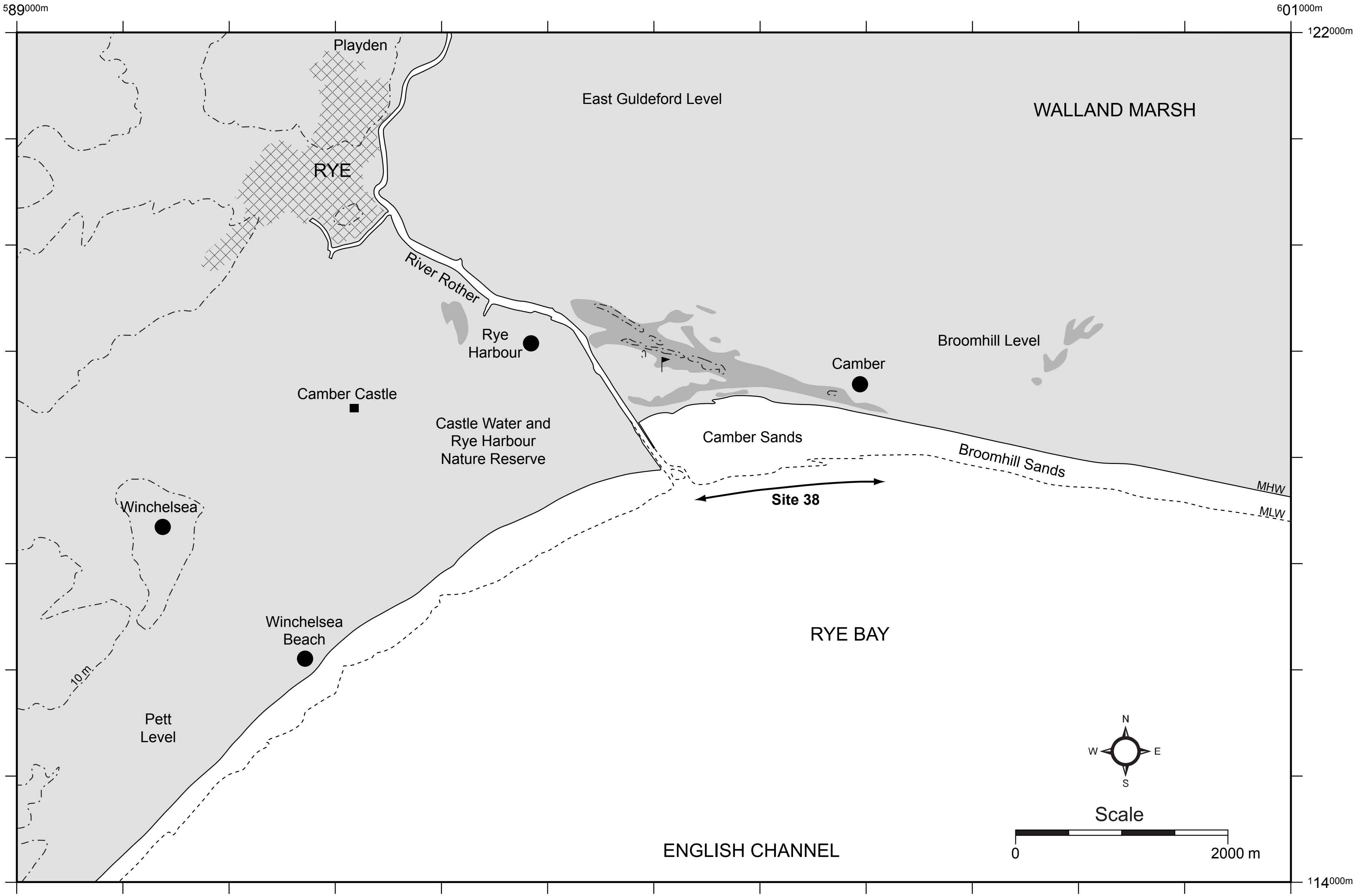


Figure 3.41 Site 38 (Camber Sands)

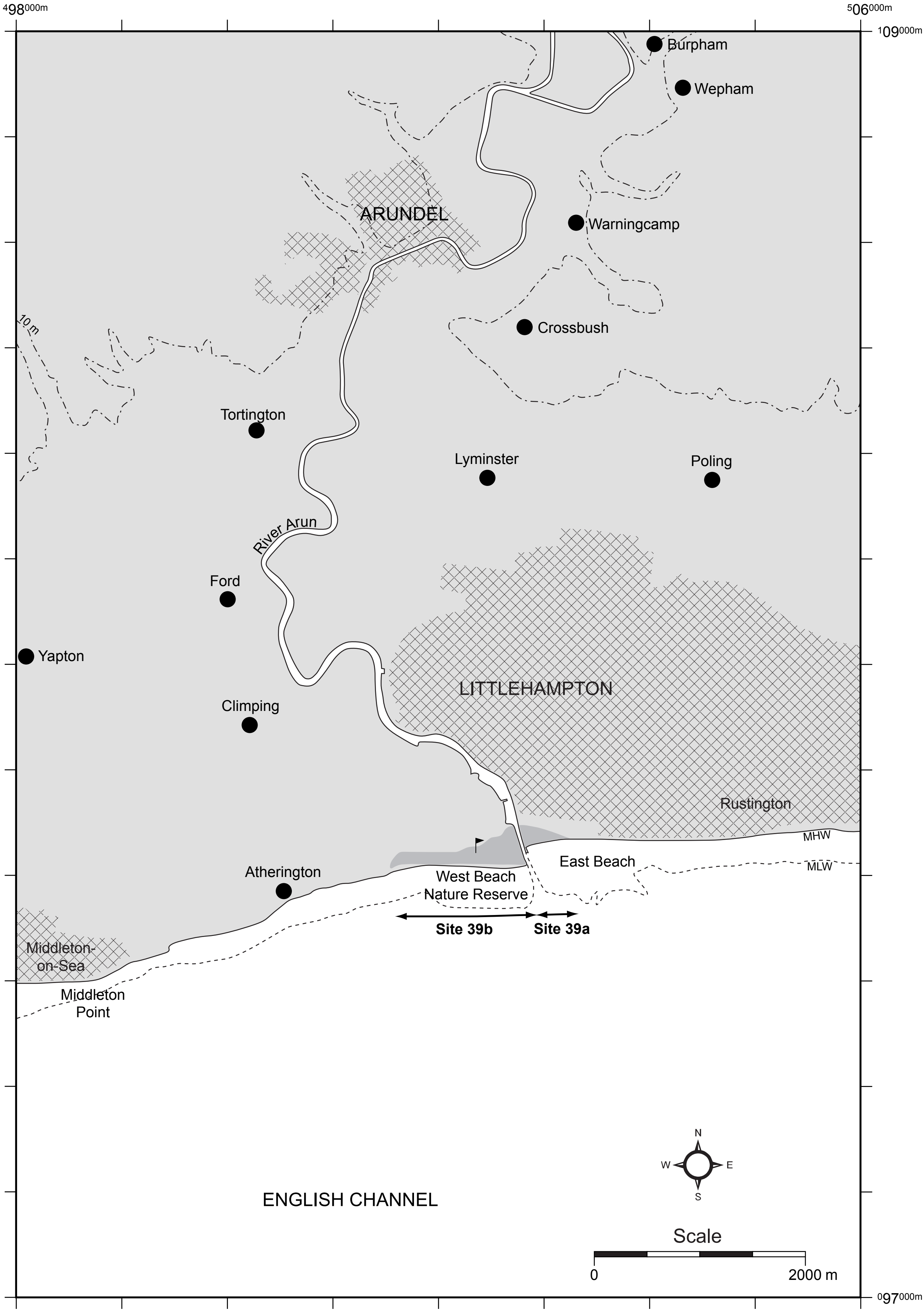


Figure 3.42 Site 39 (Littlehampton): Site 39a (East Beach) and Site 39b (West Beach)

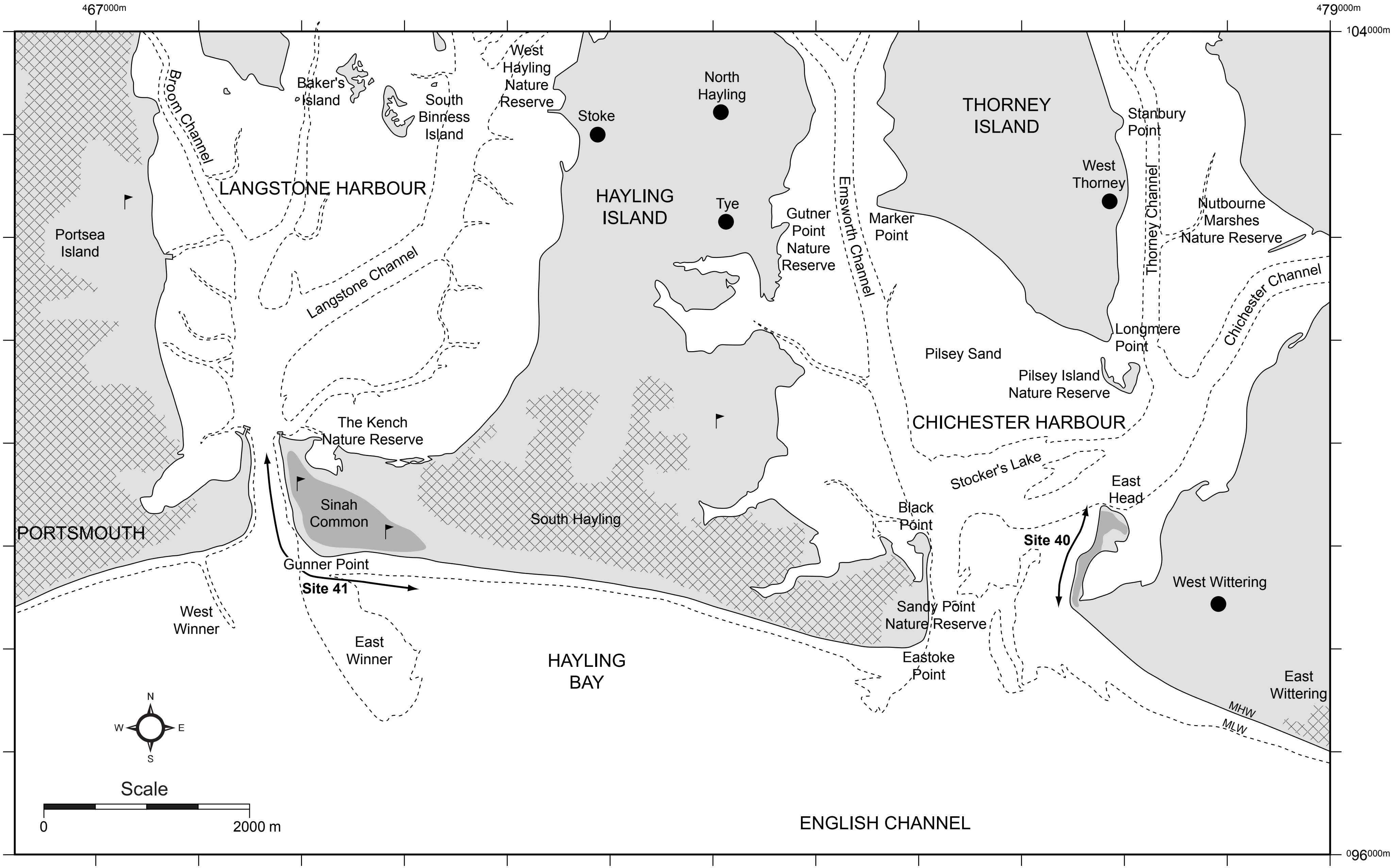


Figure 3.43 Site 40 (East Head, West Wittering) and Site 41 (Sinah Common, Hayling Island)

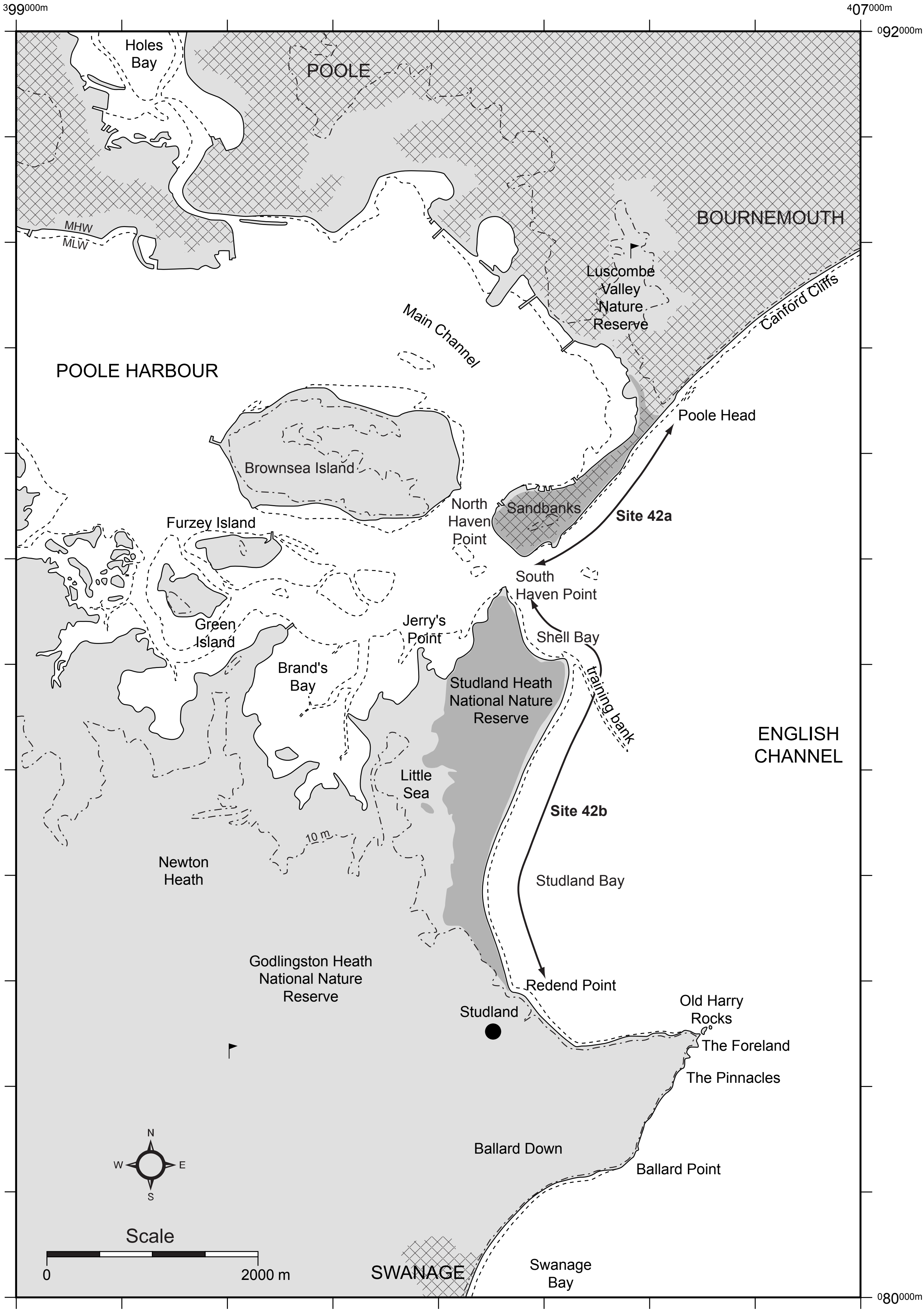


Figure 3.44 Site 42 (Poole Harbour): Site 42a (Sandbanks) and Site 42b (Studland)

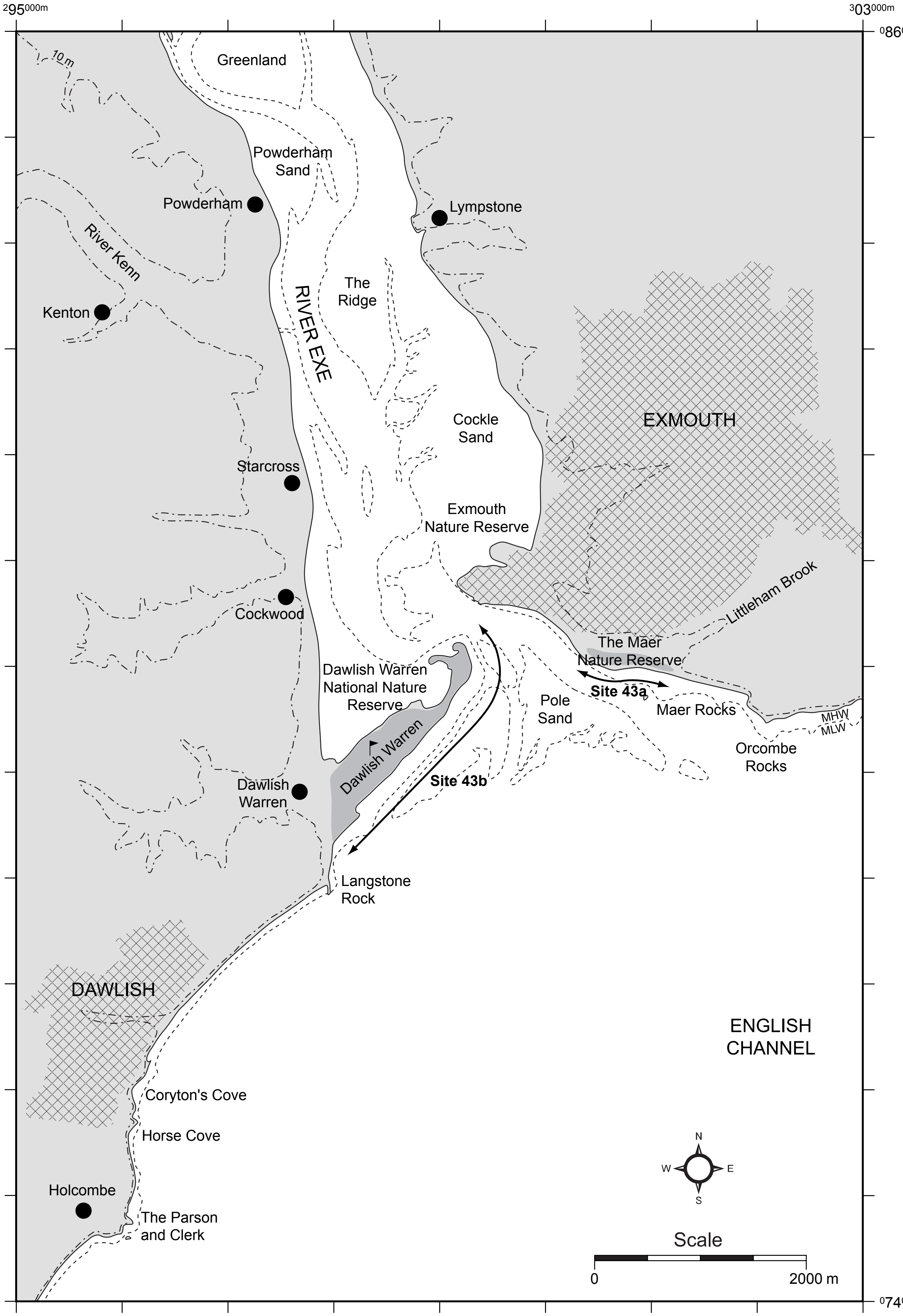


Figure 3.45 Site 43 (Exe Estuary): Site 43a (The Maer, Exmouth) and Site 43b (Dawlish Warren)

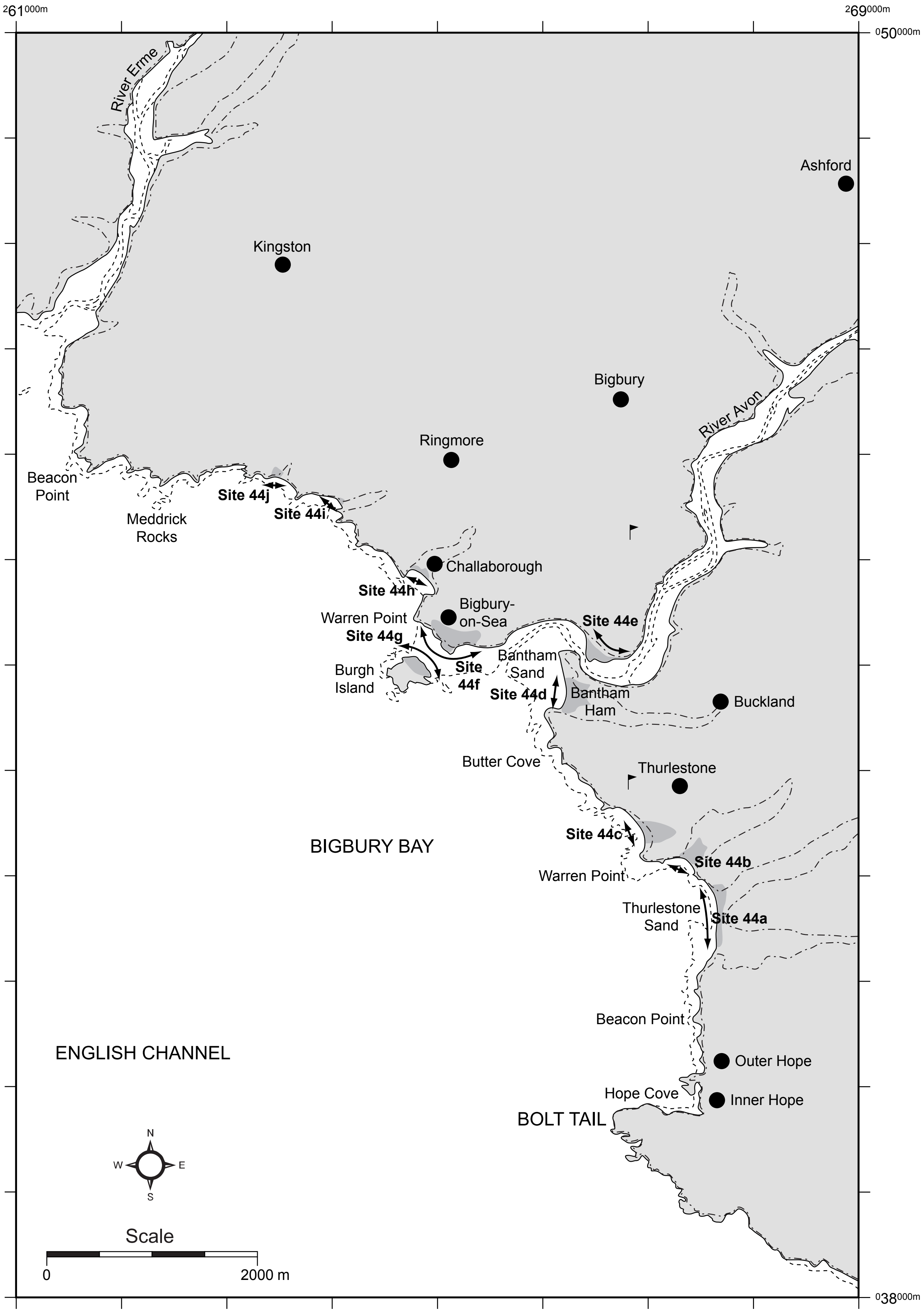


Figure 3.46 Site 44 (Bigbury Bay): Site 44a (Thurlestone Sands), Site 44b (Leas Foot Sand), Site 44c (Yarmouth Sand), Site 44d (Bantham Ham), Site 44e (Cockleridge Ham), Site 44f (Bigbury-on-Sea), Site 44g (Burgh Island), Site 44h (Challaborough), Site 44i (Ayrmer Cove), Site 44j (Westcombe Beach)

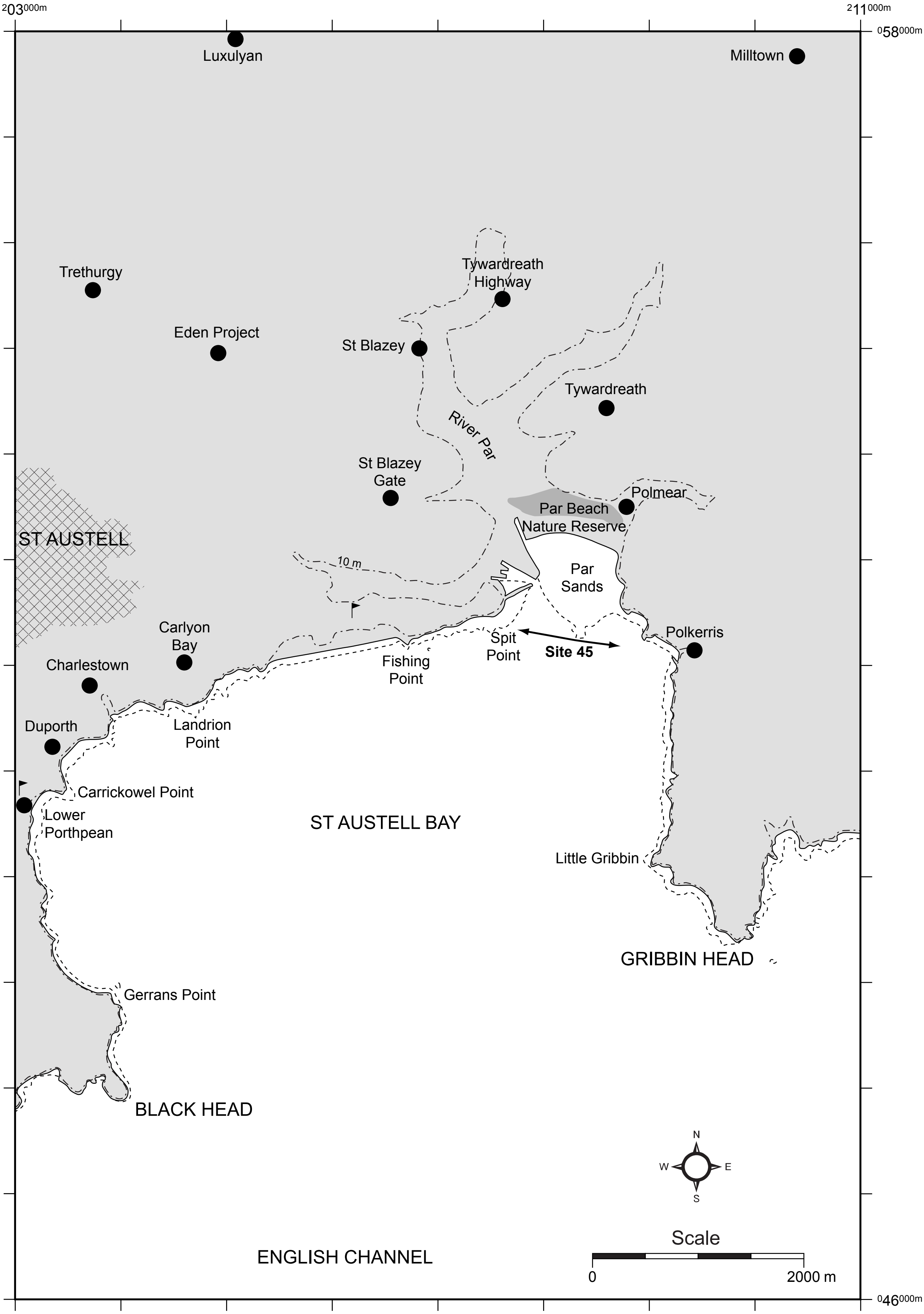


Figure 3.47 Site 45 (Par Sands)

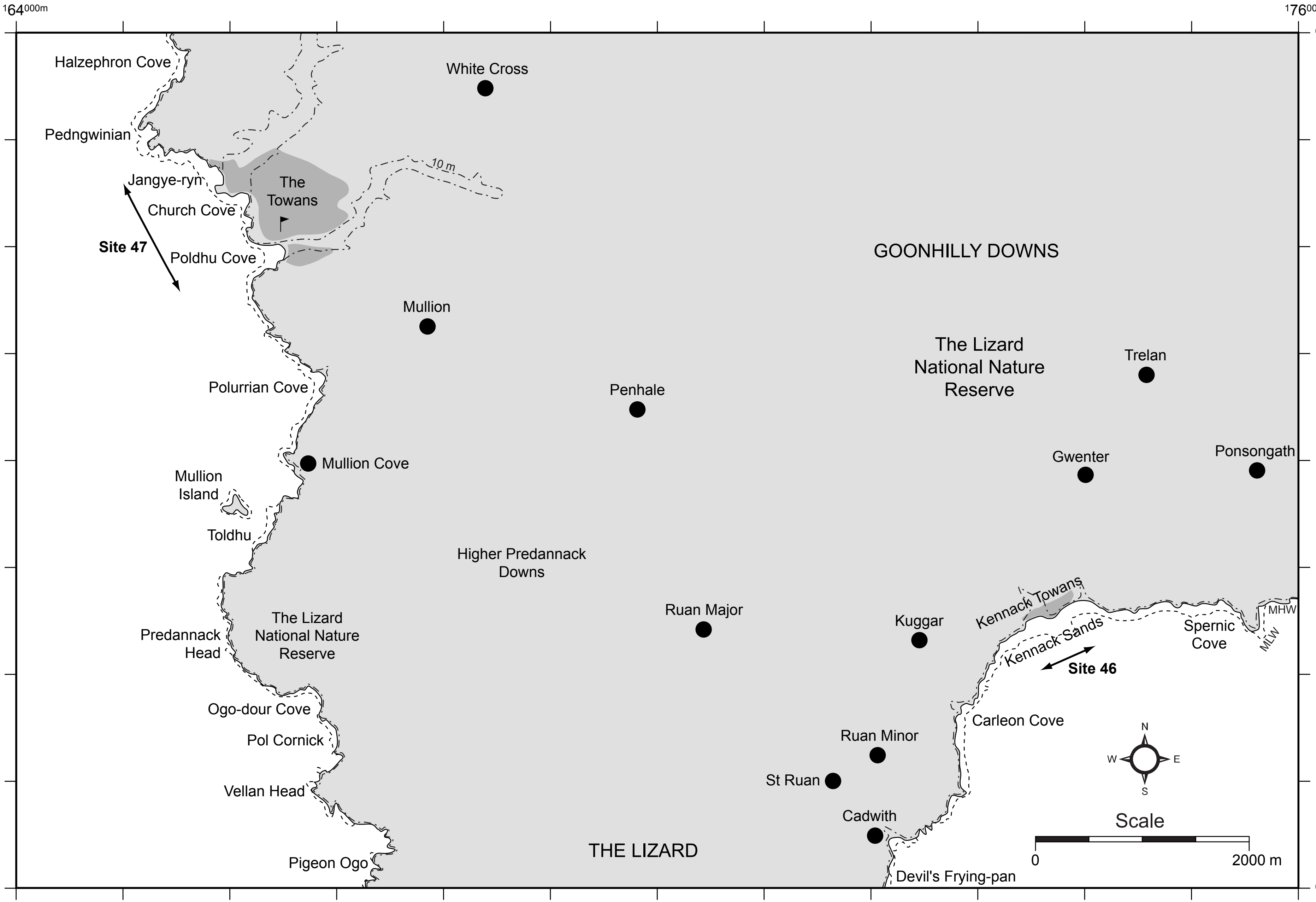


Figure 3.48 Site 46 (Kennack Towans) and Site 47 (The Towans, Mullion)

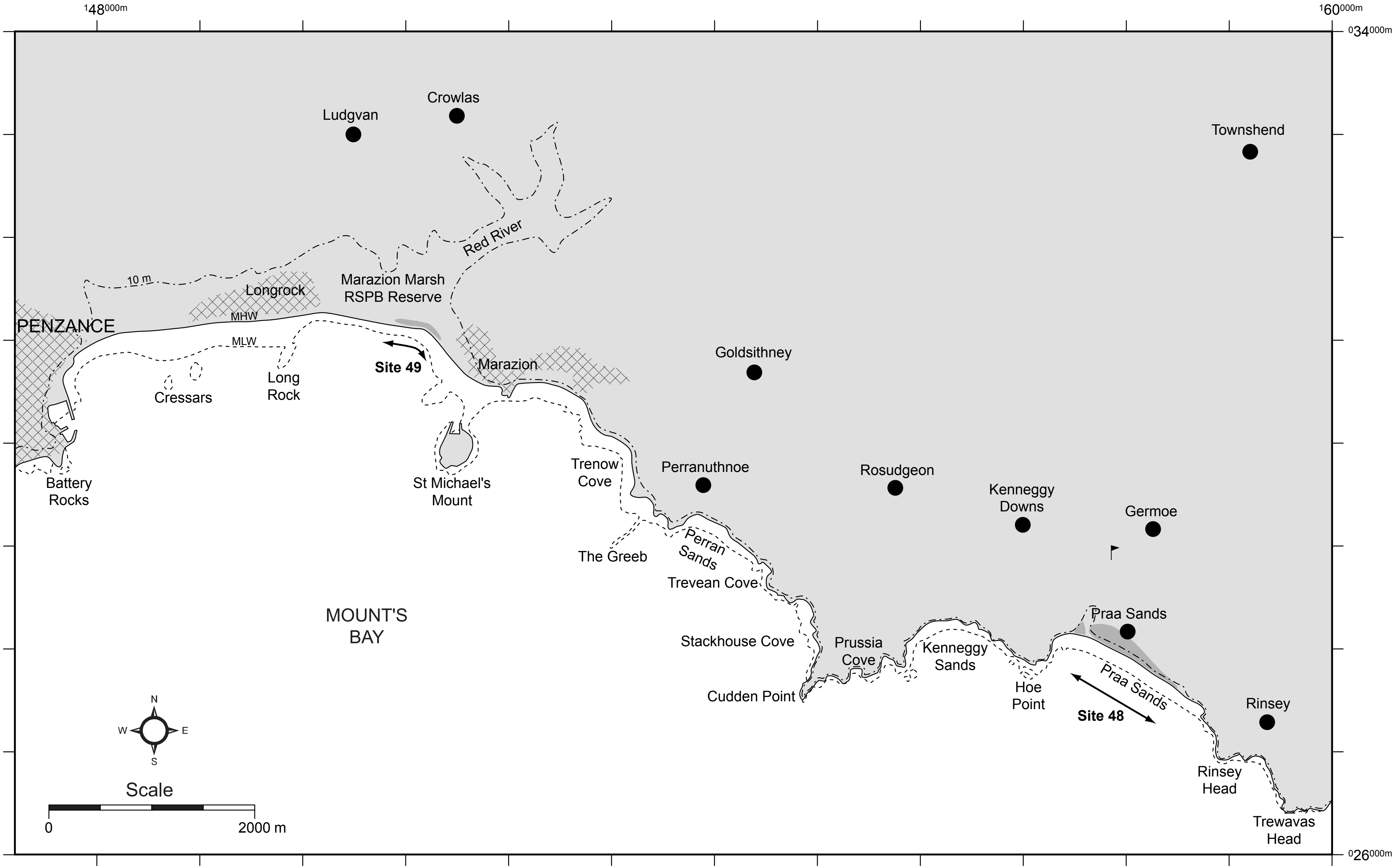


Figure 3.49 Site 48 (Praa Sands) and Site 49 (Marazion)

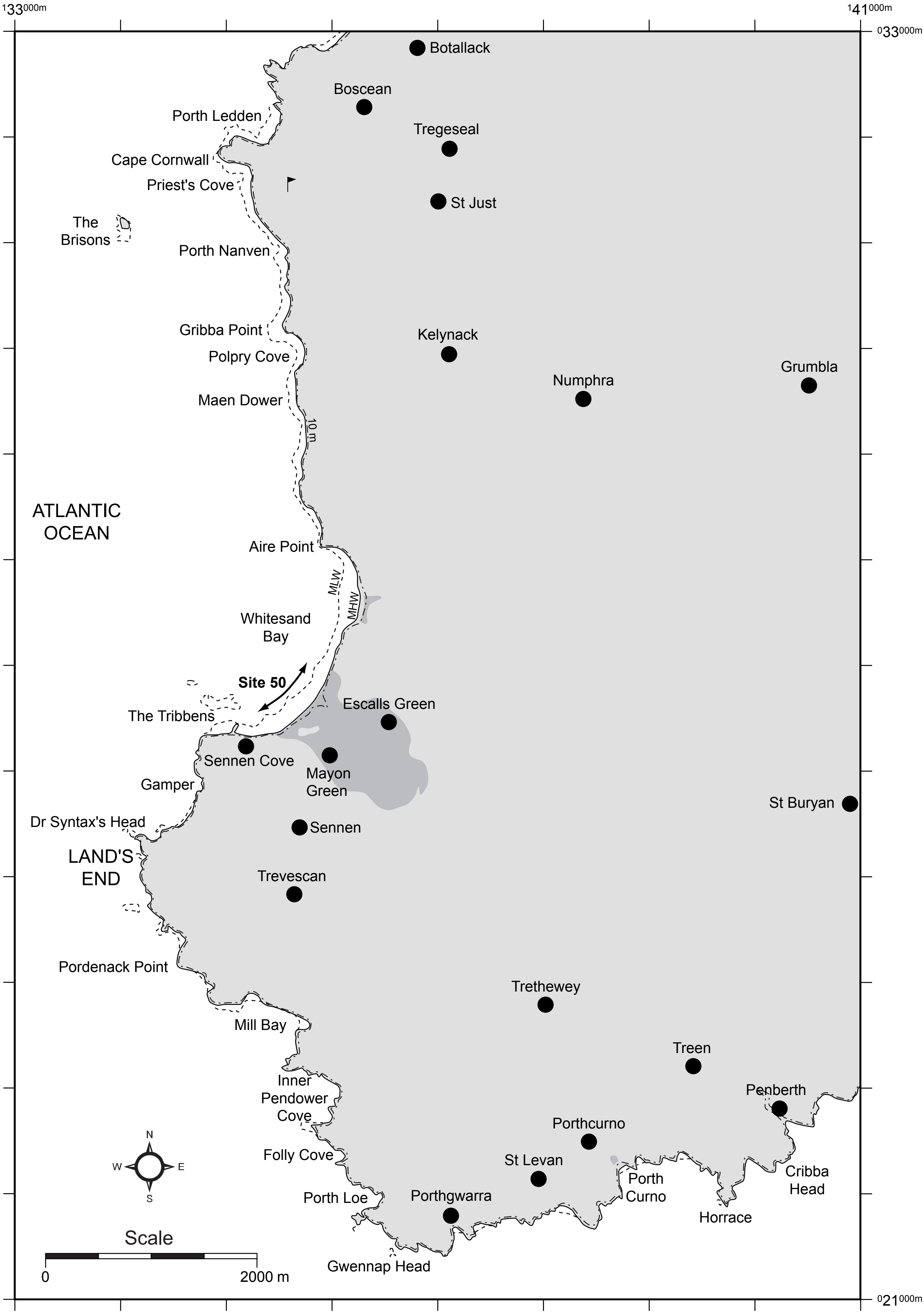


Figure 3.50 Site 50 (Whitesand Bay)

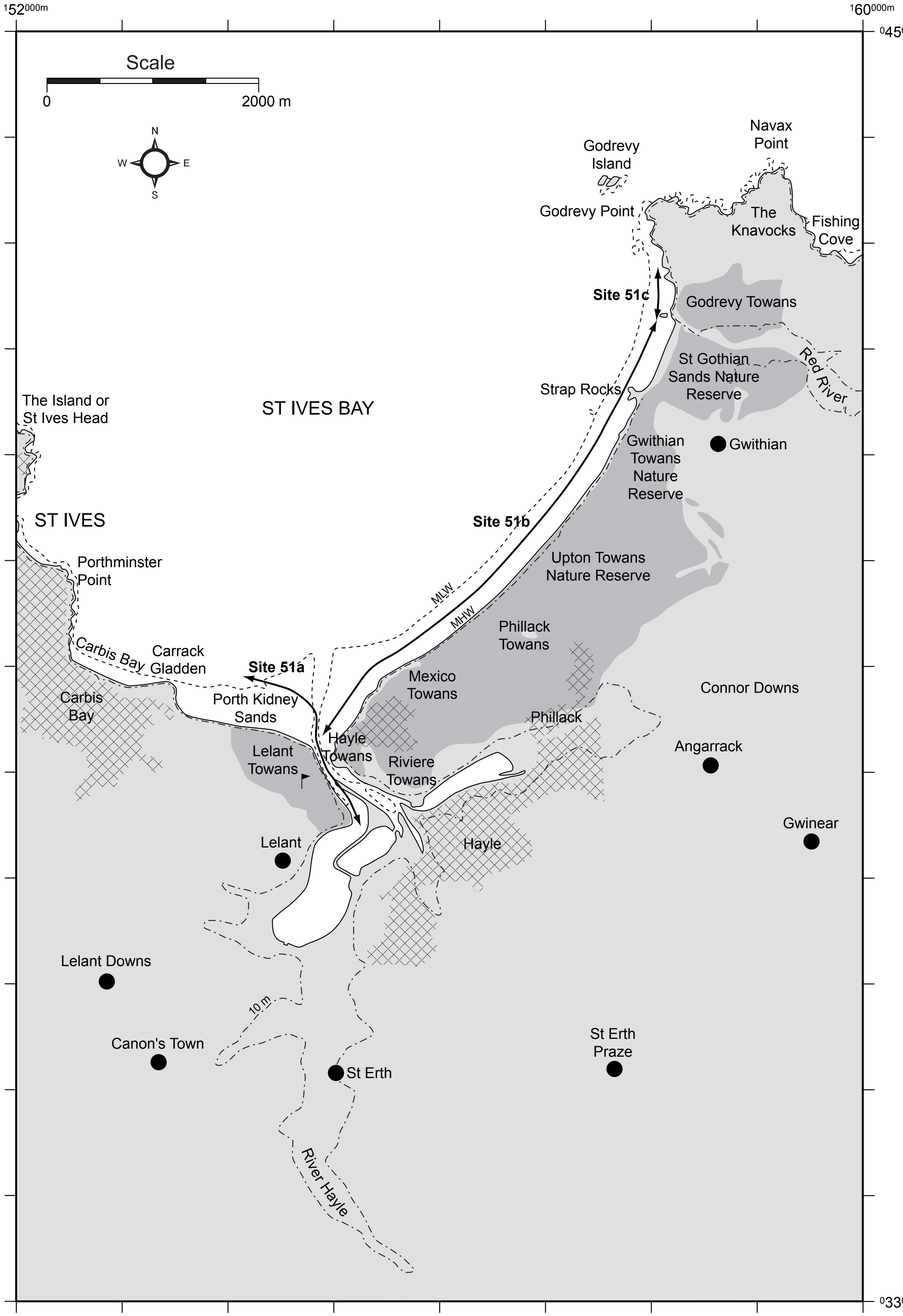


Figure 3.51 Site 51 (St Ives Bay): Site 51a (Lelant Towans), Site 51b (Hayle Towans, Upton Towans and Gwithian Towans) and Site 51c (Godrevy Towans)

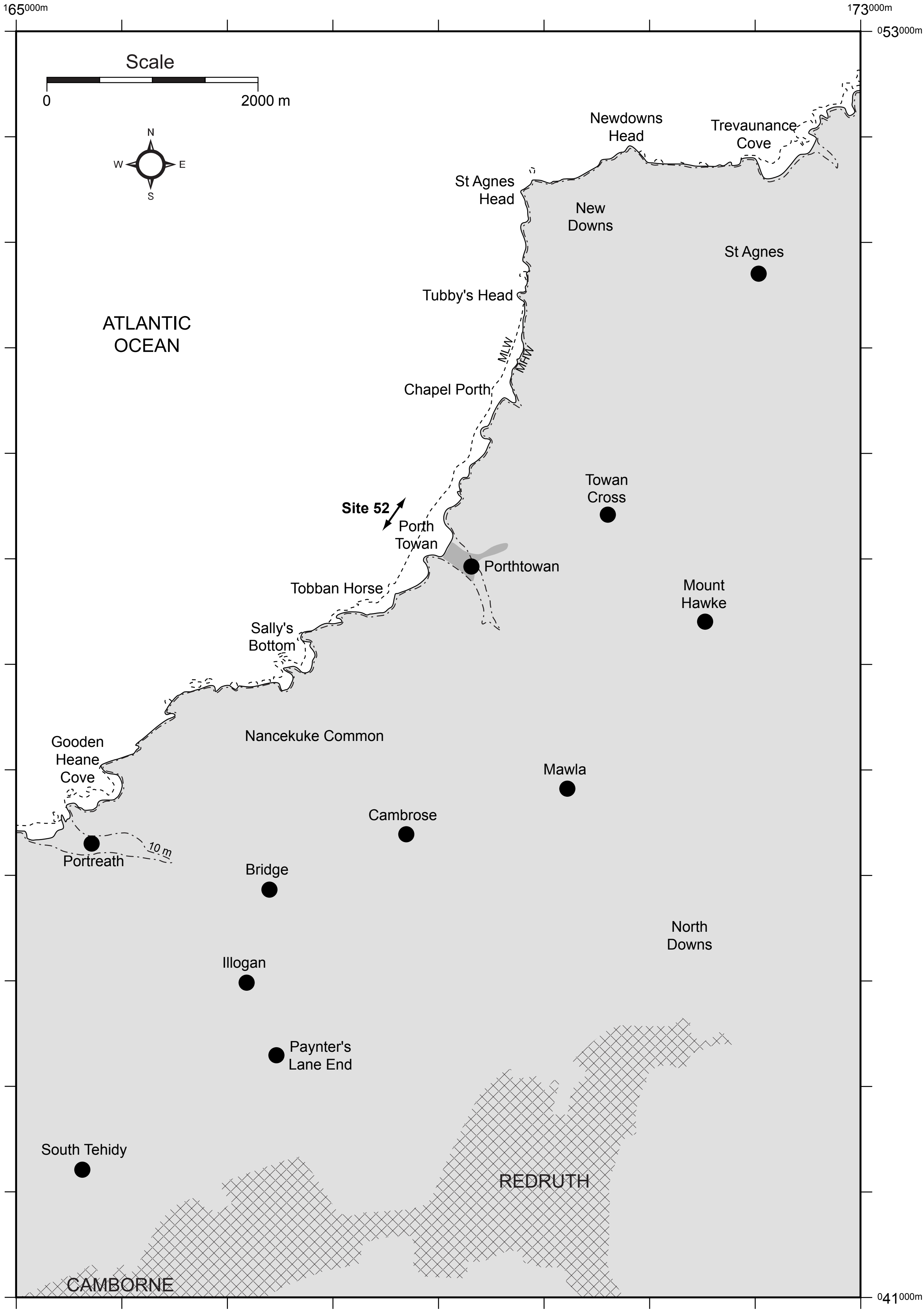


Figure 3.52 Site 52 (Porth Towan)

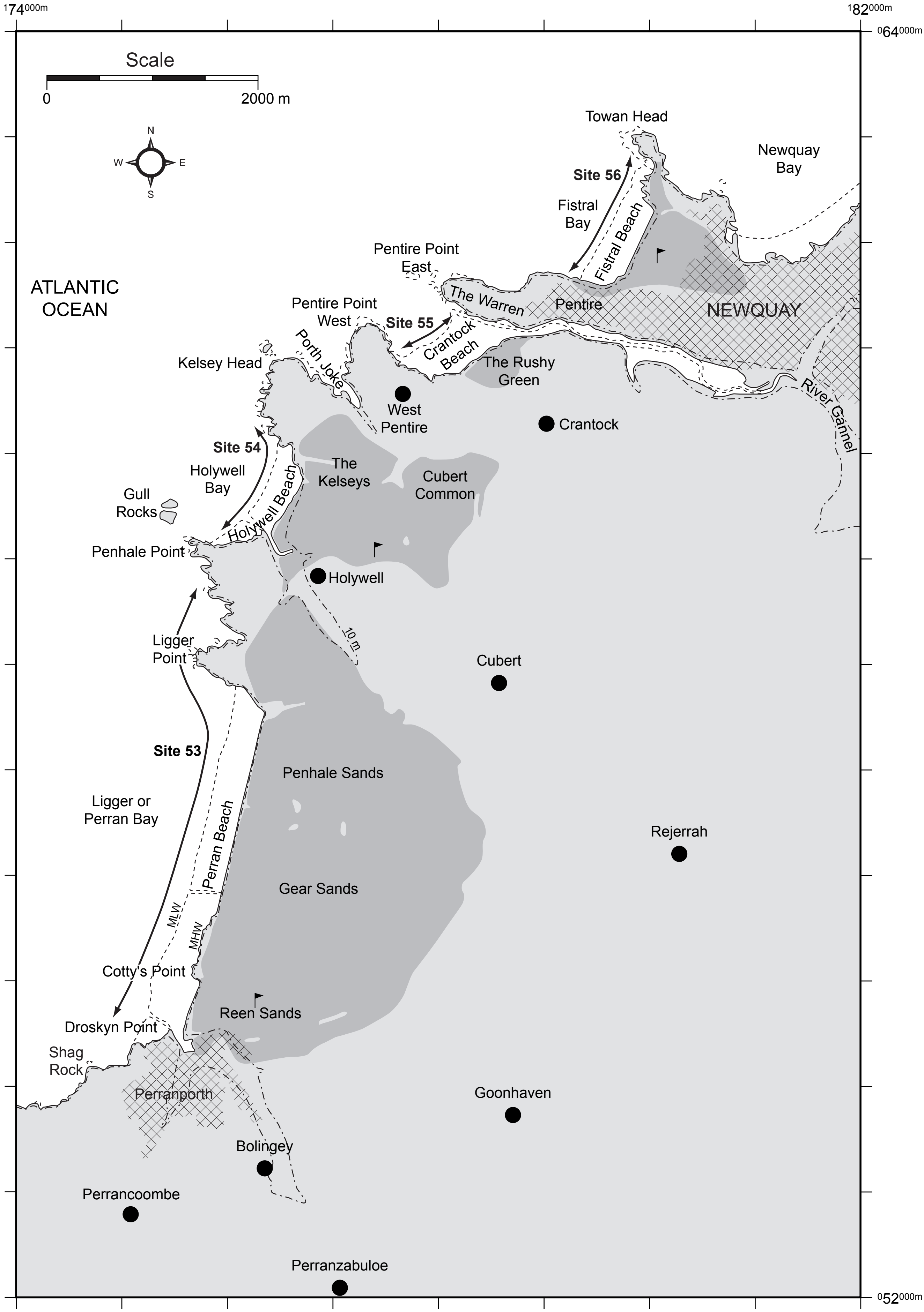


Figure 3.53 Site 53 (Perran Bay), Site 54 (Holywell Bay), Site 55 (Crantock Bay) and Site 56 (Fistral Bay)

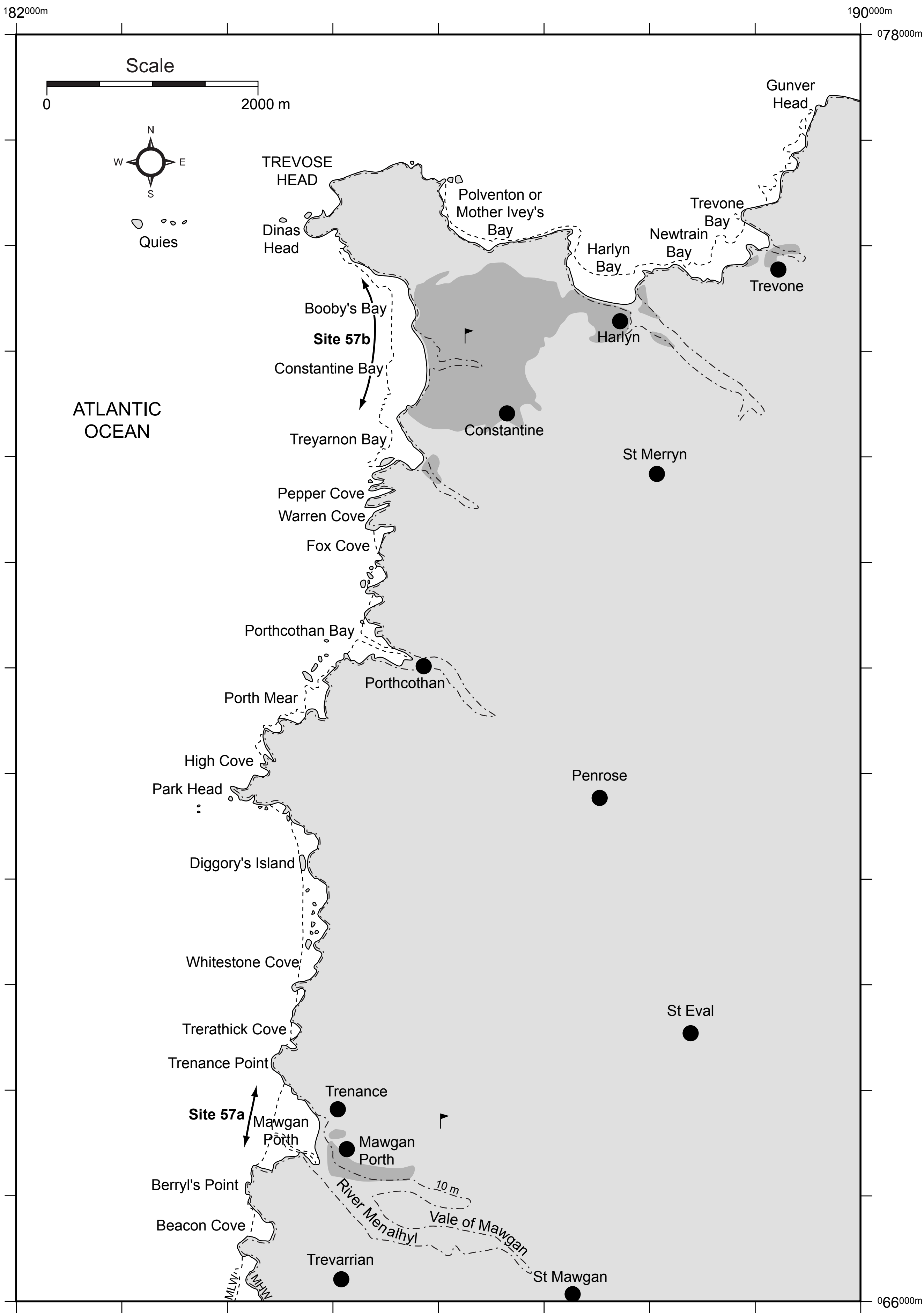


Figure 3.54 Site 57 (Berryl's Point to Trevose Head): Site 57a (Mawgan Porth) and Site 57b (Constantine Bay)

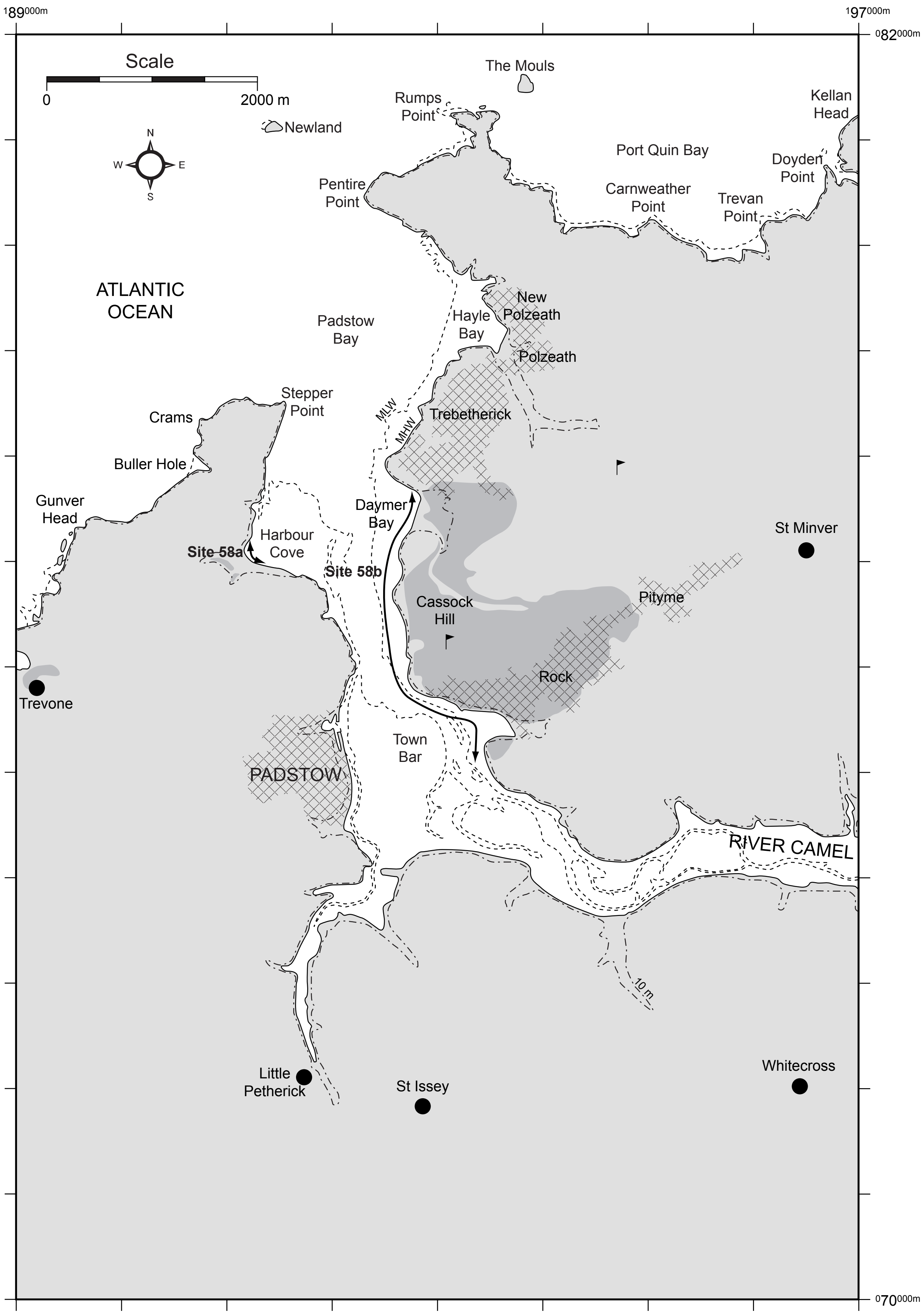


Figure 3.55 Site 58 (Camel Estuary): Site 58a (Harbour Cove) and Site 58b (Rock to Daymer Bay)

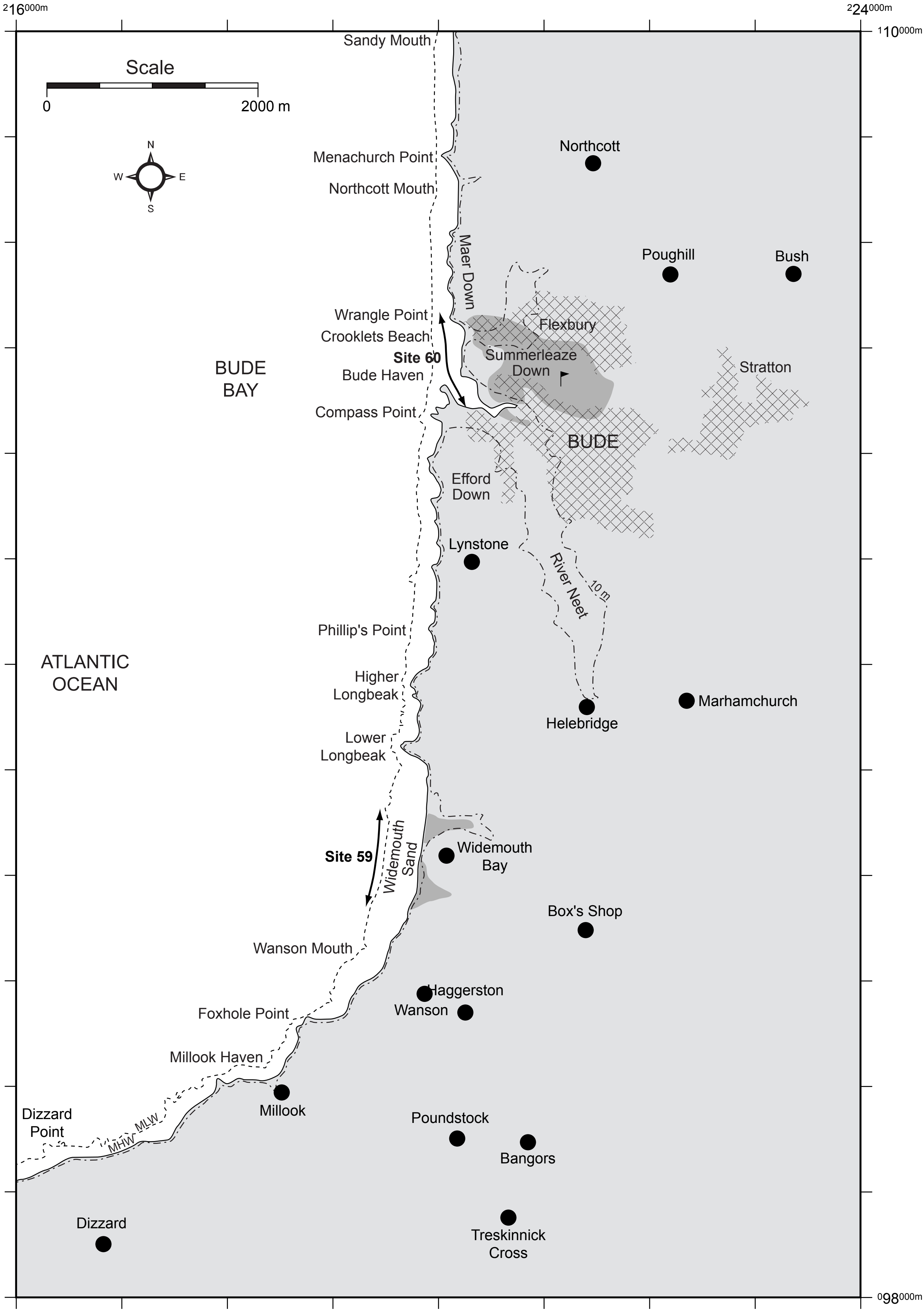


Figure 3.56 Site 59 (Widemouth Bay) and Site 60 (Bude)

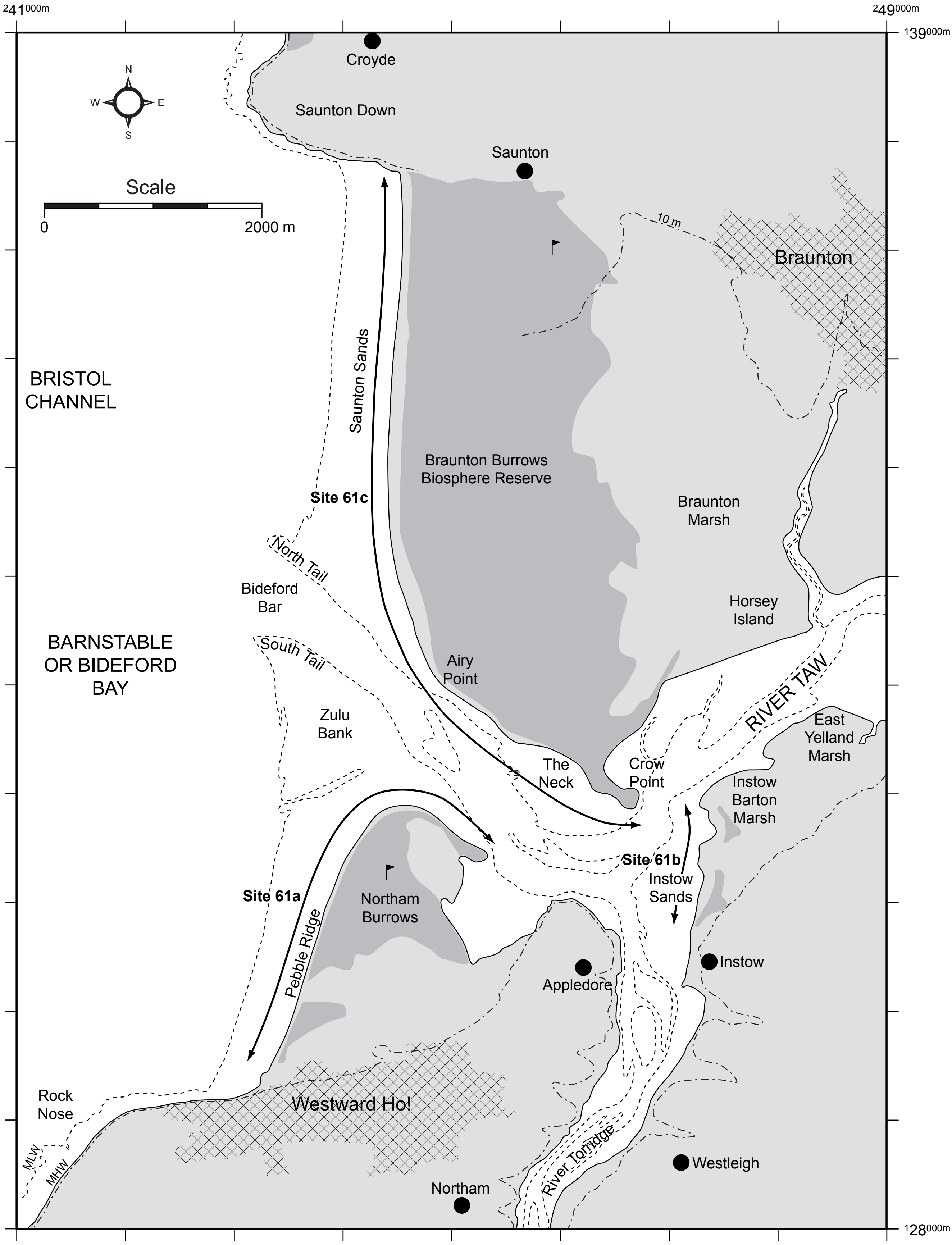


Figure 3.57 Site 61 (Taw Estuary): Site 61a (Northam Burrows), Site 61b (Instow Sands) and Site 61c (Braunton Burrows)

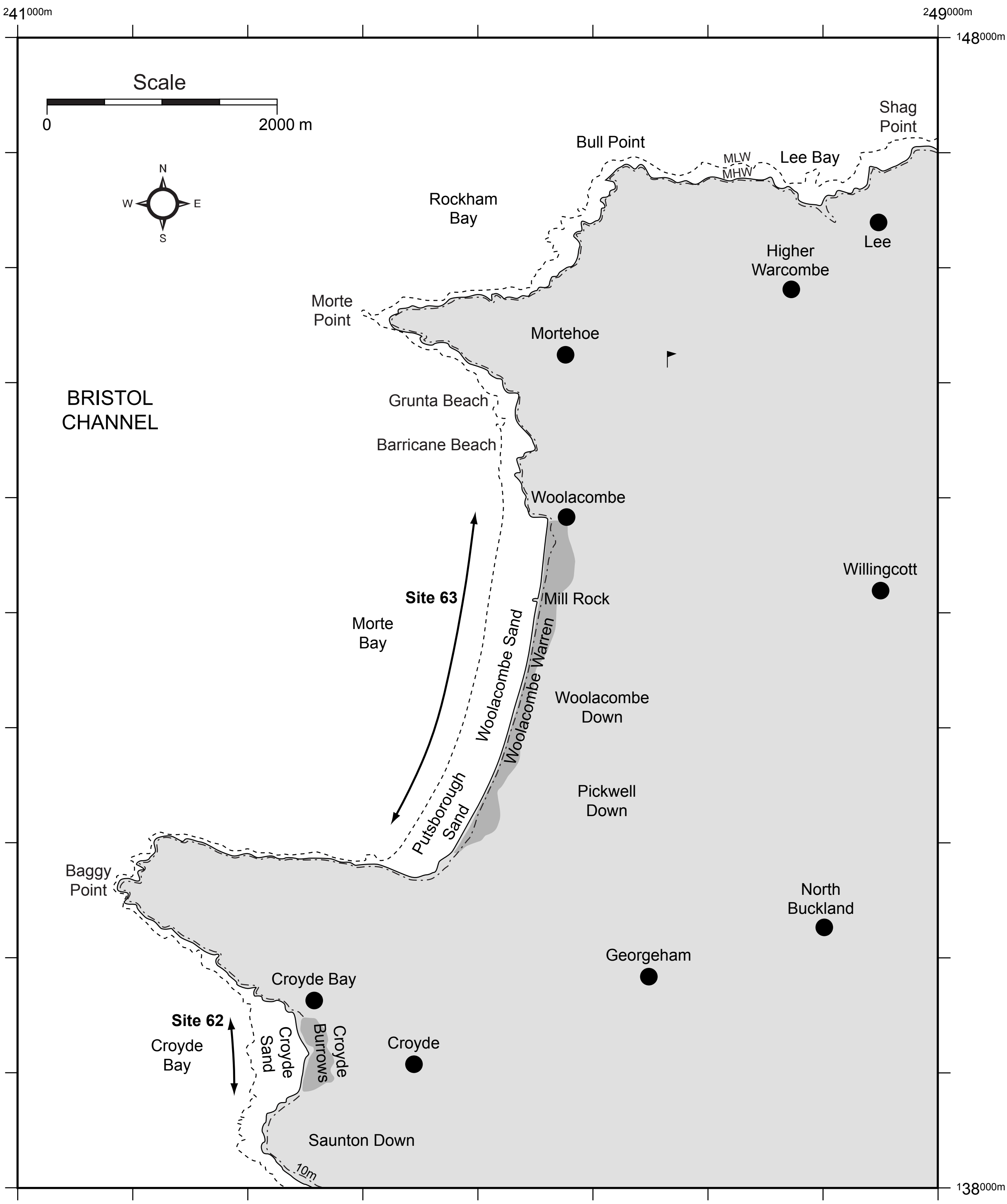


Figure 3.58 Site 62 (Croyde Burrows) and Site 63 (Woolacombe Warren)

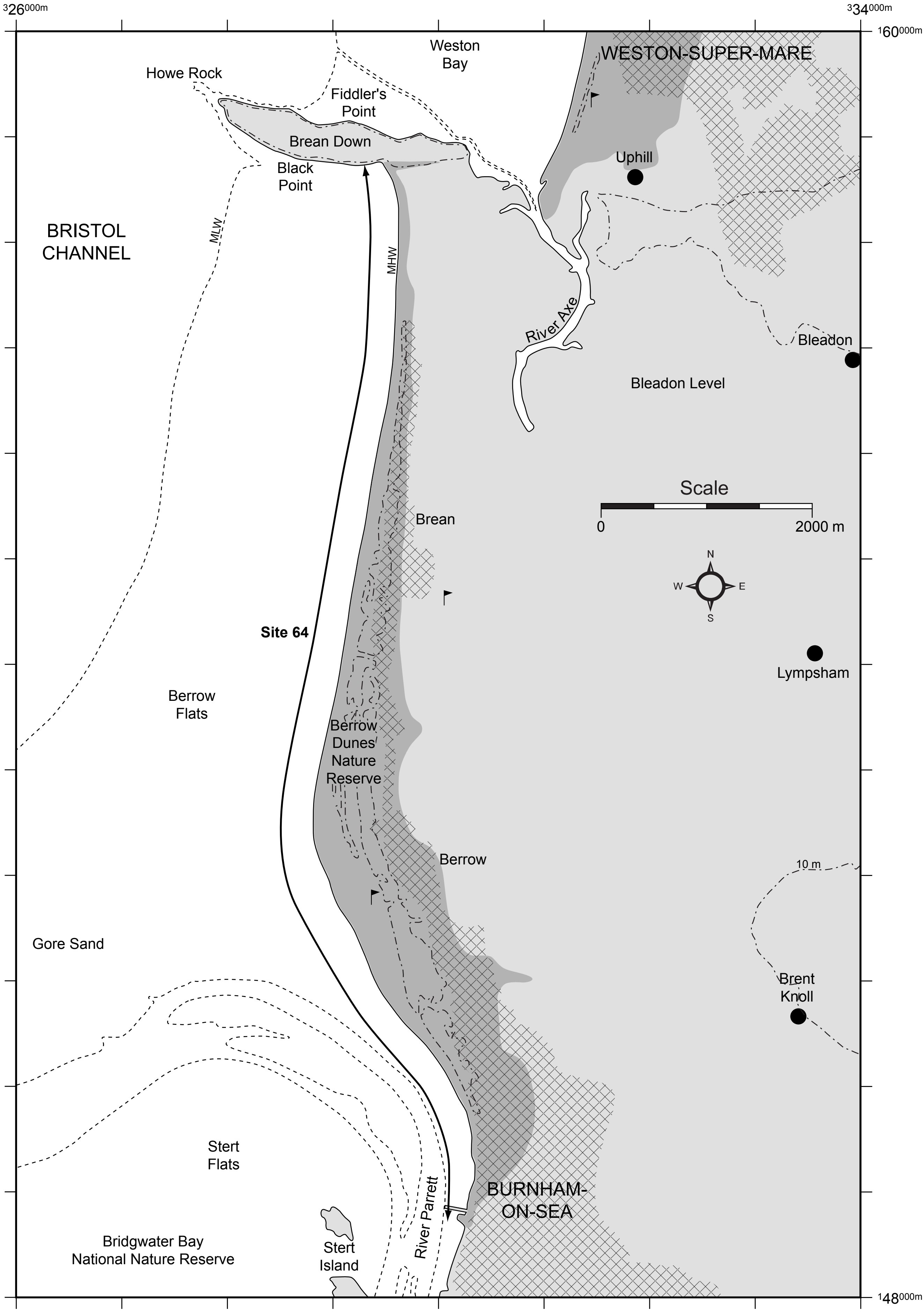


Figure 3.59 Site 64 (Berrow and Brean)

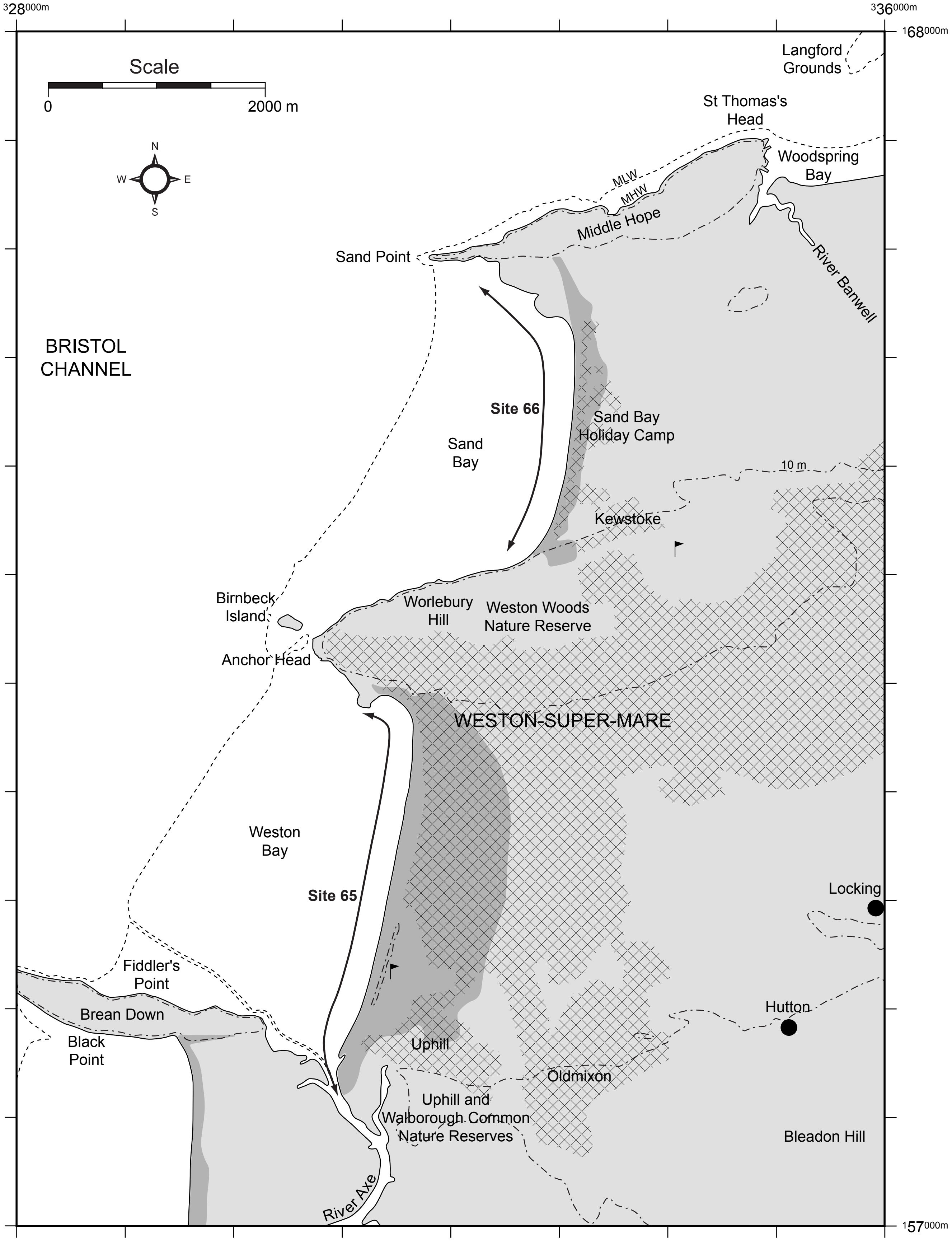


Figure 3.60 Site 65 (Weston Bay) and Site 66 (Sand Bay)

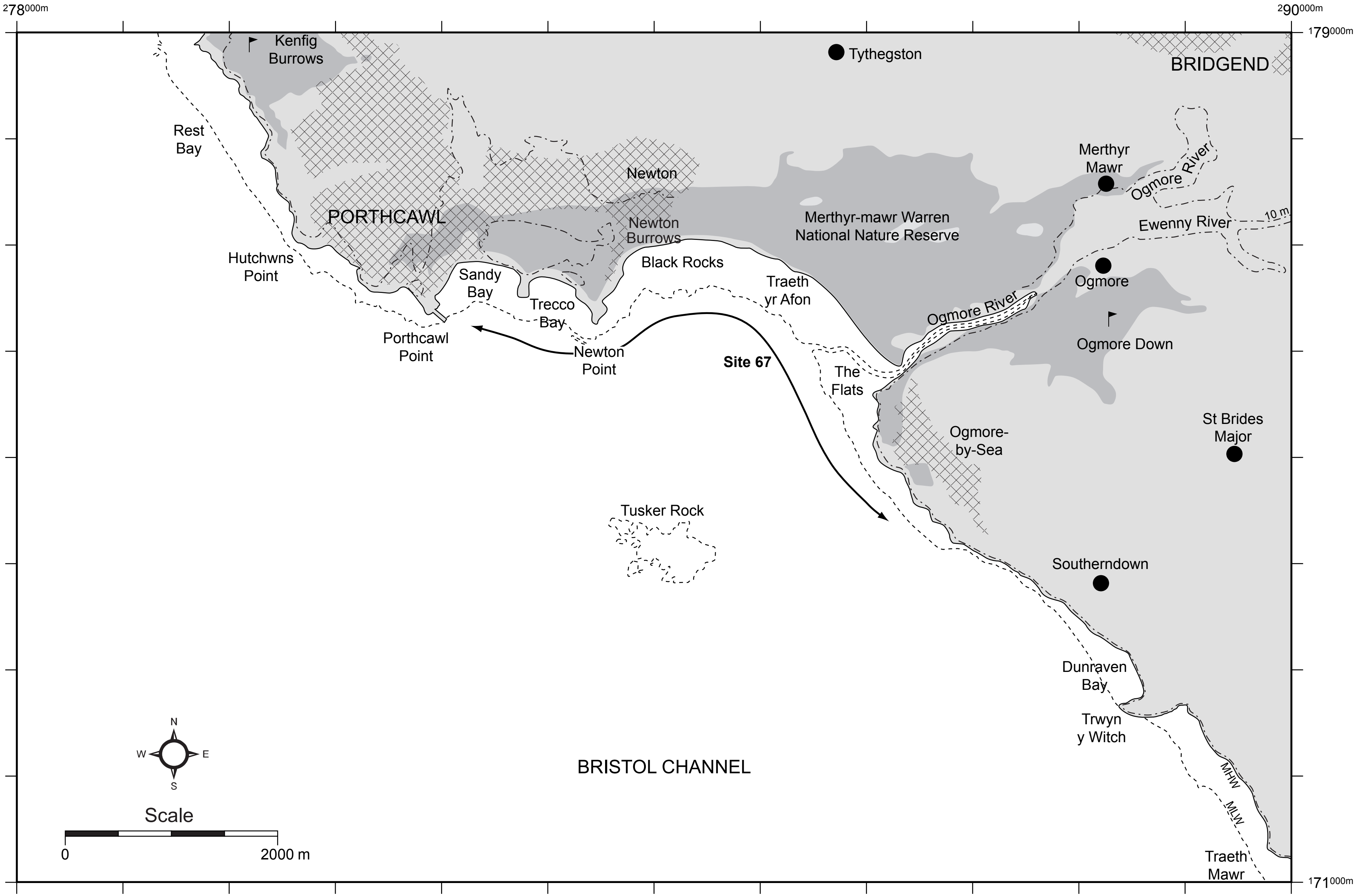


Figure 3.61 Site 67 (Merthyr-mawr Warren)

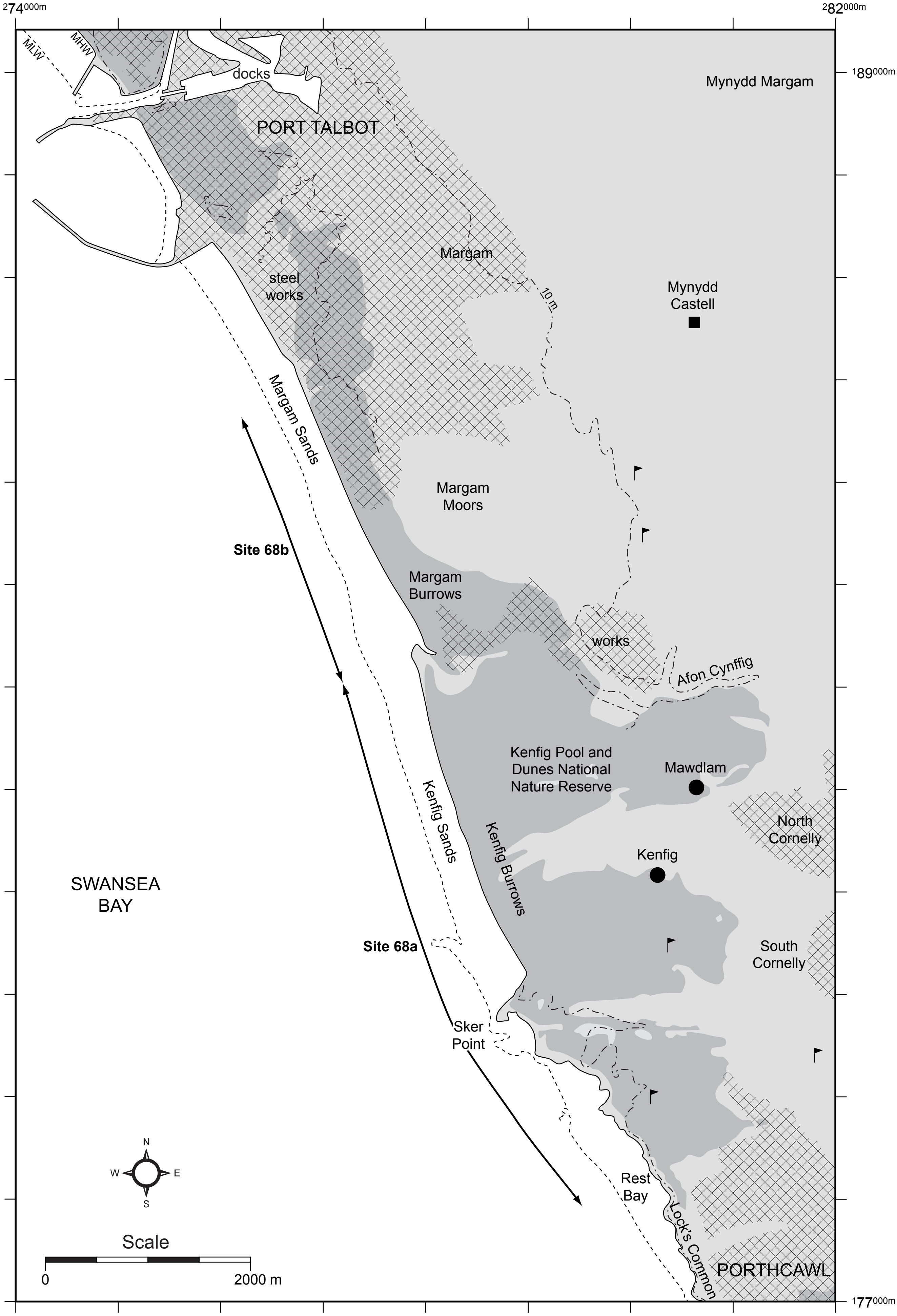


Figure 3.62 Site 68 (Swansea Bay): Site 68a (Kenfig Burrows) and Site 68b (Margam Burrows)

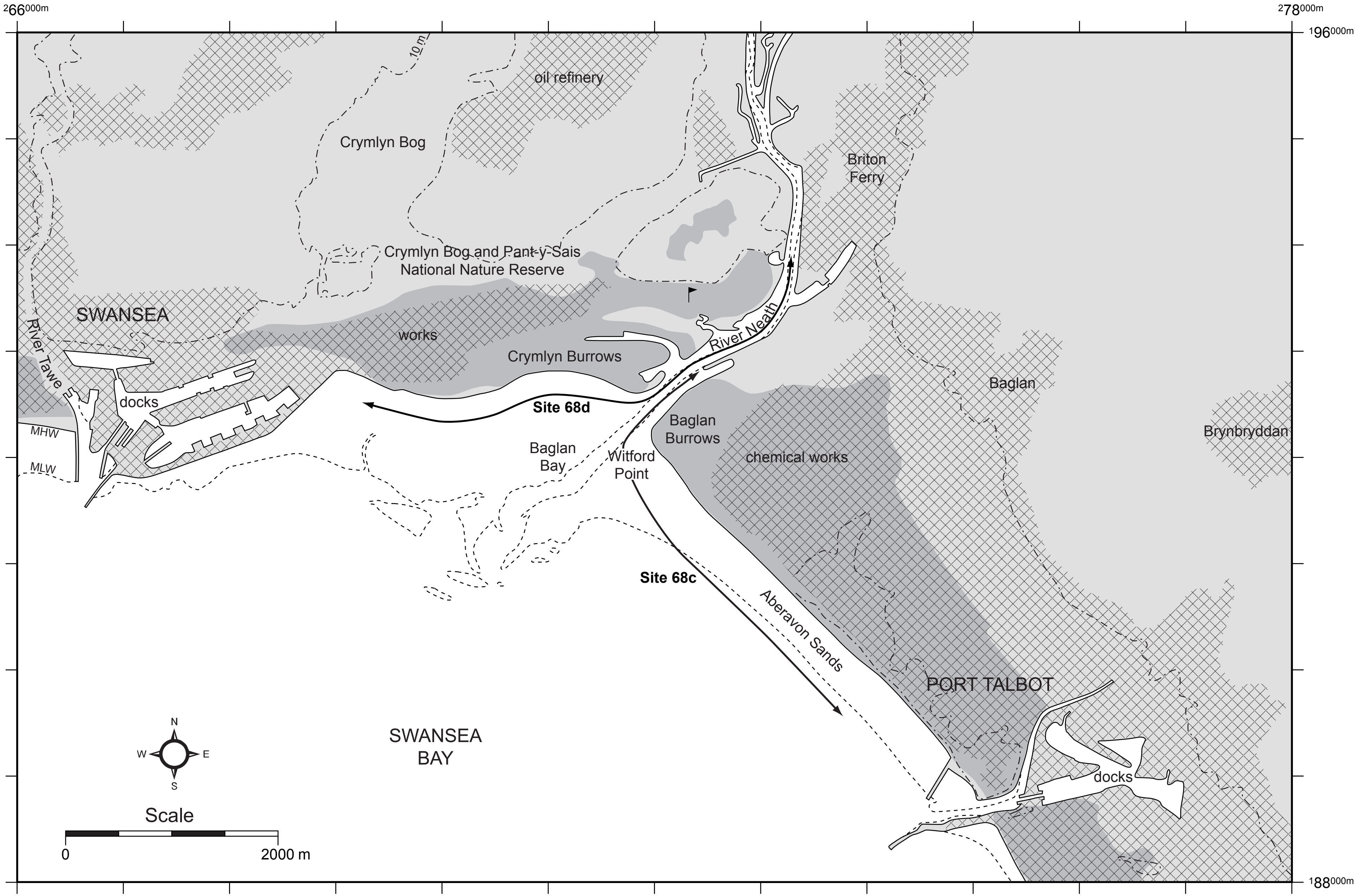


Figure 3.63 Site 68 (Swansea Bay): Site 68c (Baglan Burrows) and Site 68d (Crymlyn Burrows)

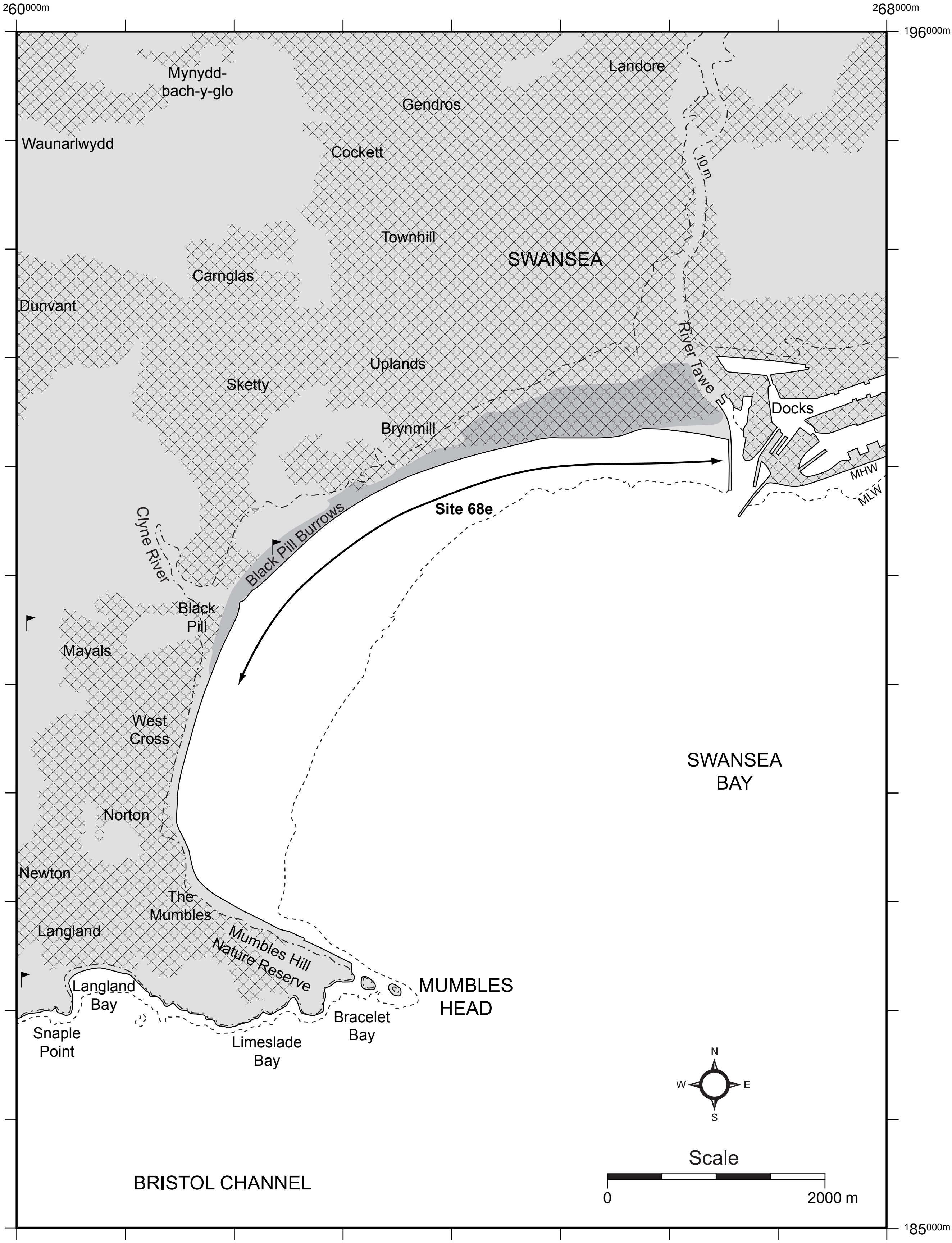


Figure 3.64 Site 68 (Swansea Bay): Site 68e (Black Pill Burrows)

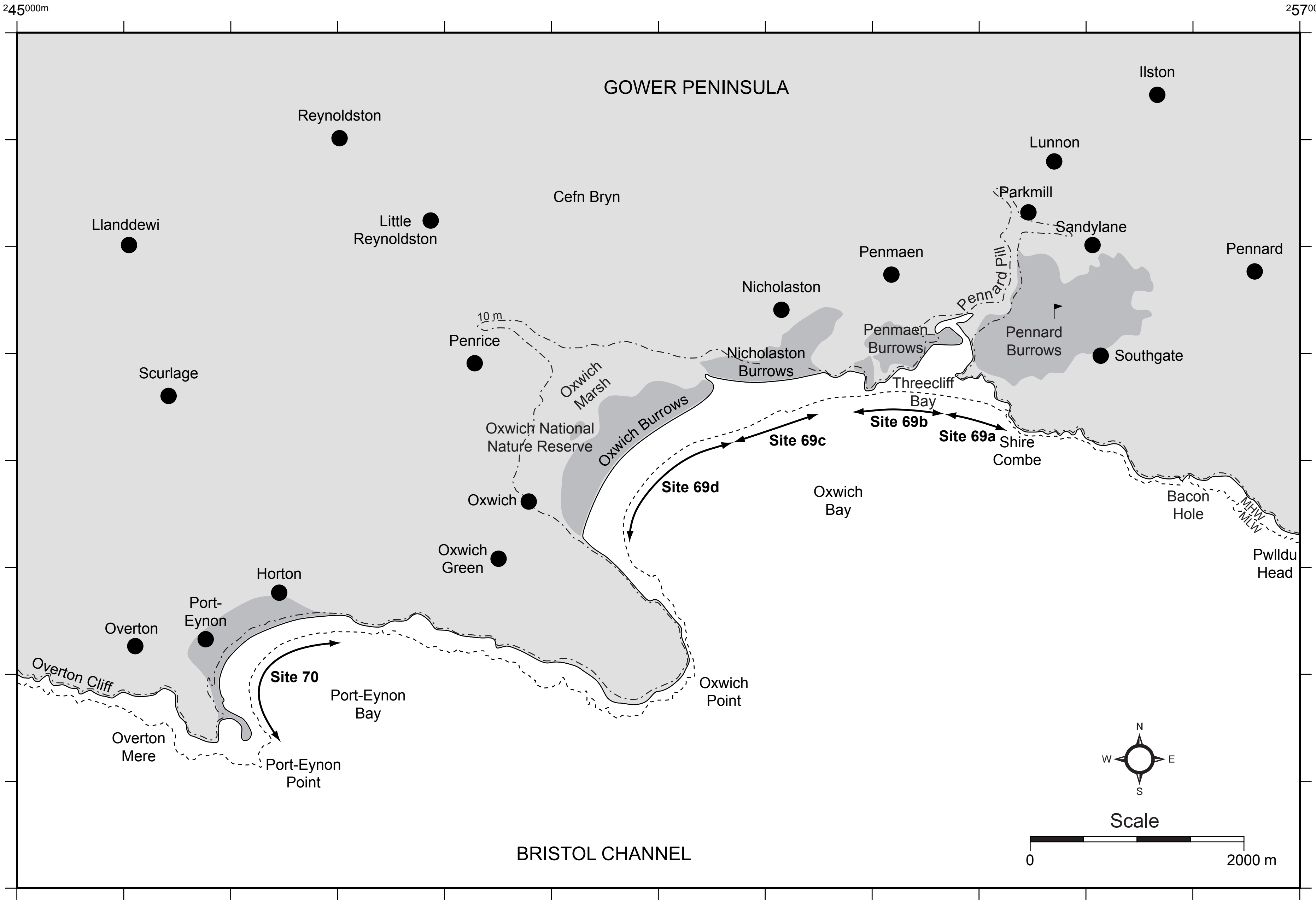


Figure 3.65 Site 69 (Oxwich Bay): Site 69a (Pennard Burrows), Site 69b (Penmaen Burrows), Site 69c (Nicholaston Burrows) and Site 69d (Oxwich Burrows), and Site 70 (Port-Eynon Bay)

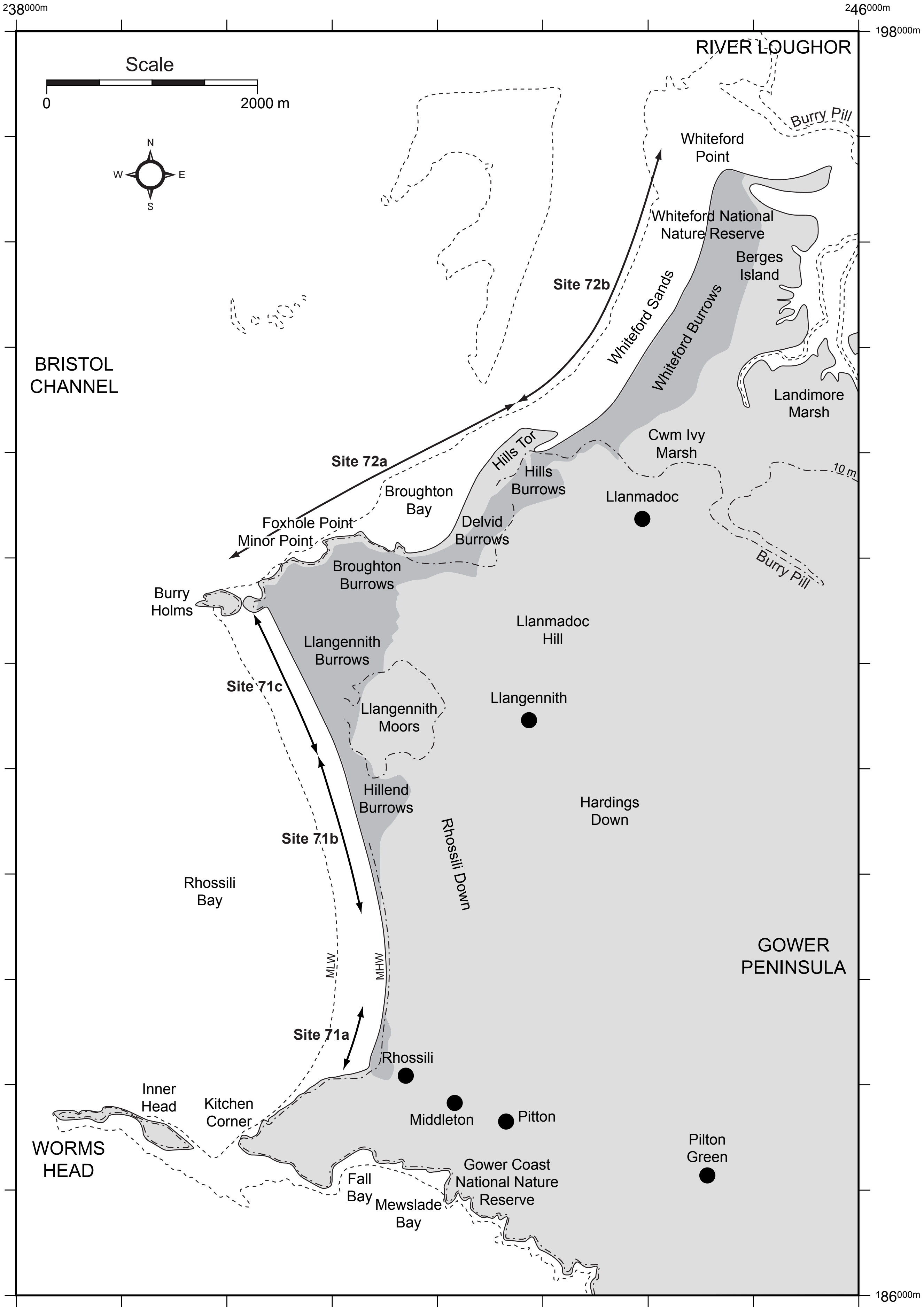


Figure 3.66 Site 71 (Rhossilli Bay): Site 71a (Rhossilli), Site 71b (Hillend Burrows) and Site 71c (Llangennith Burrows), and Site 72 (Burry Holms to Whiteford Point): Site 72a (Broughton Burrows, Delvid Burrows and Hills Burrows) and Site 72b (Whiteford Burrows)

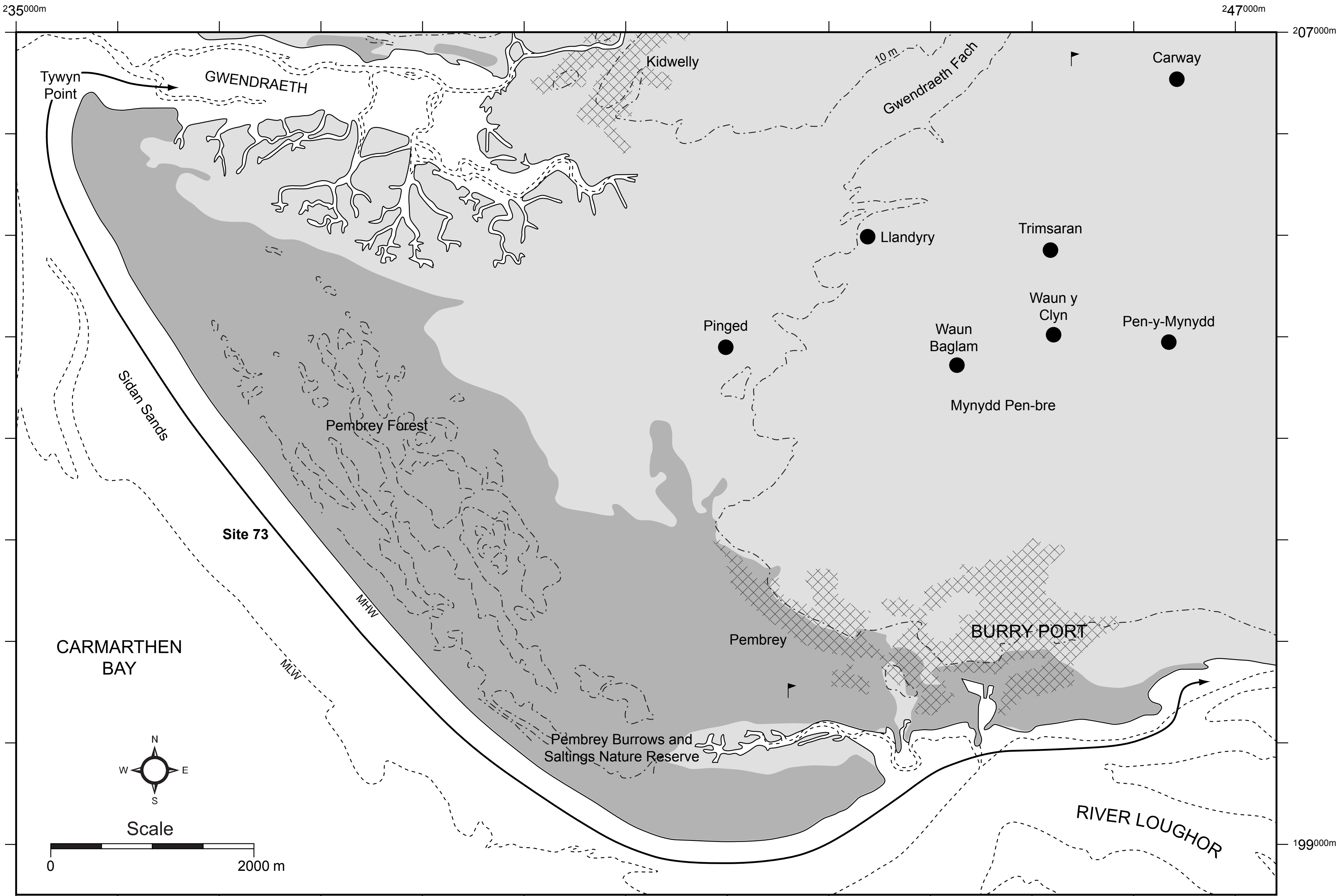


Figure 3.67 Site 73 (Pembrey Burrows)

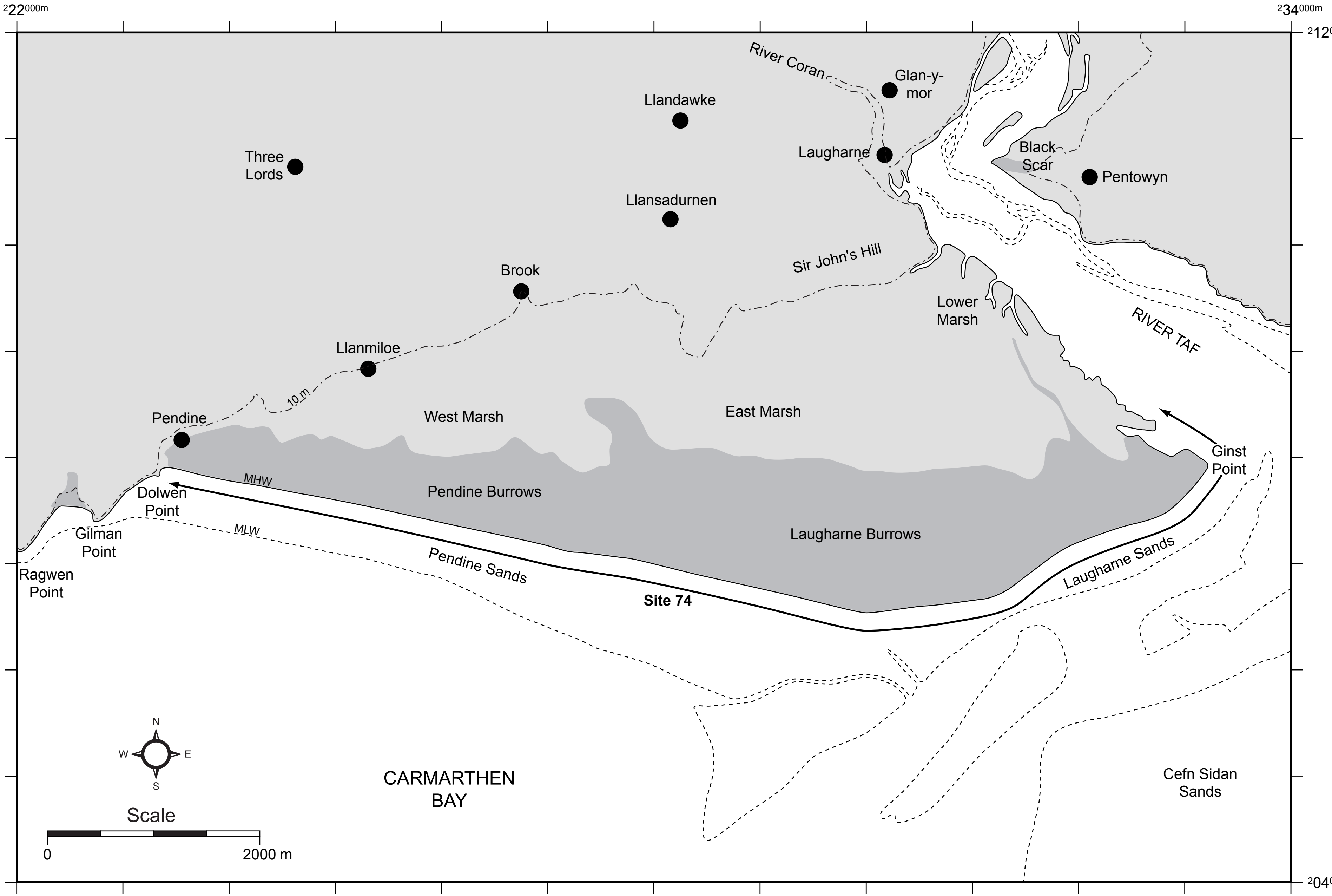


Figure 3.68 Site 74 (Laugharne Burrows and Pendine Burrows)

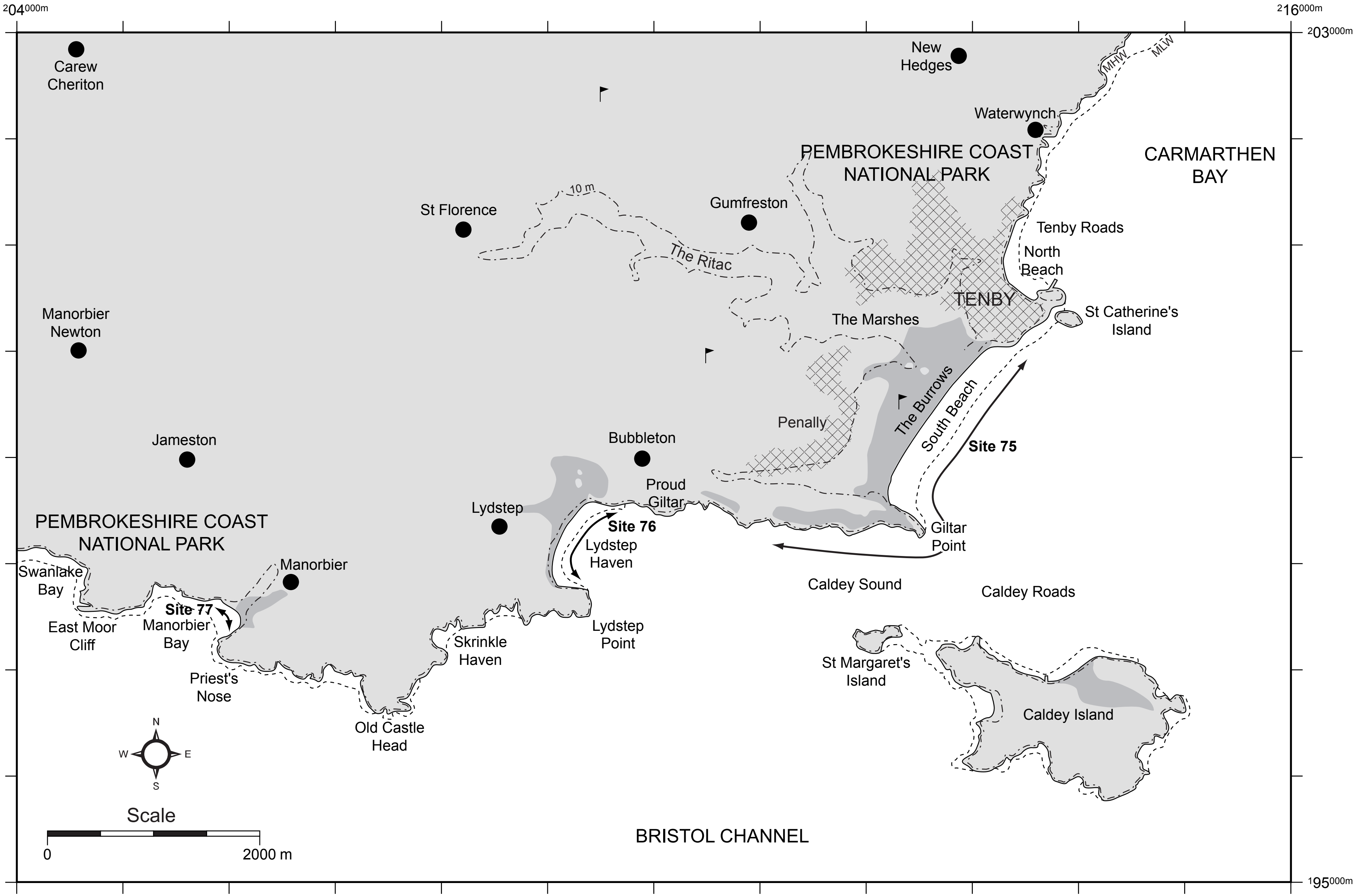


Figure 3.69 Site 75 (The Burrows, Tenby), Site 76 (Lydstep Haven) and Site 77 (Manorbier Bay)

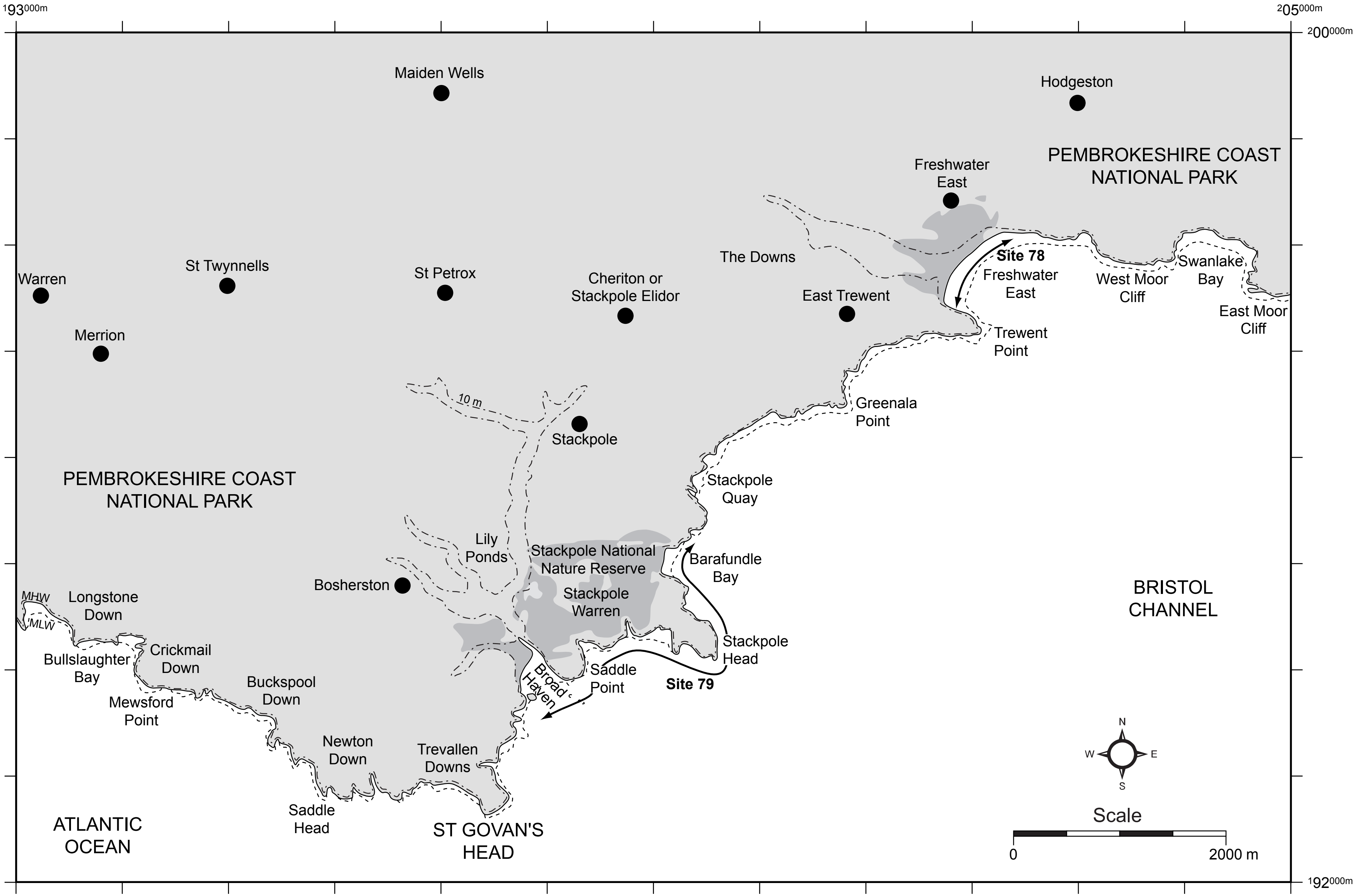


Figure 3.70 Site 78 (Freshwater East) and Site 79 (Stackpole Warren)

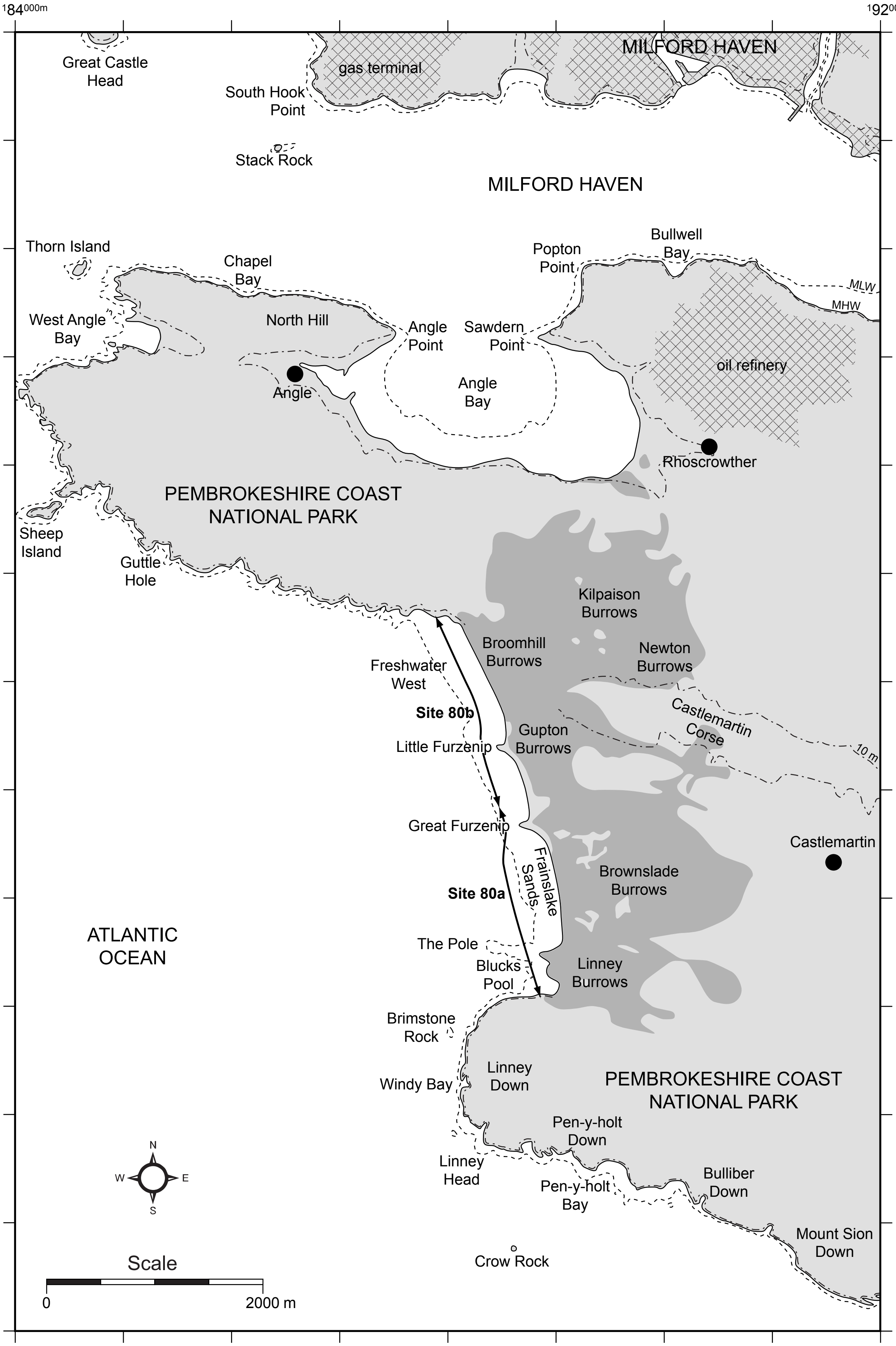


Figure 3.71 Site 80 (Linney, Brownslade and Broomhill Burrows): Site 80a (Linney Burrows and Brownslade Burrows) and Site 80b (Gupton Burrows, Broomhill Burrows and Kilpaison Burrows)

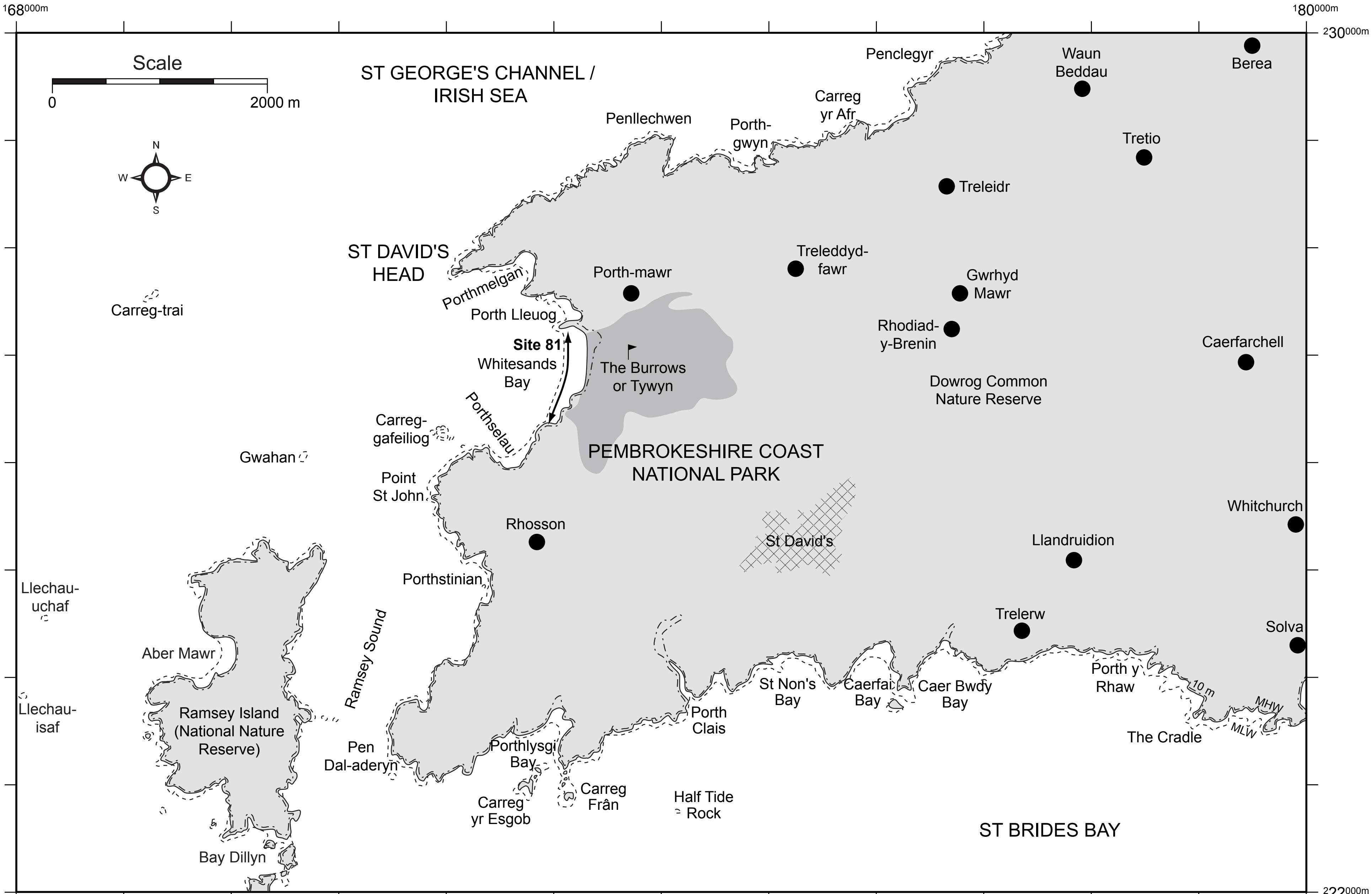


Figure 3.72 Site 81 (The Burrows, Whitesands Bay)

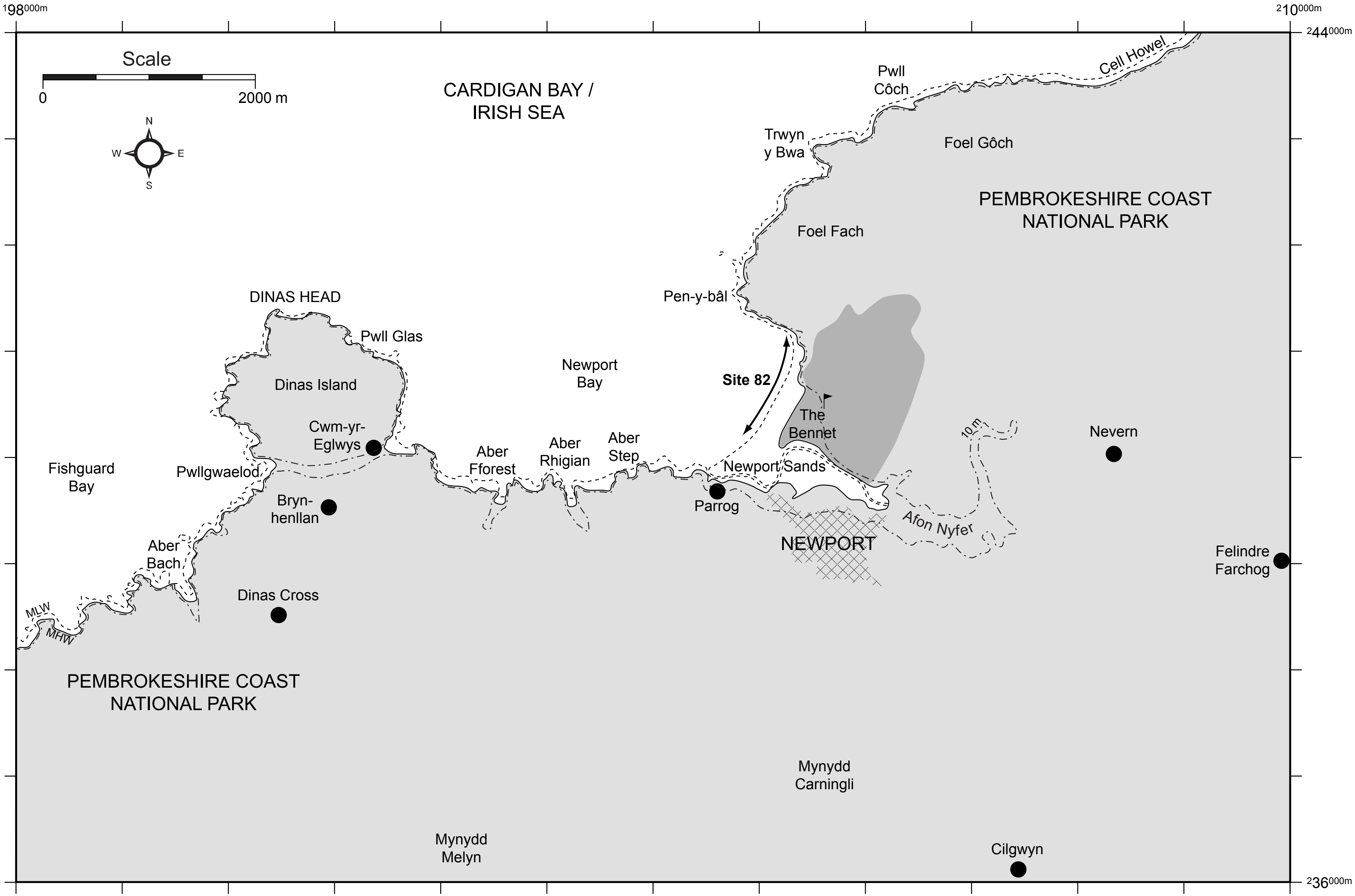


Figure 3.73 Site 82 (Newport Bay)

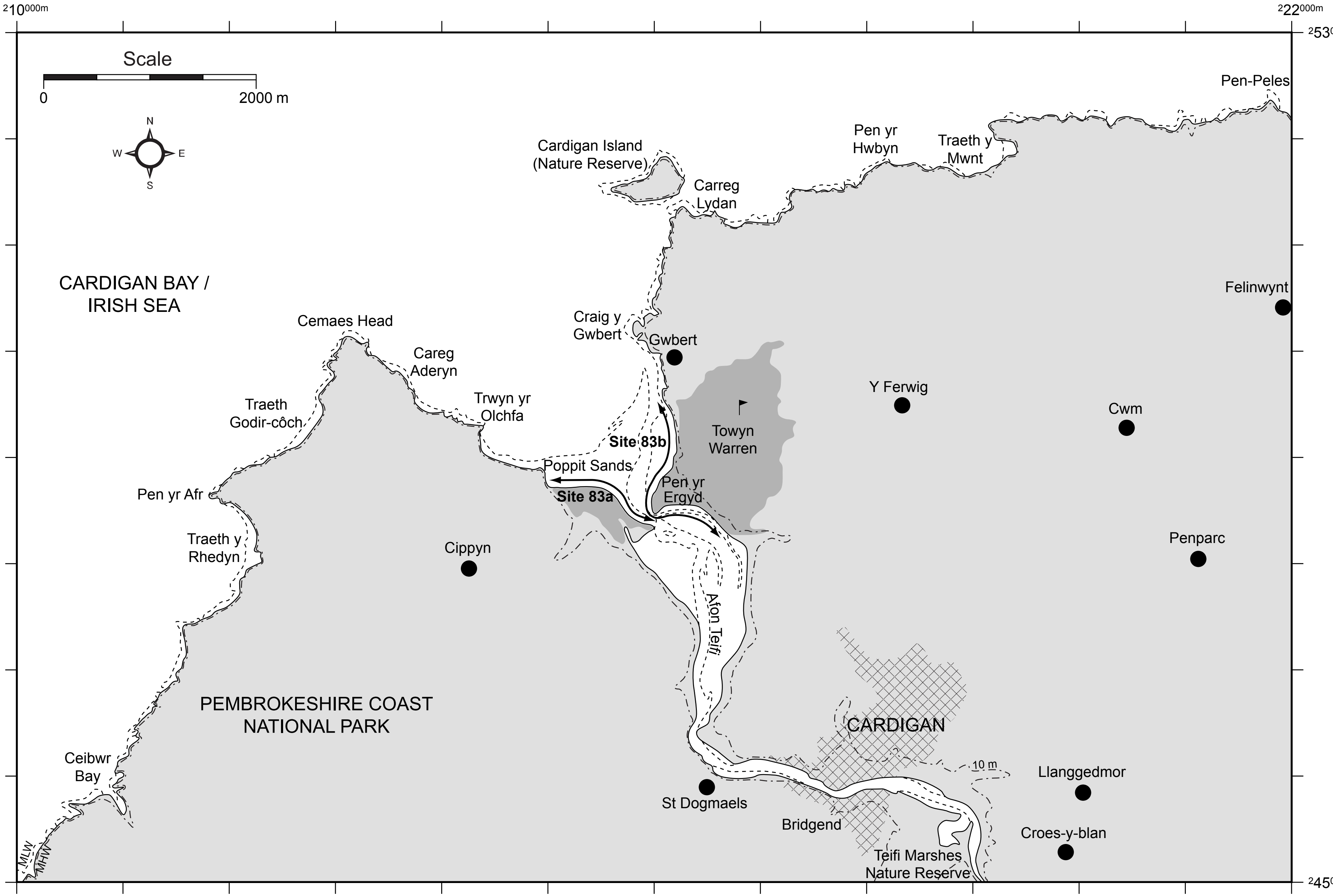


Figure 3.74 Site 83 (Teifi Estuary): Site 83a (Poppit Sands) and Site 83b (Towyn Warren)

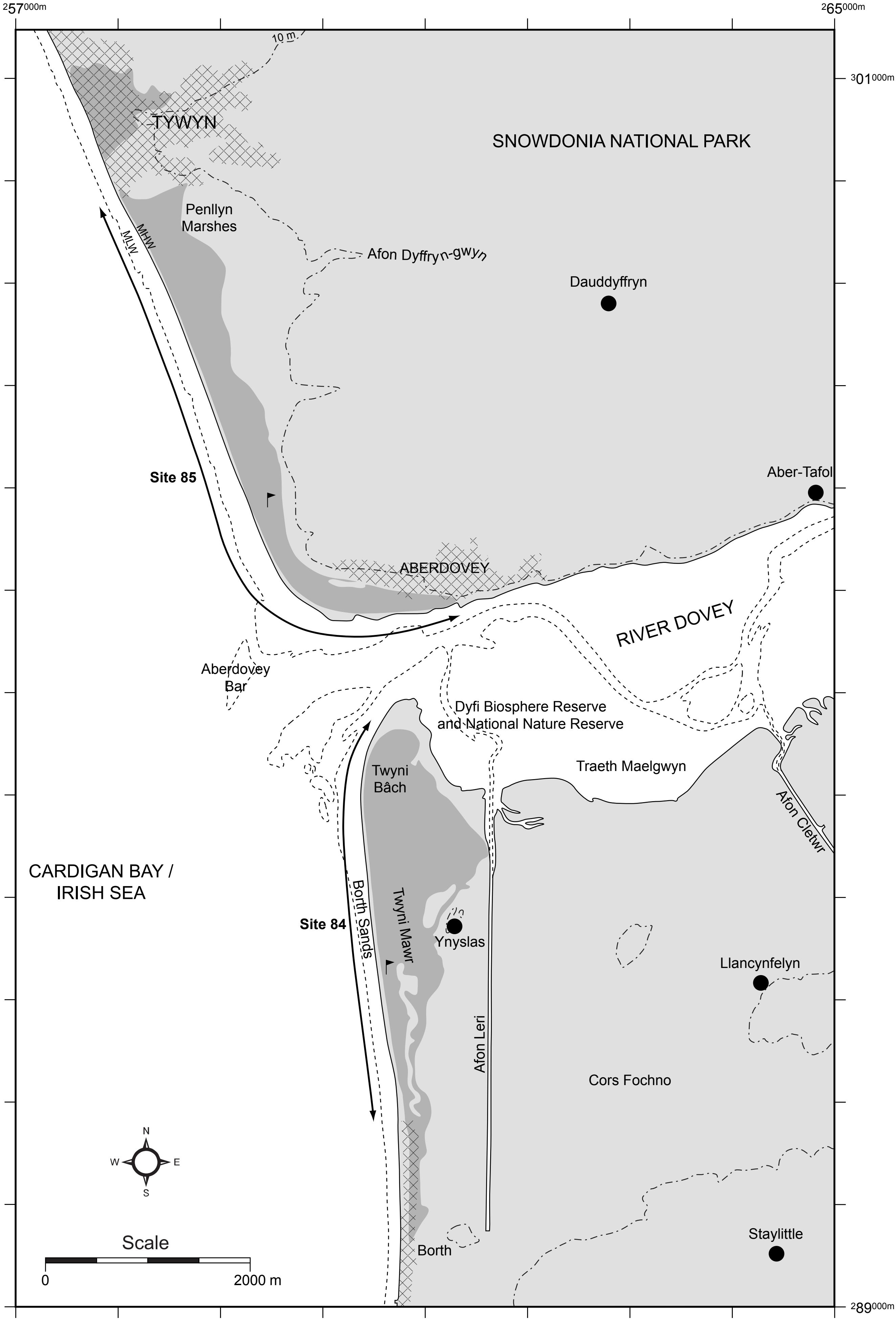


Figure 3.75 Site 84 (Ynyslas) and Site 85 (Aberdovey to Tywyn)

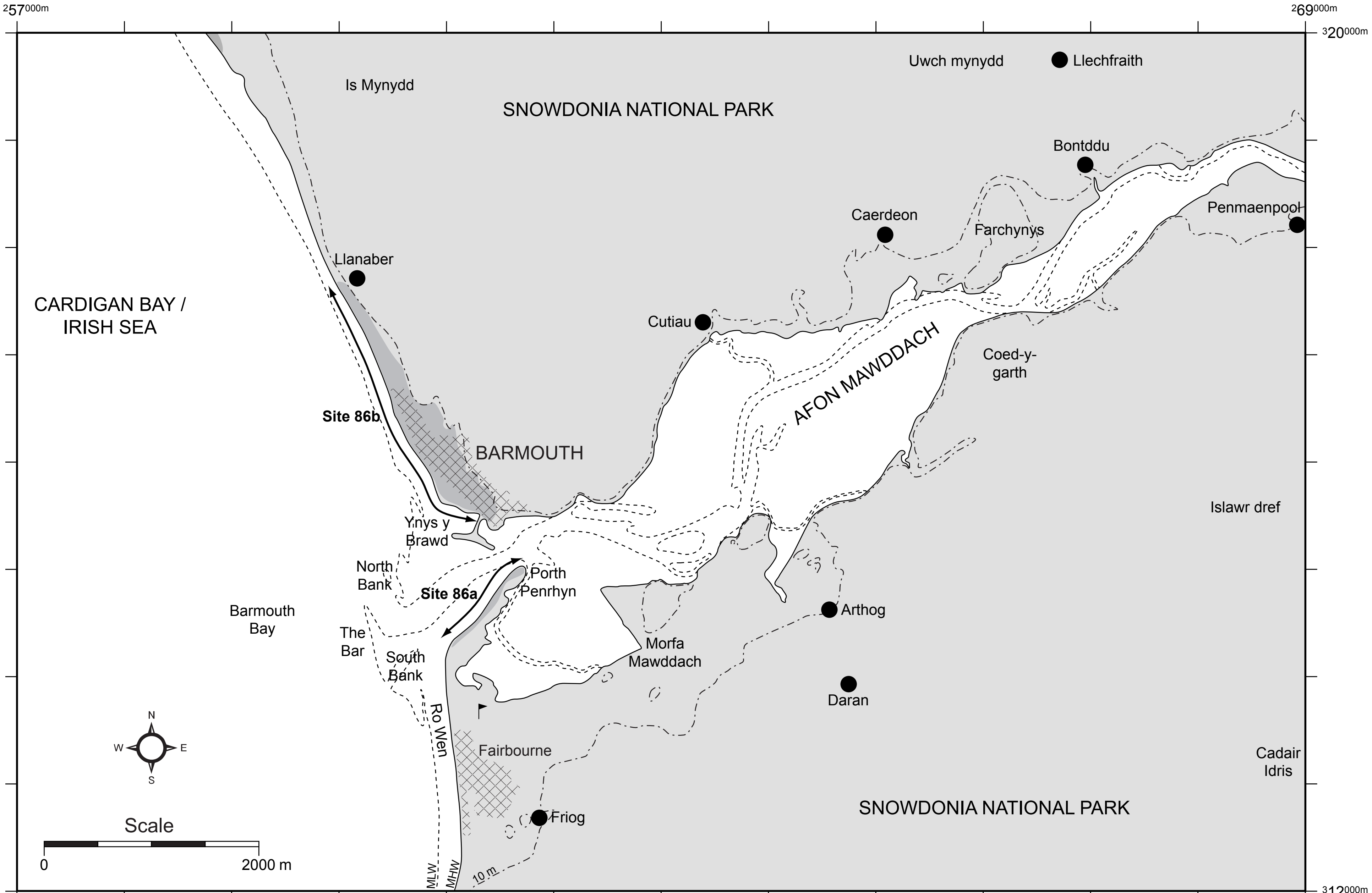


Figure 3.76 Site 86 (Mawddach Estuary): Site 86a (Fairbourne spit) and Site 86b (Barmouth)

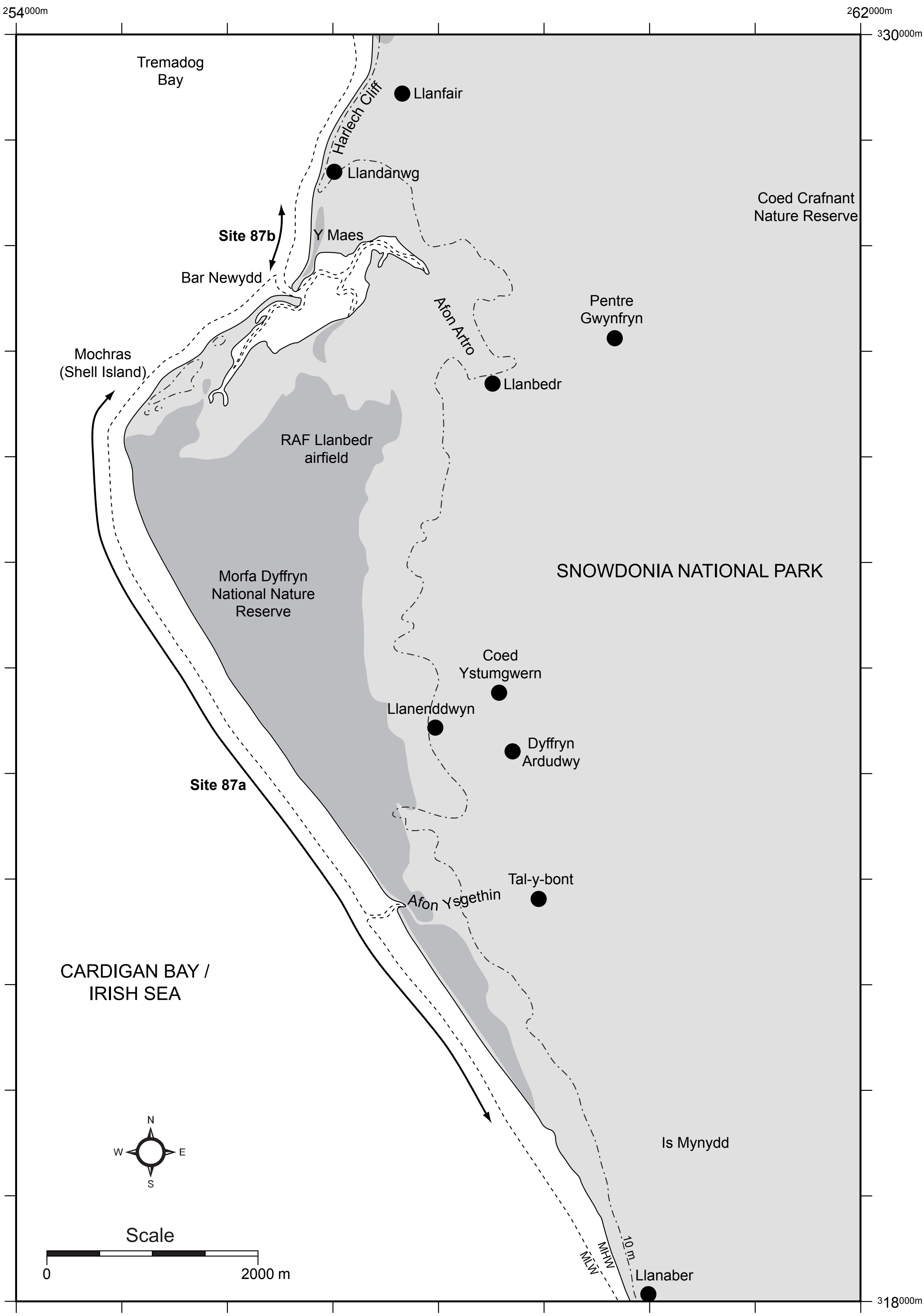


Figure 3.77 Site 87 (Morfa Dyffryn and Llandanwg): Site 87a (Morfa Dyffryn) and Site 87b (Llandanwg)

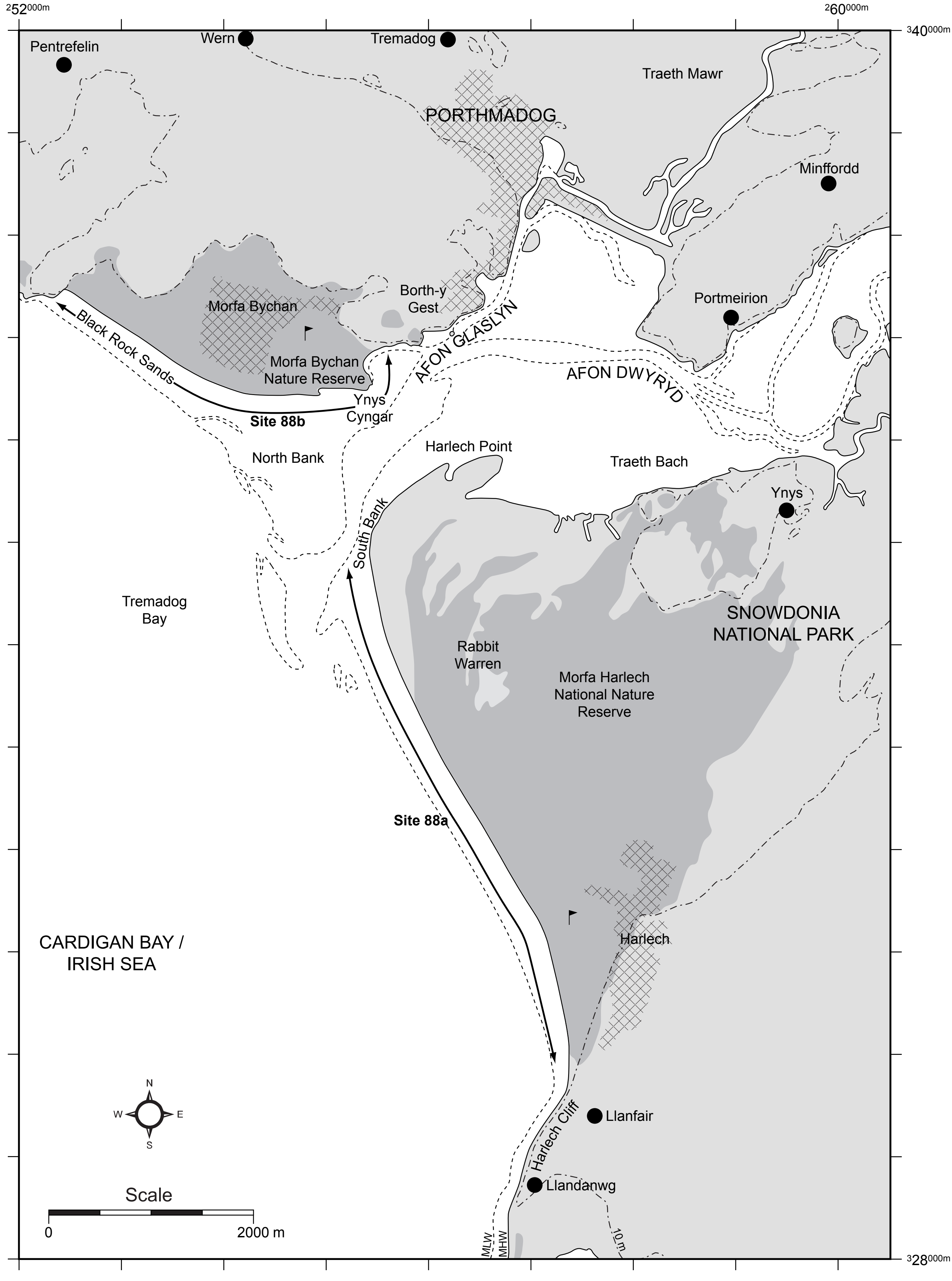


Figure 3.78 Site 88 (Dwyryd-Glaslyn Estuary): Site 88a (Morfa Harlech) and Site 88b (Morfa Bychan)

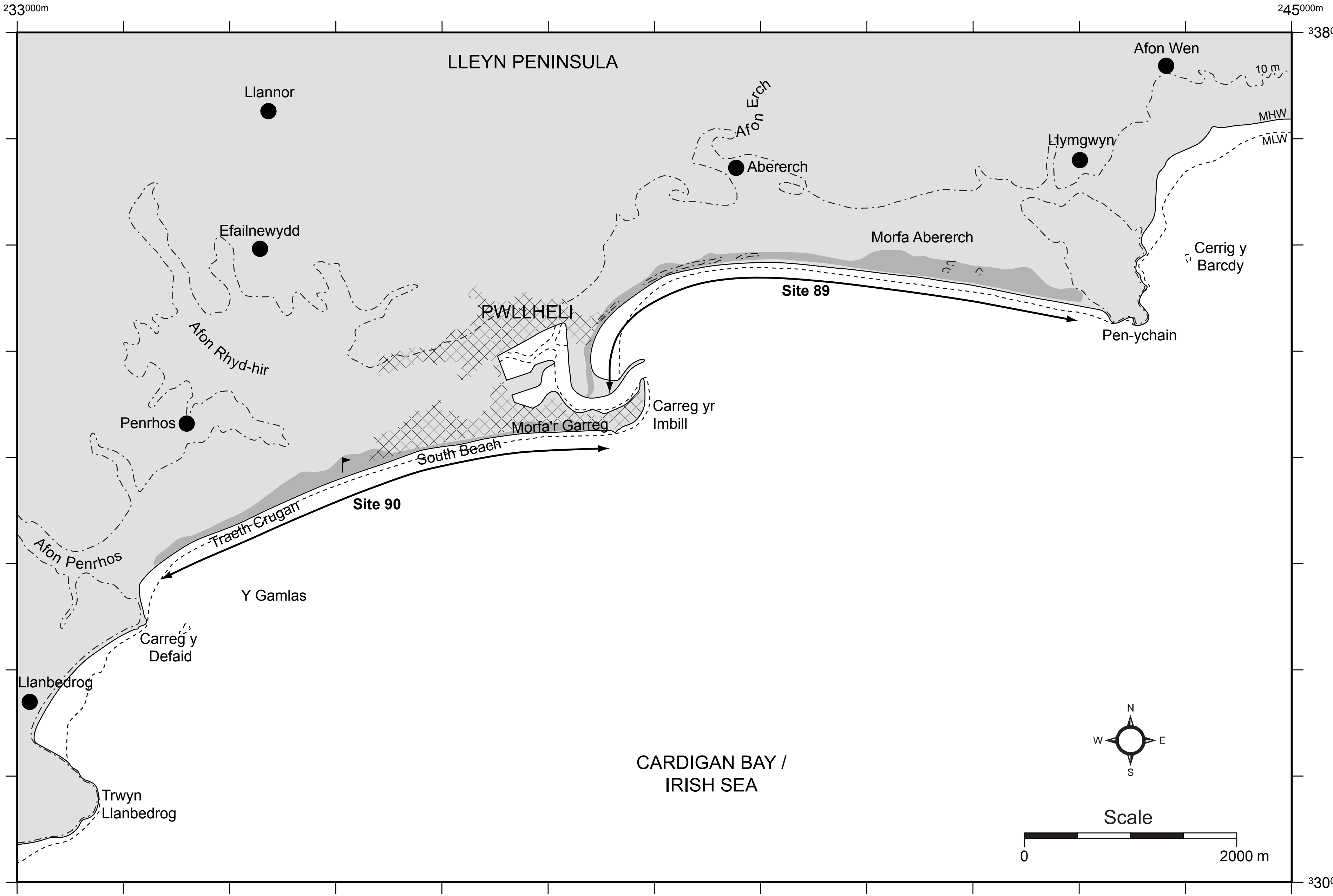


Figure 3.79 Site 89 (Morfa Abererch) and Site 90 (Pwllheli and Traeth Crugan)

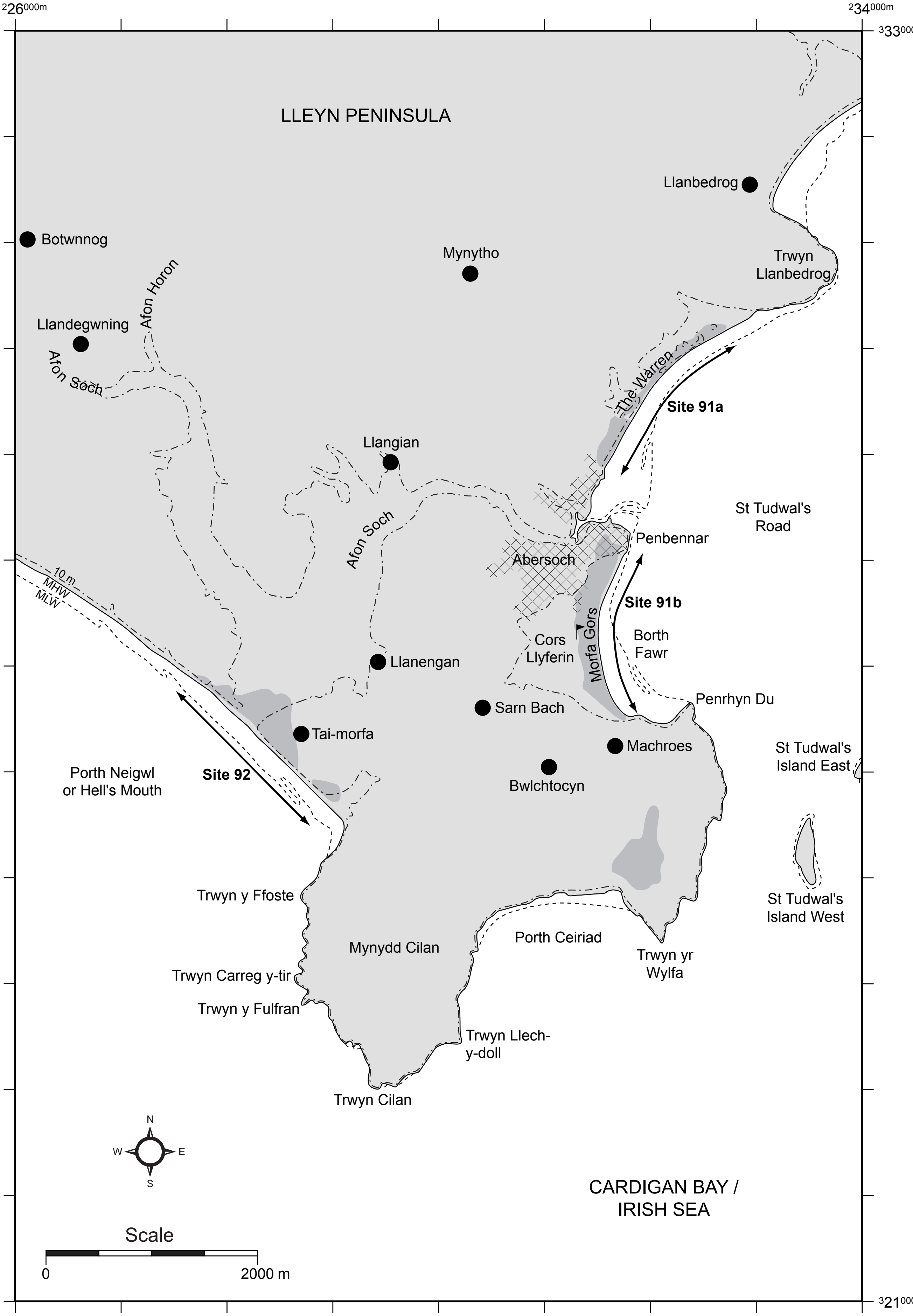


Figure 3.80 Site 91 (Abersoch): Site 91a (The Warren, Abersoch) and Site 91b (Morfa Gors), and Site 92 (Tai Morfa)

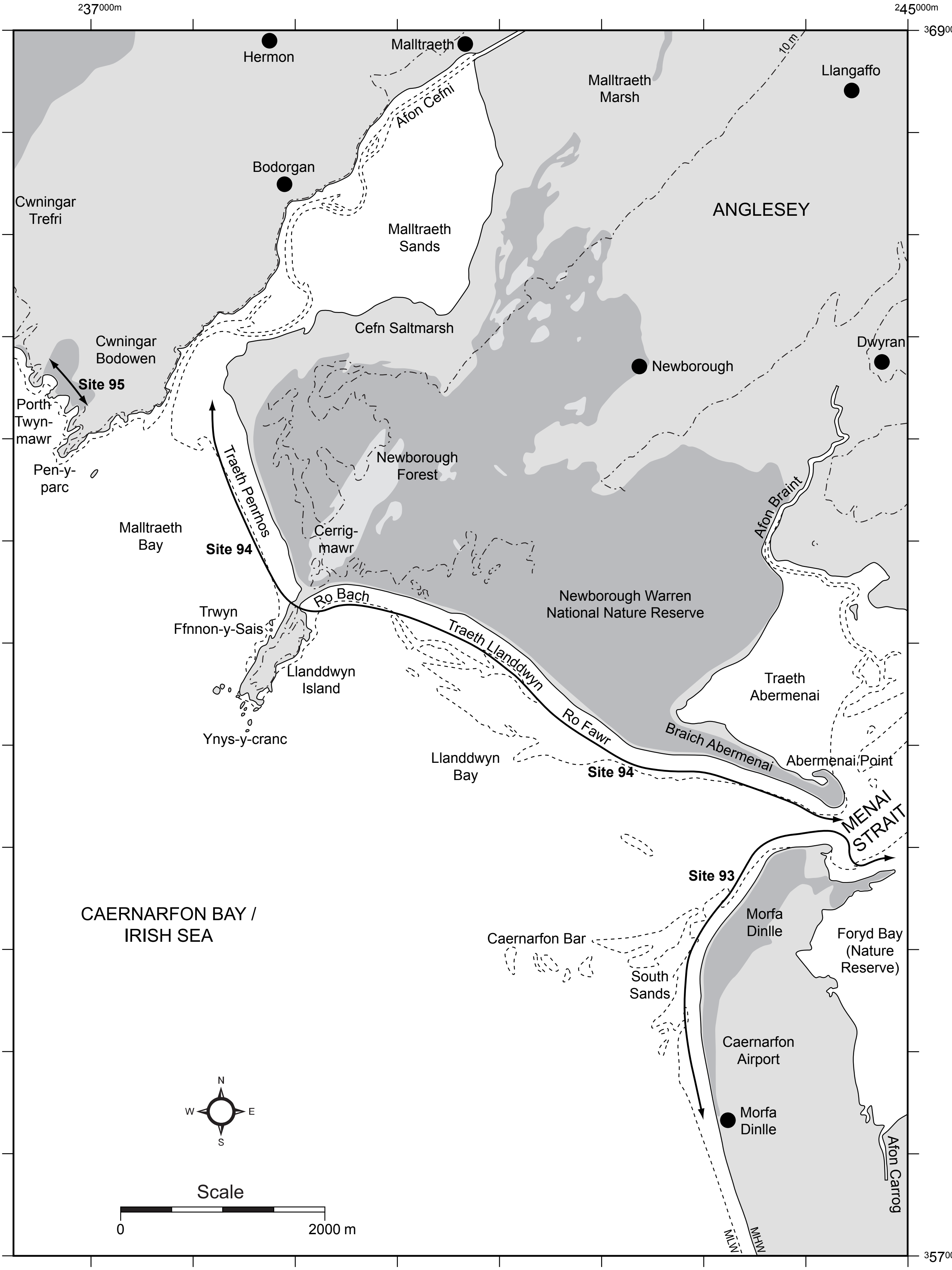


Figure 3.81 Site 93 (Morfa Dinlle), Site 94 (Newborough Warren) and Site 95 (Porth Twyn-mawr)

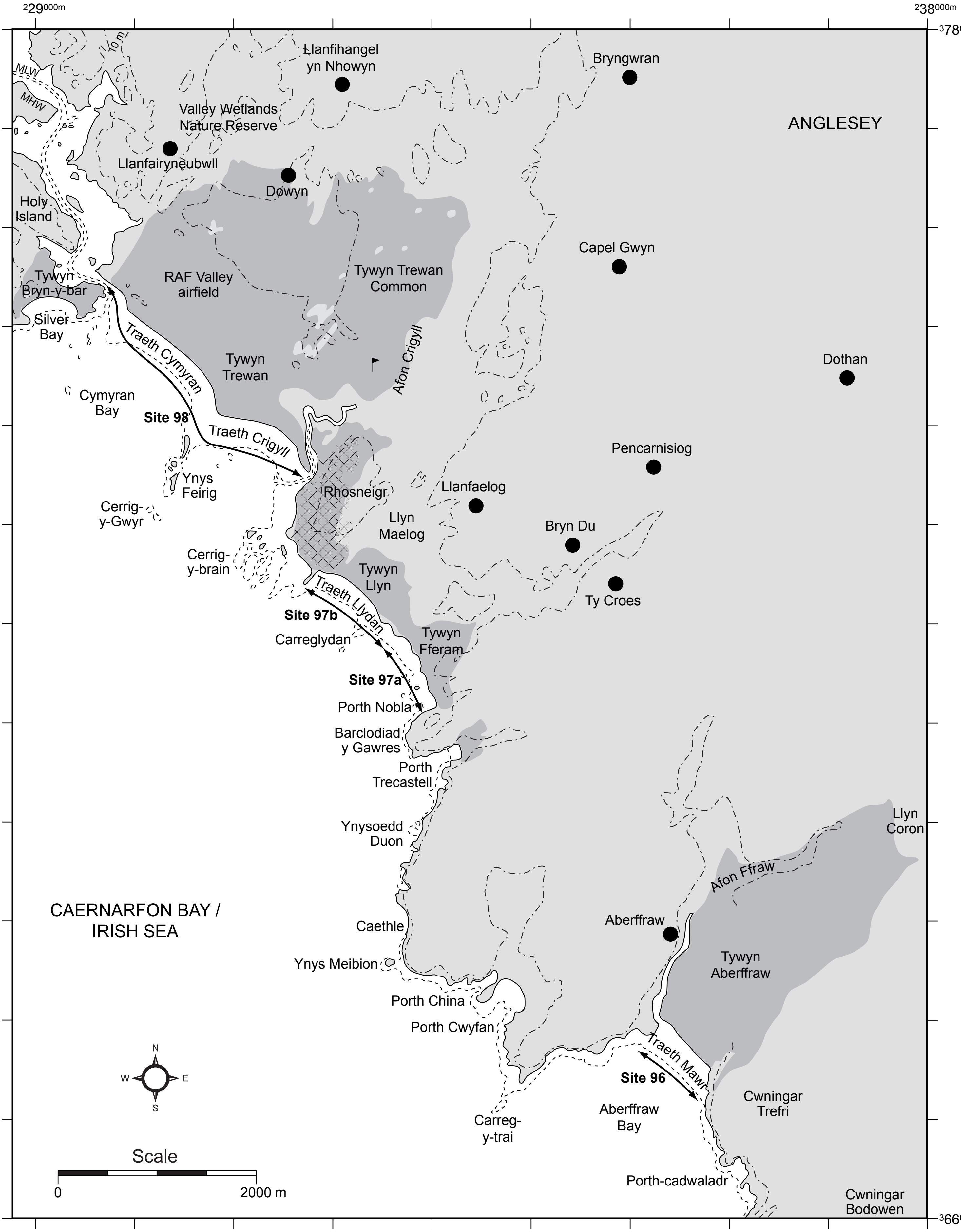


Figure 3.82 Site 96 (Tywyn Aberffraw), Site 97 (Tywyn Fferam and Tywyn Llyn): Site 97a (Tywyn Fferam) and Site 97b (Tywyn Llyn), and Site 98 (Tywyn Trewan)

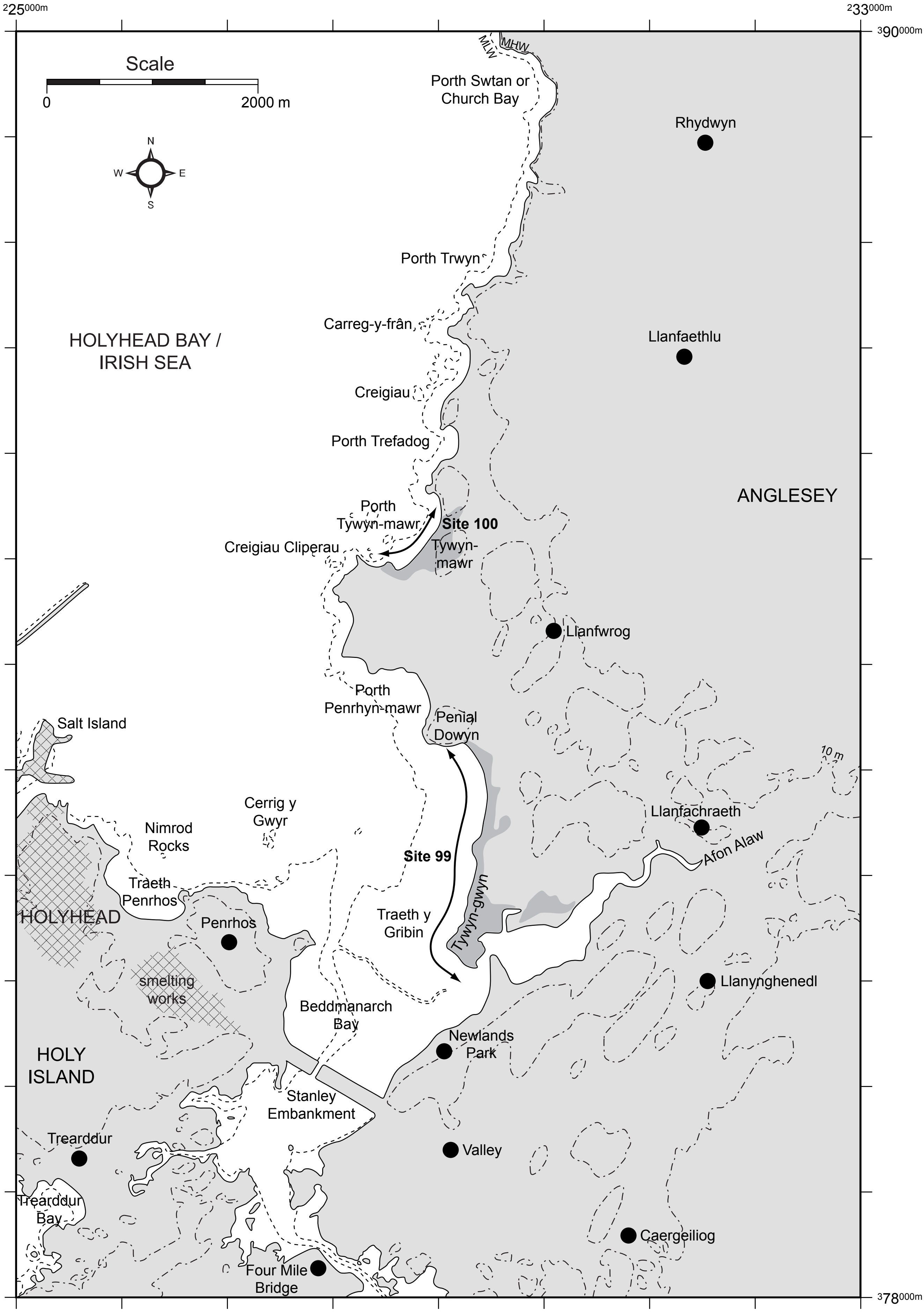


Figure 3.83 Site 99 (Tywyn-gywyn) and Site 100 (Tywyn-mawr)

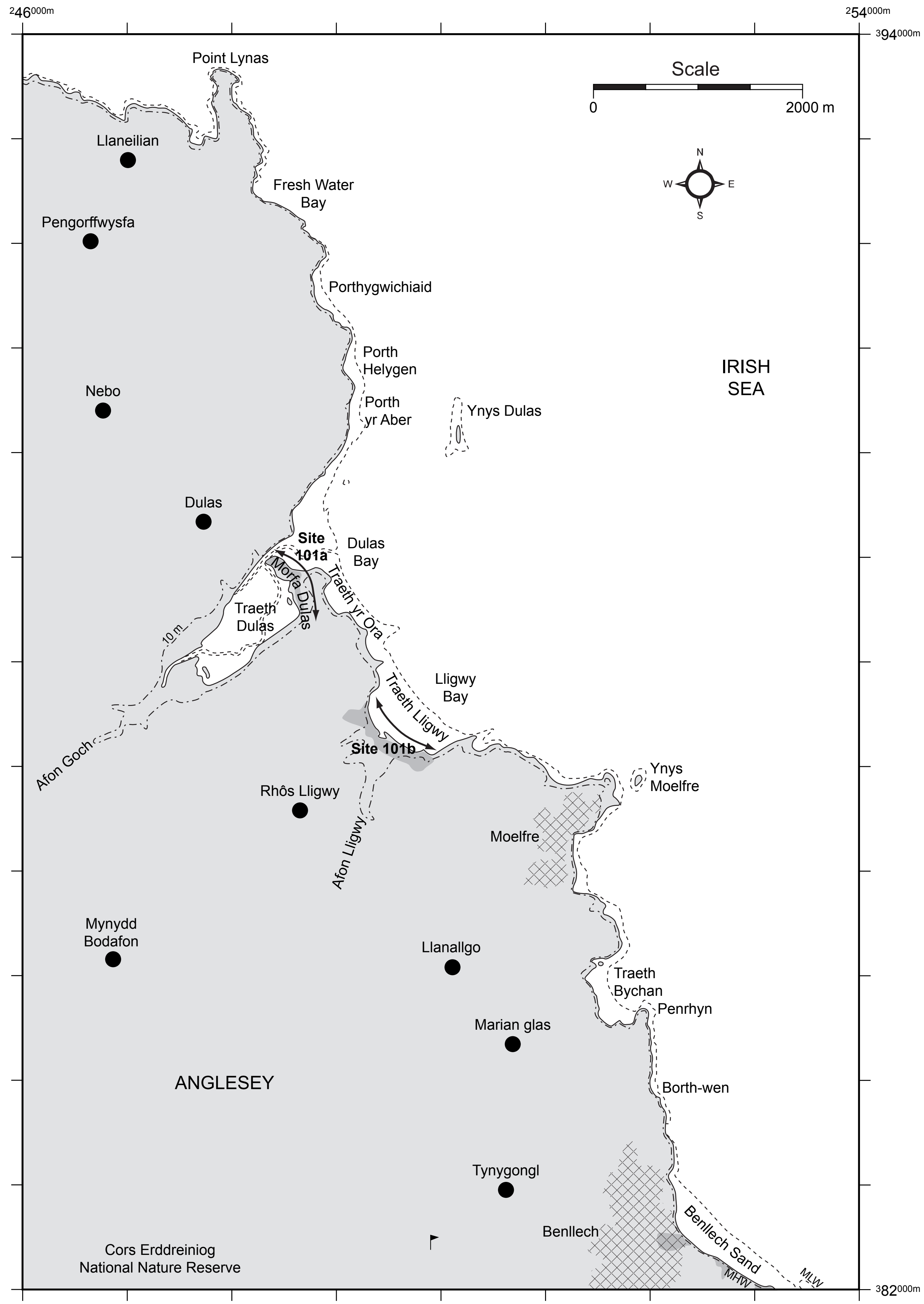


Figure 3.84 Site 101 (Dulas Bay and Lligwy Bay): Site 101a (Dulas Bay) and Site 101b (Lligwy Bay)

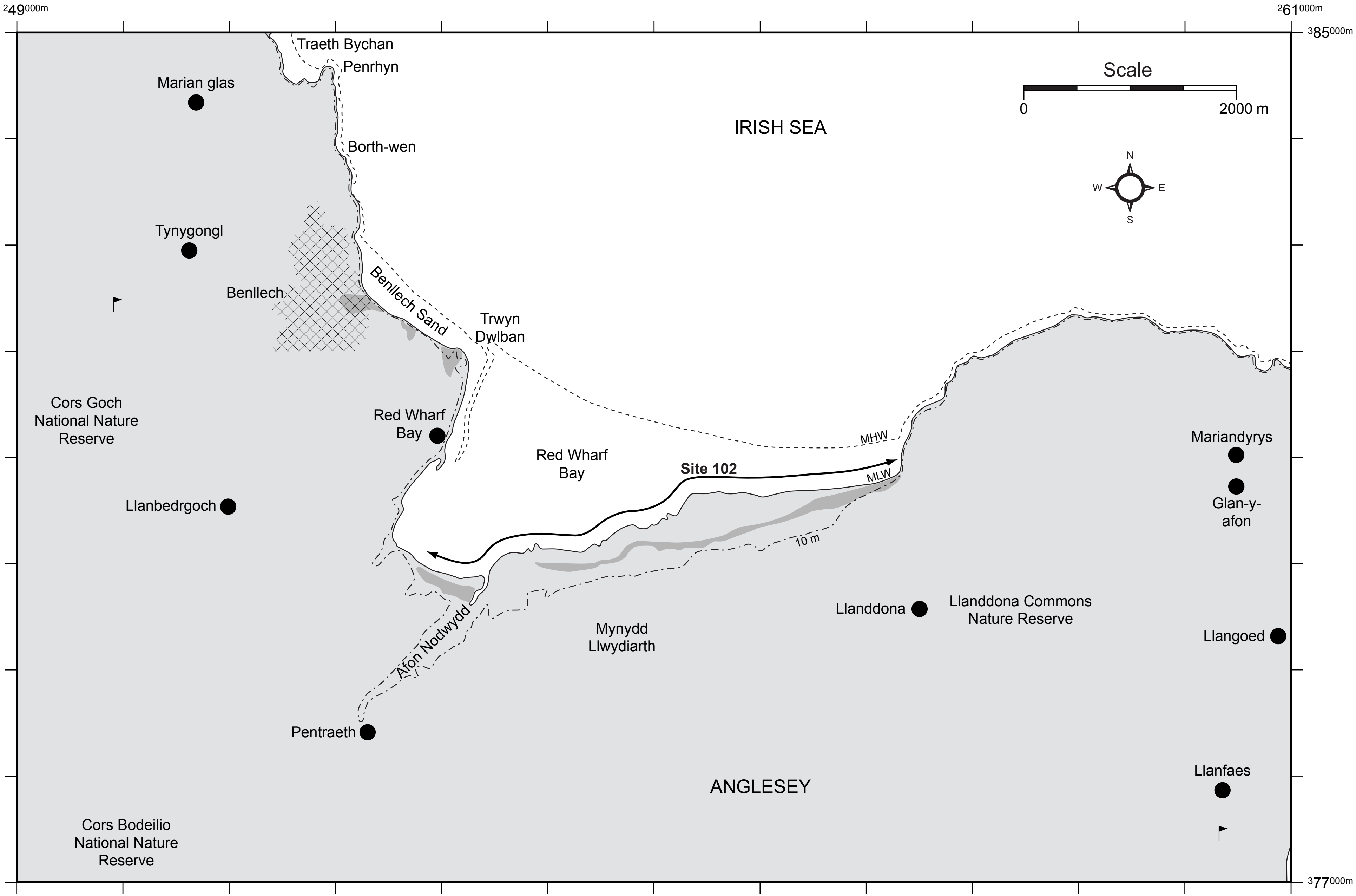


Figure 3.85 Site 102 (Red Wharf Bay)

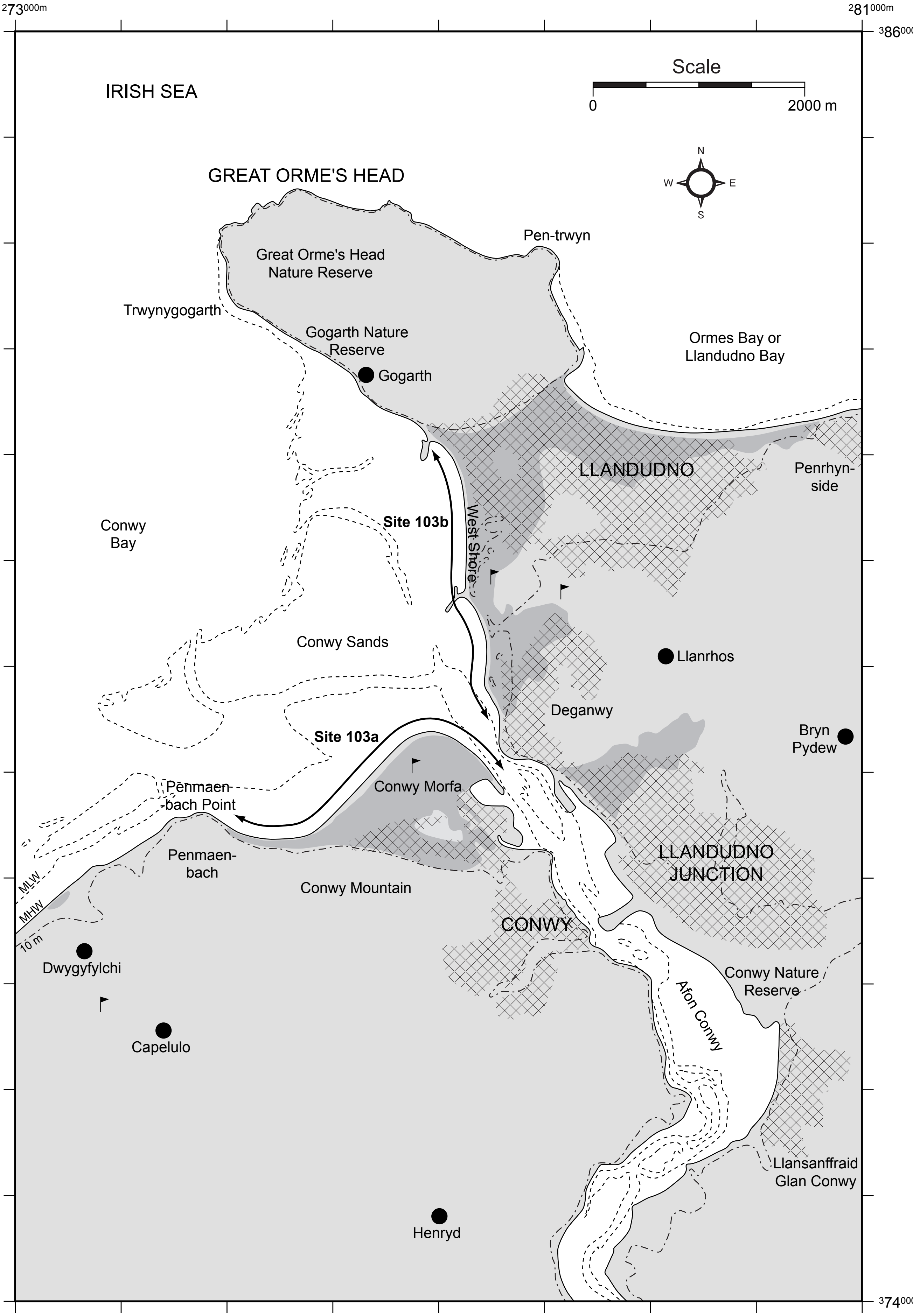


Figure 3.86 Site 103 (Conwy Bay): Site 103a (Conwy Morfa) and Site 103b (Deganwy and Llandudno)

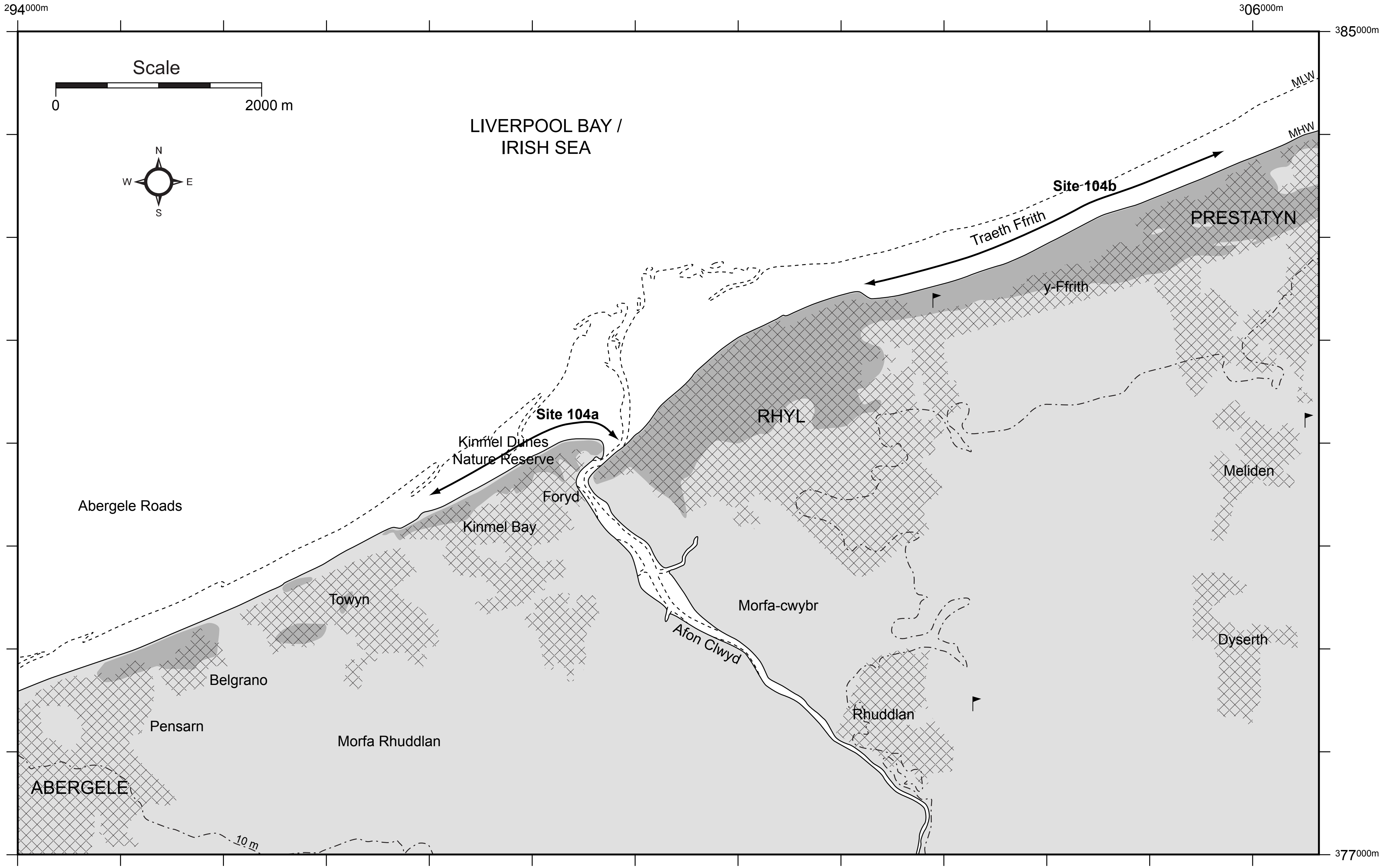


Figure 3.87 Site 104 (Abergele to Point of Ayr): Site 104a (Kinmel Dunes) and Site 104b (Rhyl to Prestatyn)

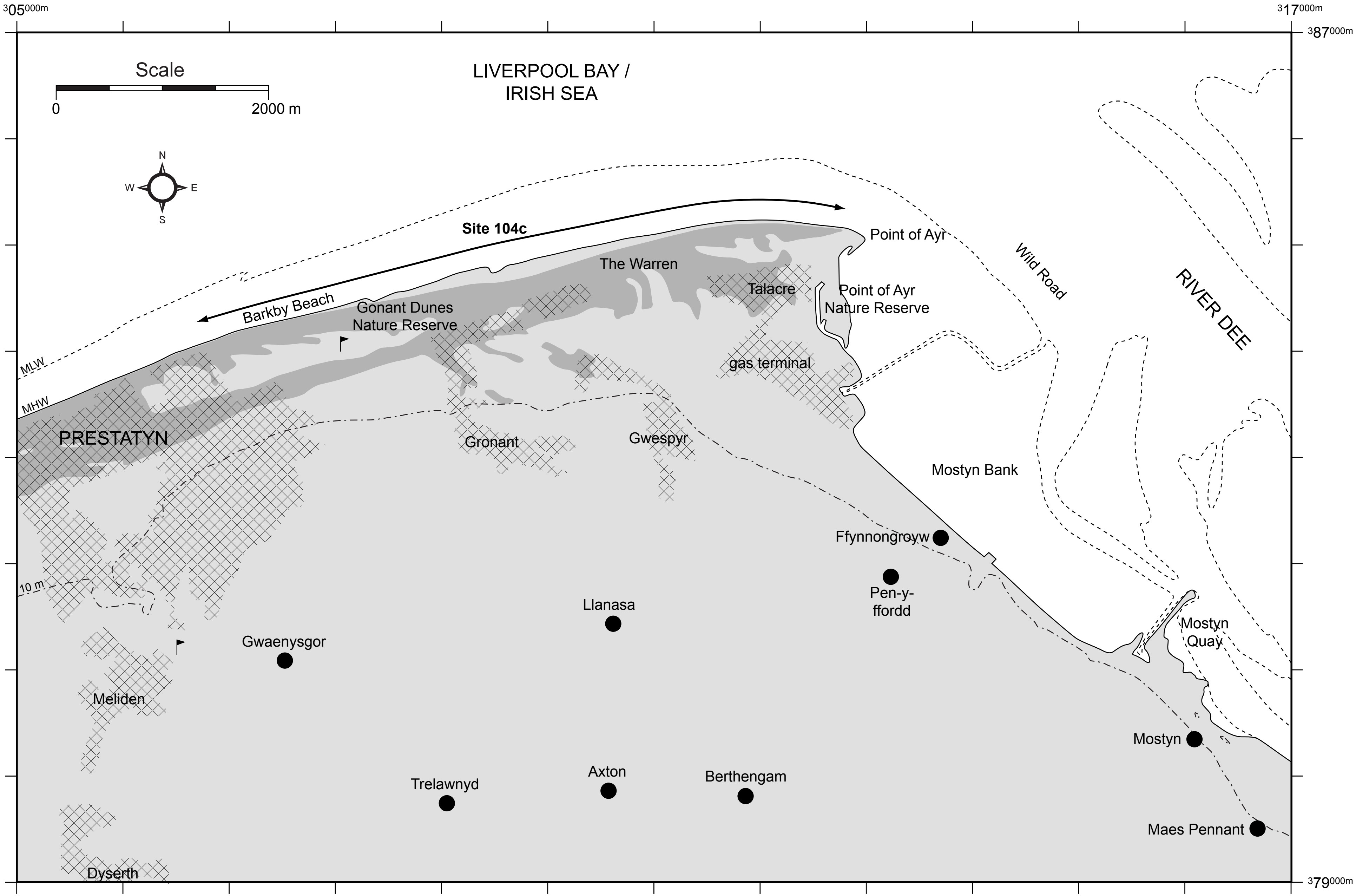


Figure 3.88 Site 104 (Abergele to Point of Ayr): Site 104c (Gronant Dunes and The Warren, Talacre)

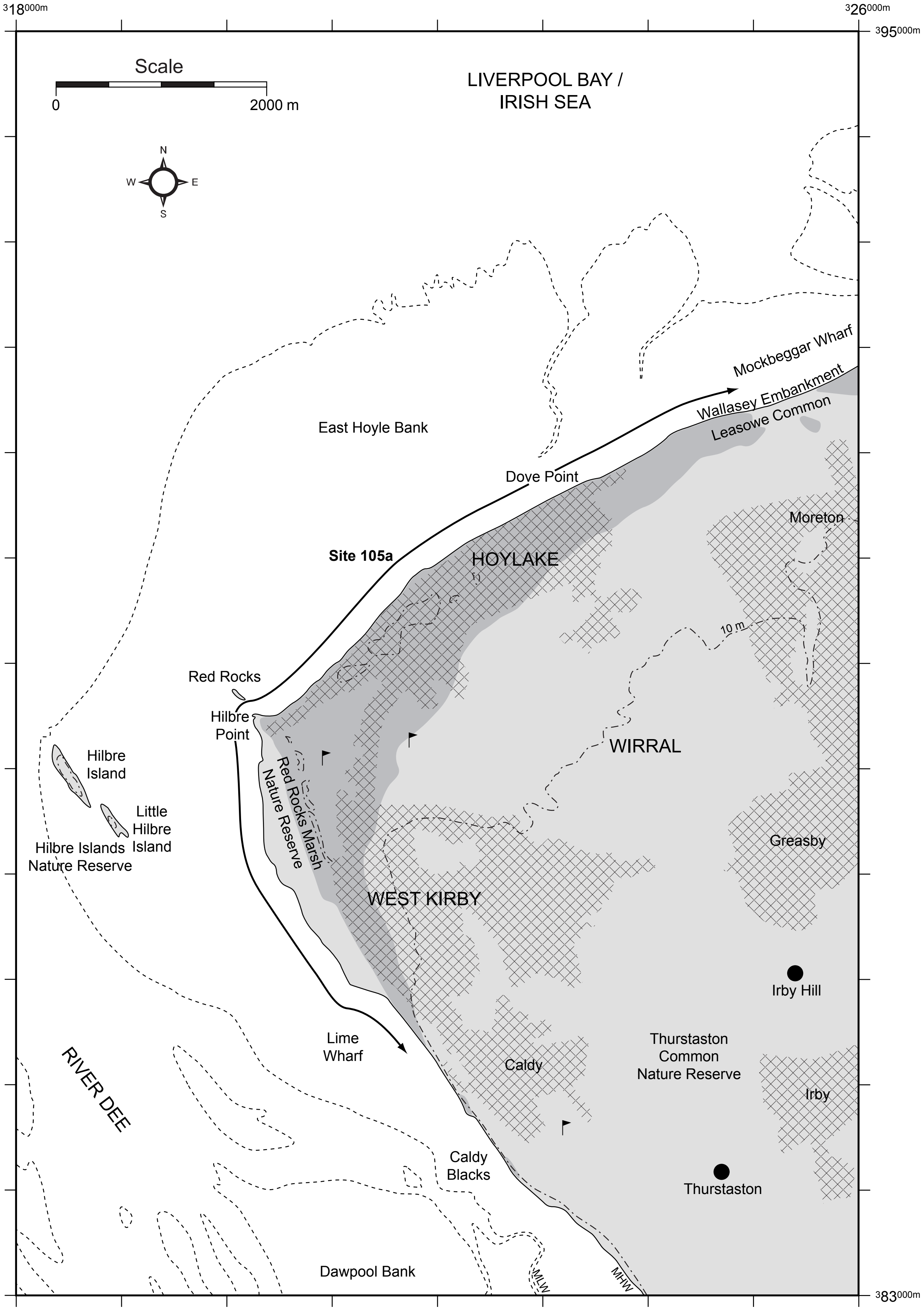


Figure 3.89 Site 105 (Wirral Peninsula): Site 105a (West Kirby to Leasowe)

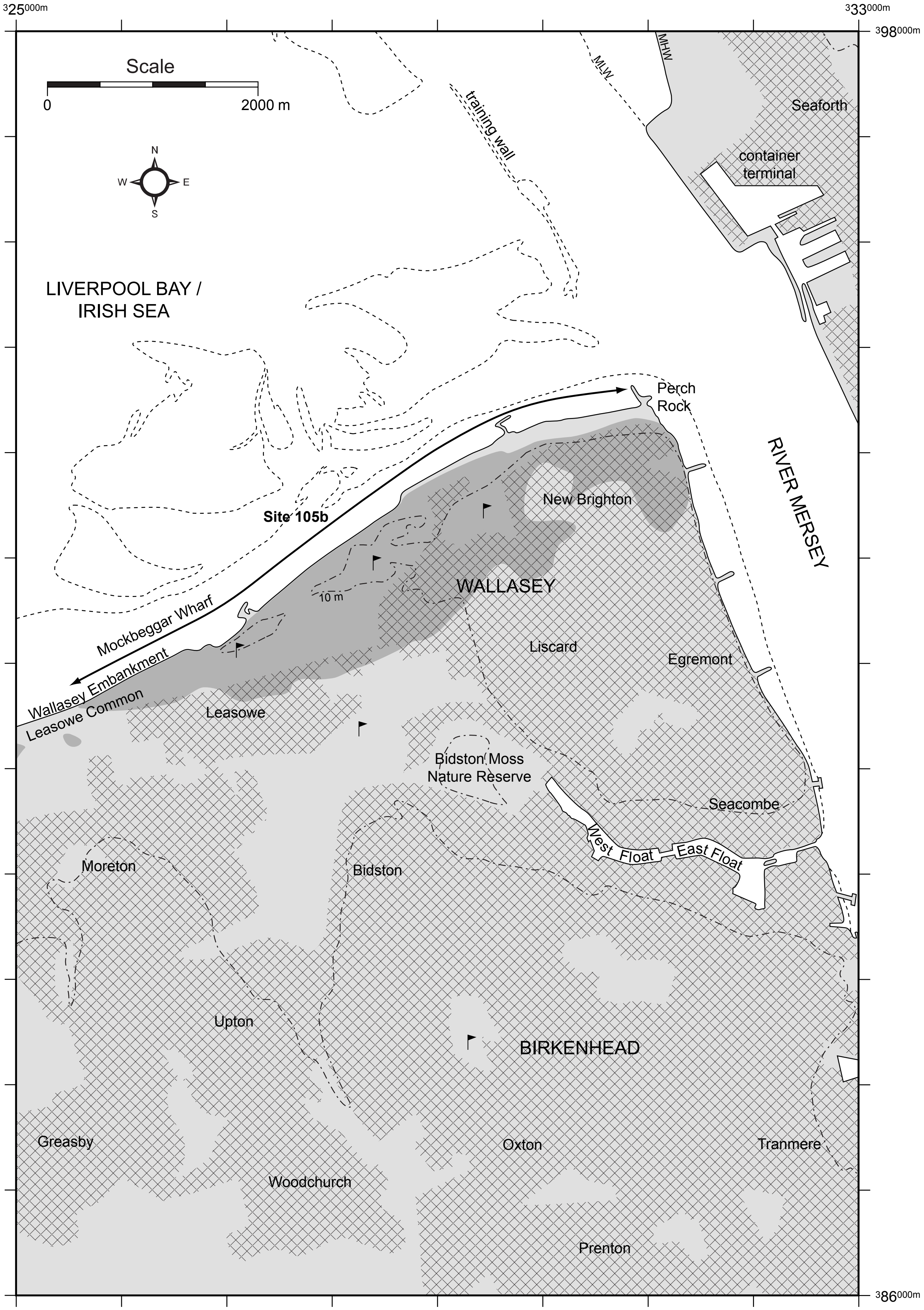


Figure 3.90 Site 105 (Wirral Peninsula): Site 105b (Leasowe to New Brighton)

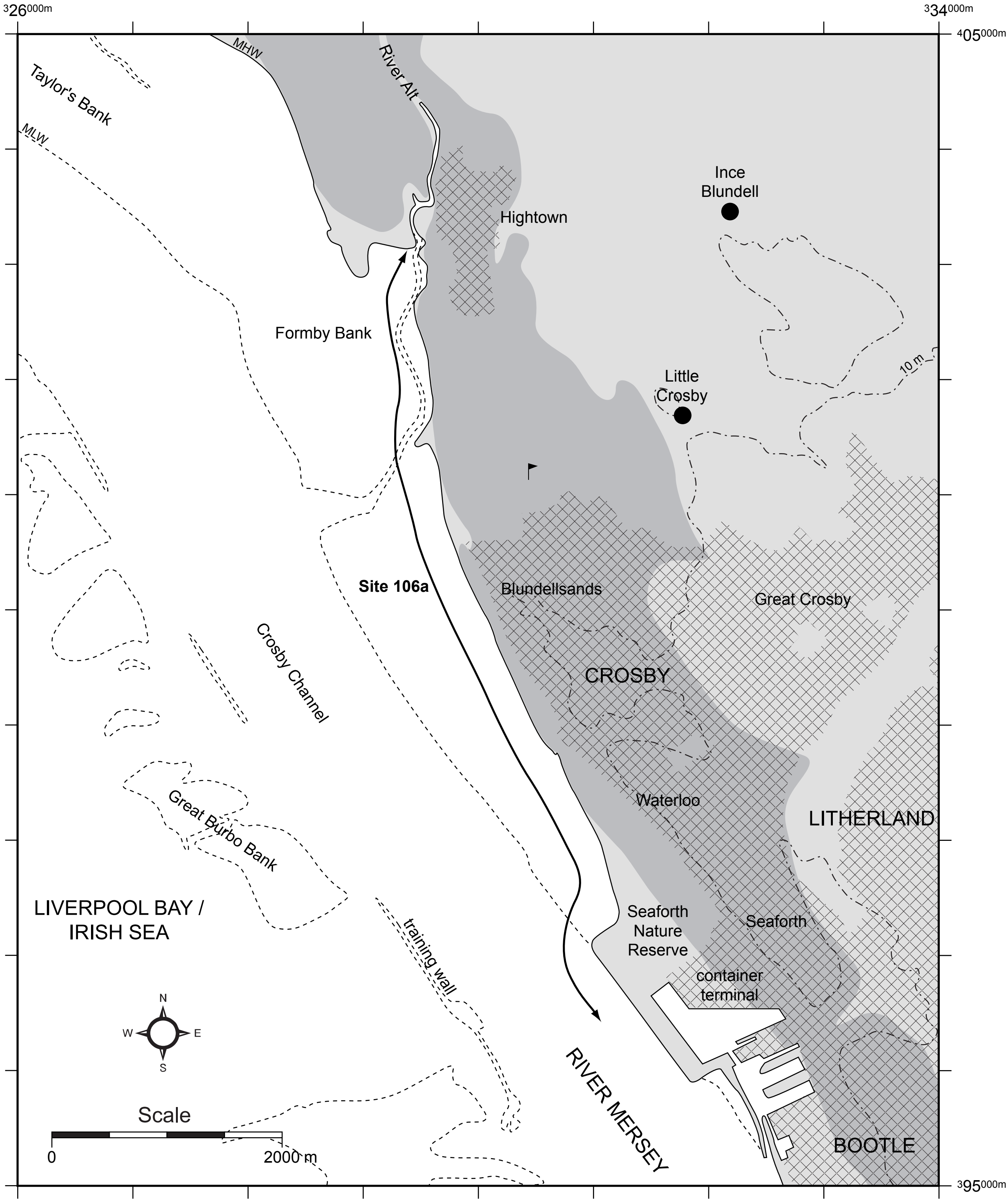


Figure 3.91 Site 106 (Sefton Coast): Site 106a (Seaforth to Hightown)

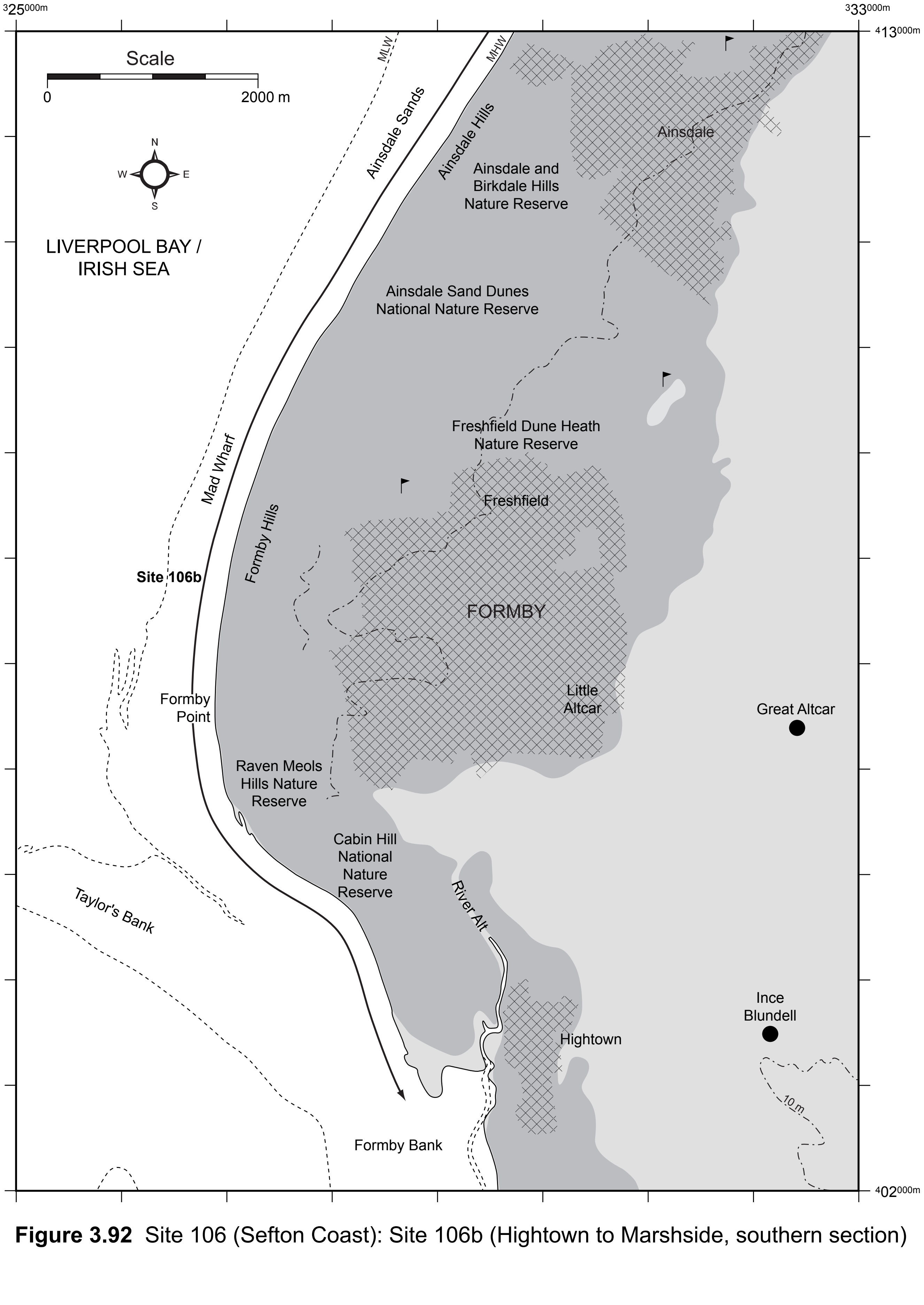


Figure 3.92 Site 106 (Sefton Coast): Site 106b (Hightown to Marshside, southern section)

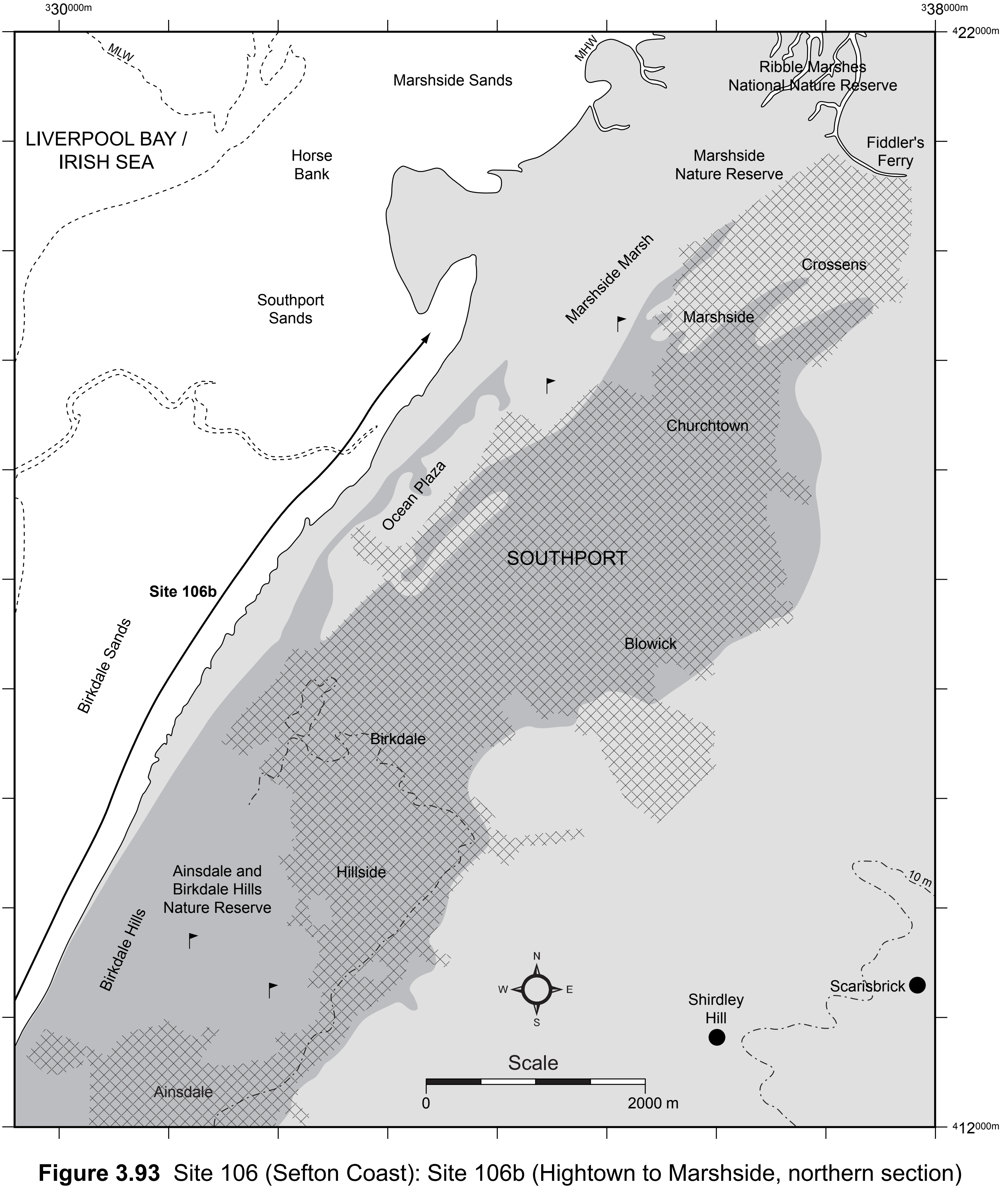


Figure 3.93 Site 106 (Sefton Coast): Site 106b (Hightown to Marshside, northern section)

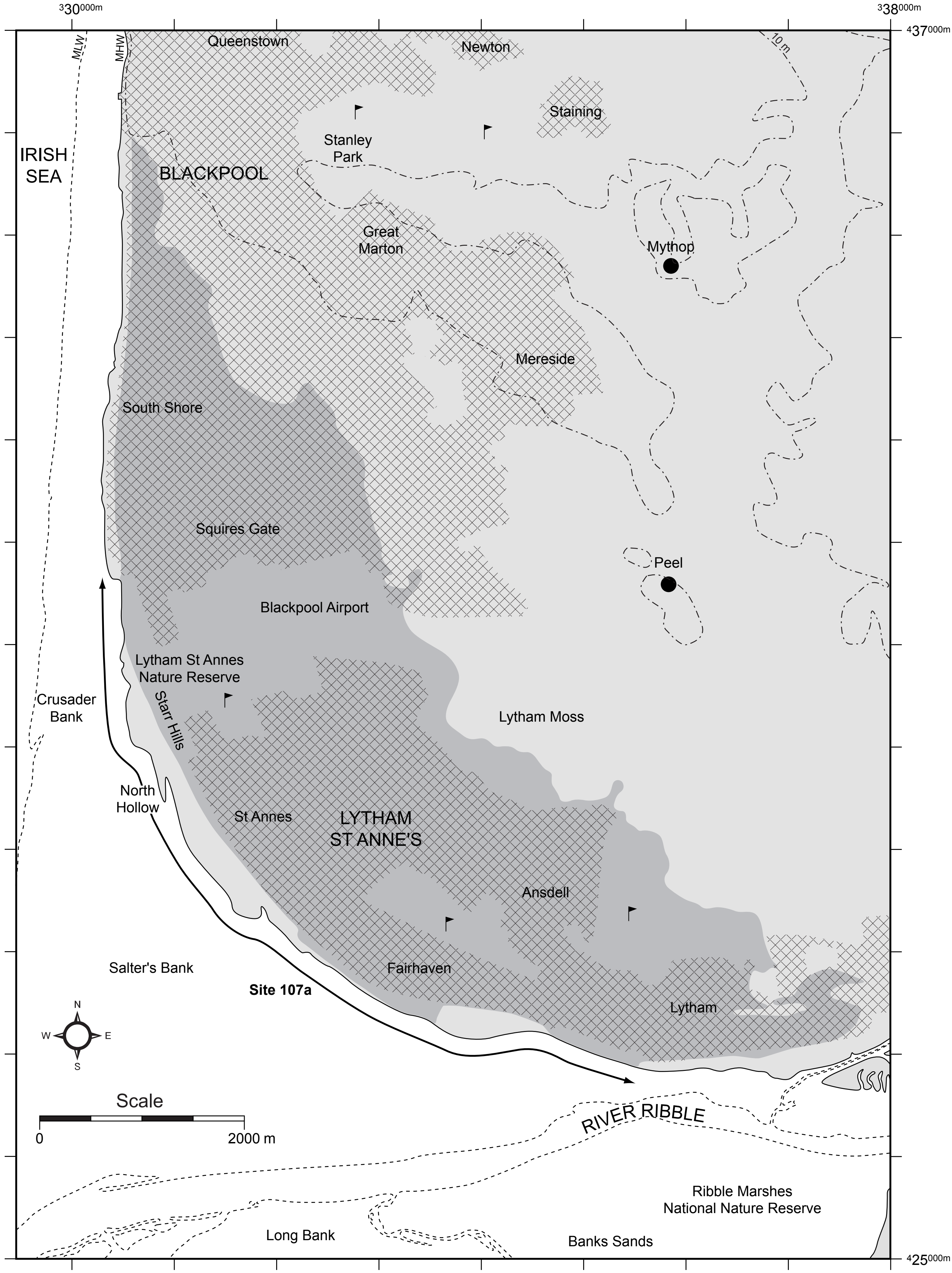


Figure 3.94 Site 107 (Fylde Coast): Site 107a (Lytham to Blackpool)

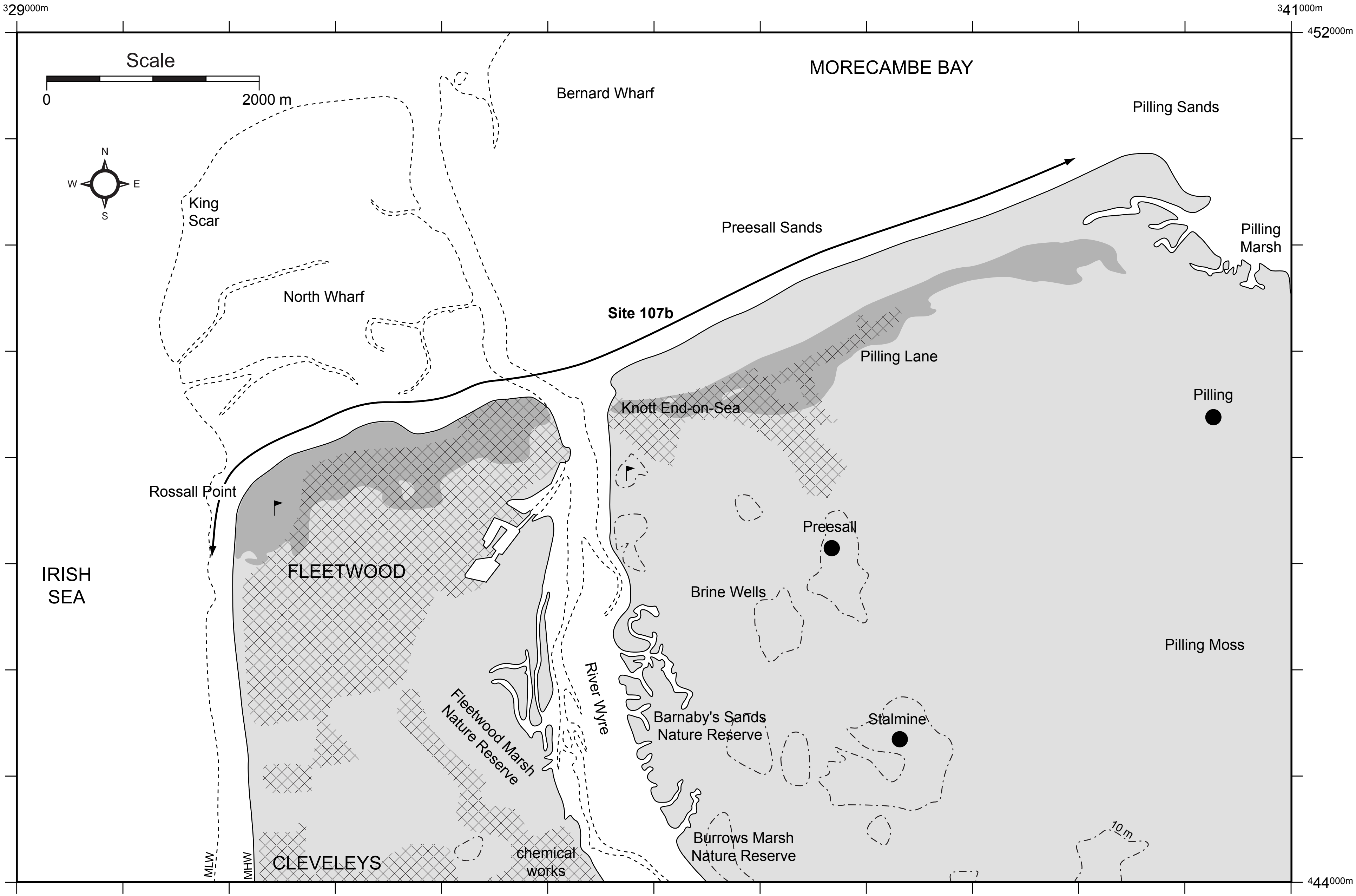


Figure 3.95 Site 107 (Fylde Coast): Site 107b (Fleetwood to Pilling)

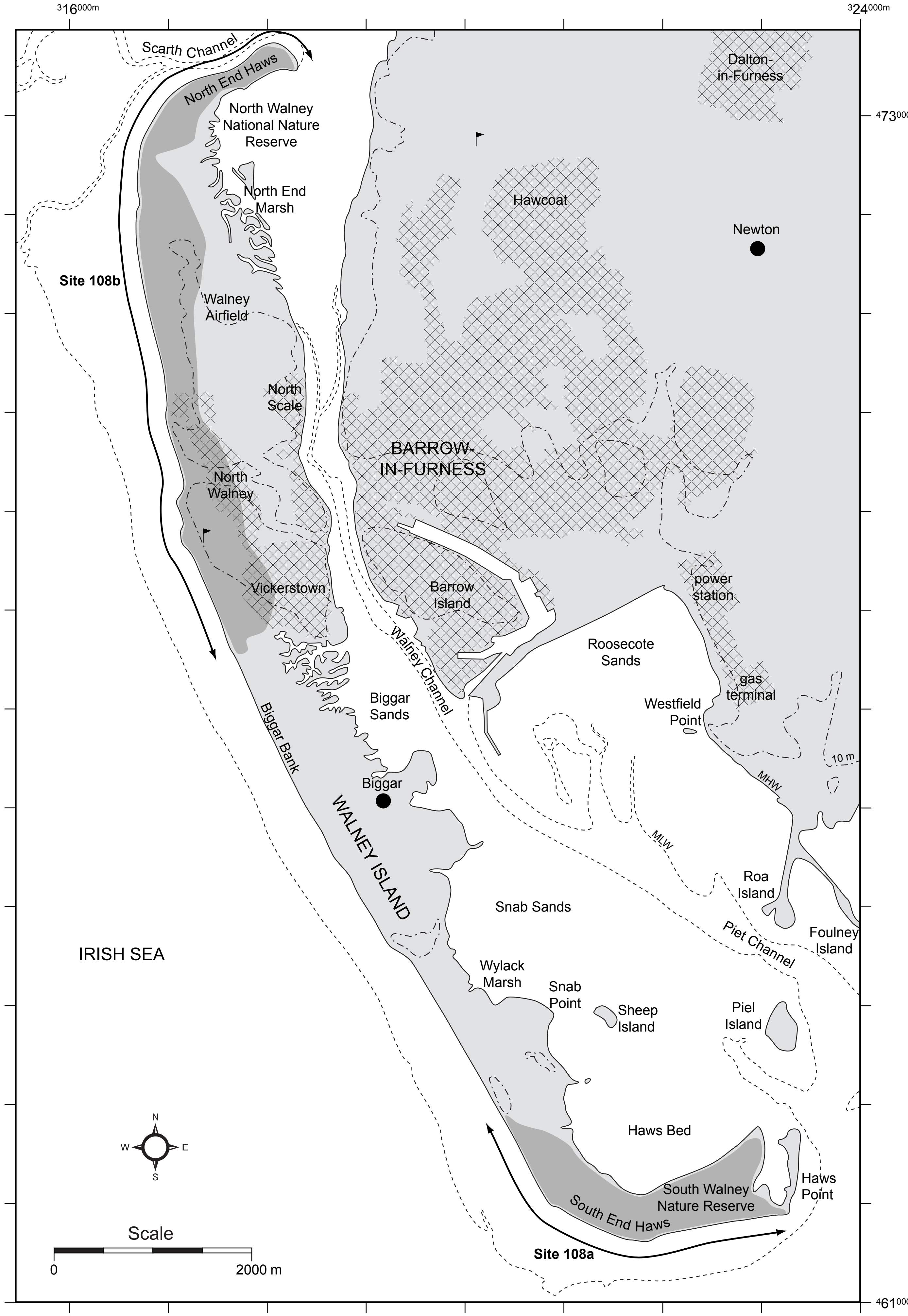


Figure 3.96 Site 108 (Walney Island): Site 108a (South End Haws) and Site 108b (North End Haws)

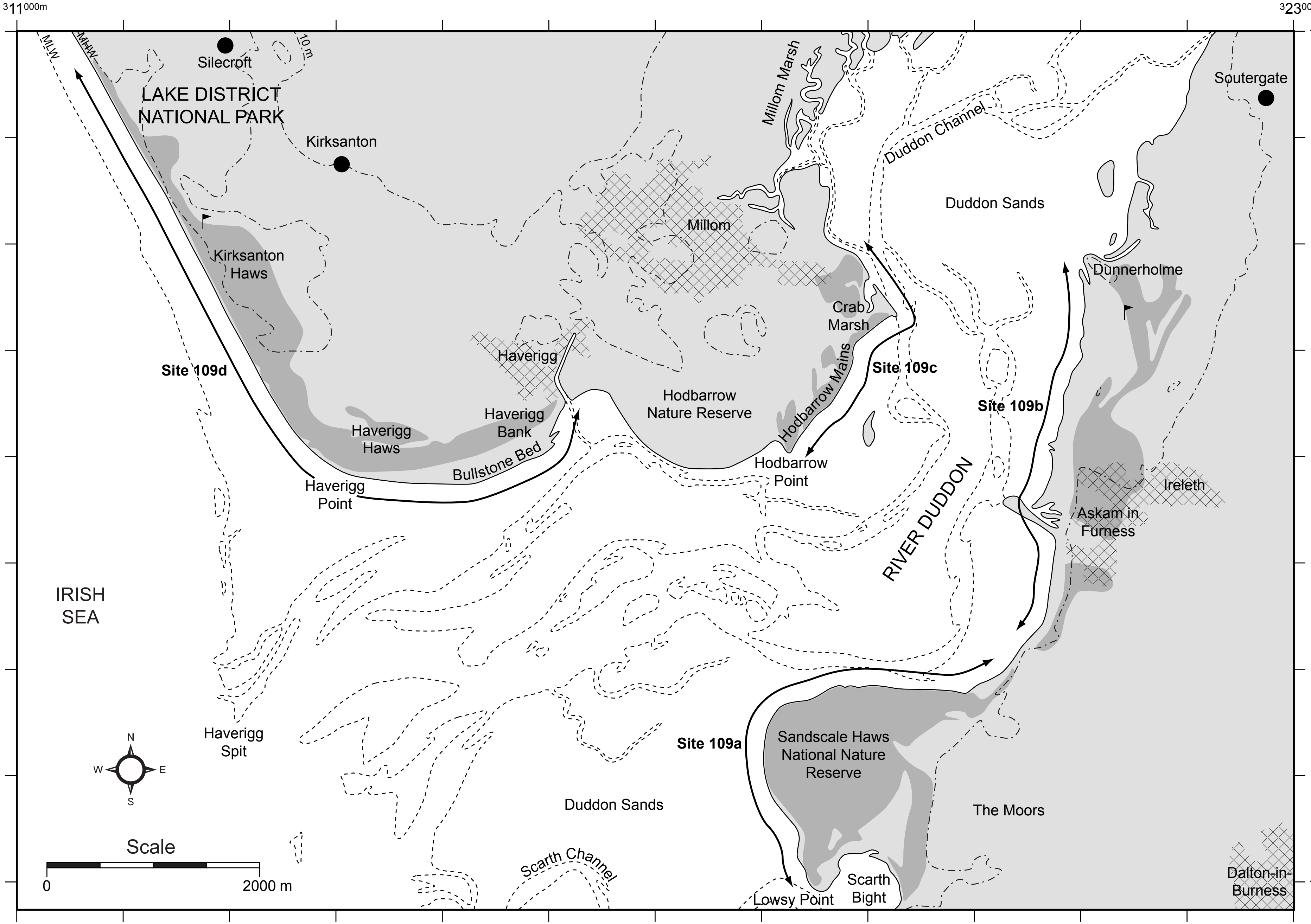


Figure 3.97 Site 109 (Duddon Estuary): Site 109a (Sandscale Haws), Site 109b (Askam in Furness to Dunnerholme), Site 109c (Hodbarrow) and Site 109d (Haverigg Haws and Kirksanton Haws)

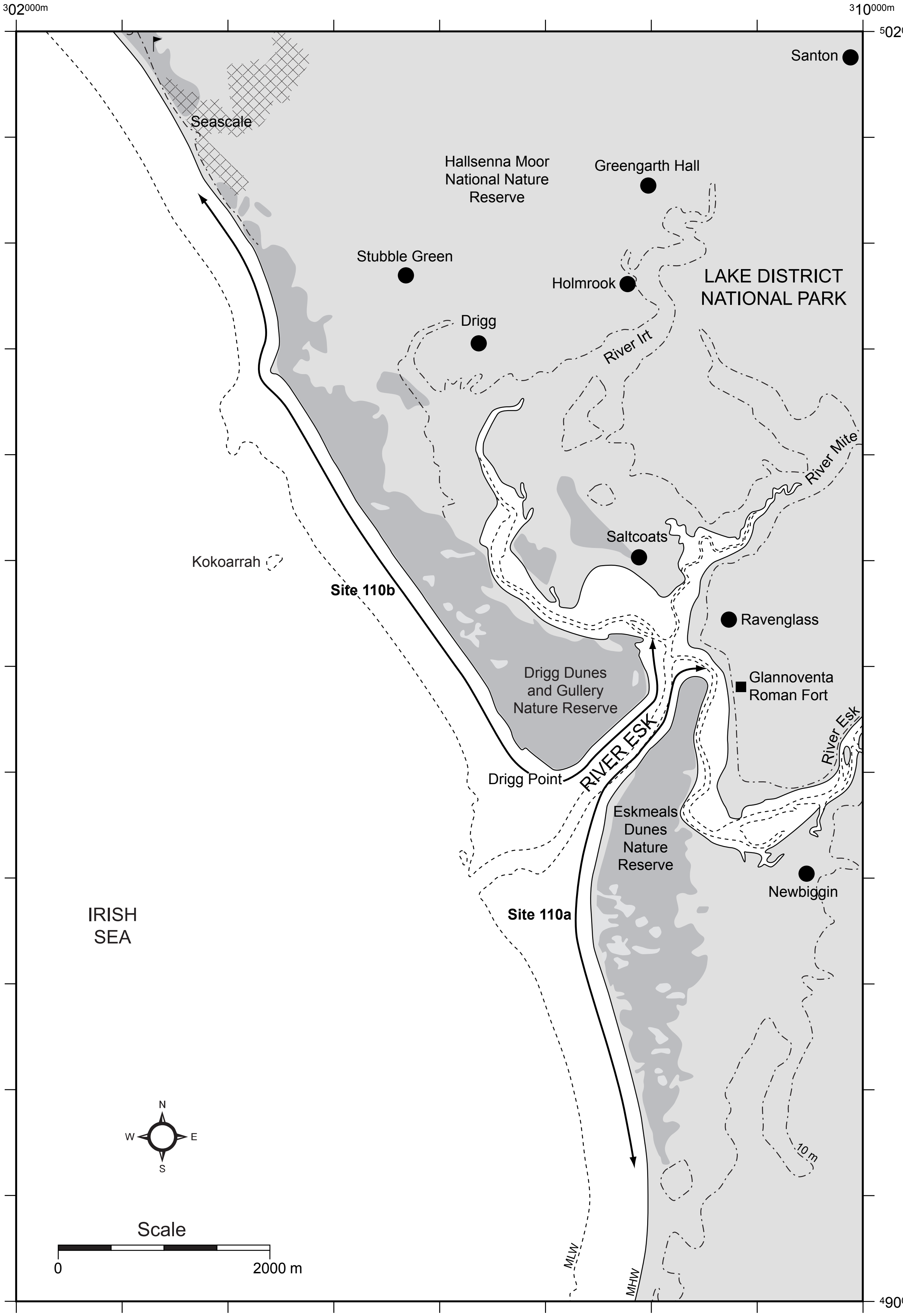


Figure 3.98 Site 110 (Esk Estuary): Site 110a (Eskmeals Dunes) and Site 110b (Drigg Dunes)

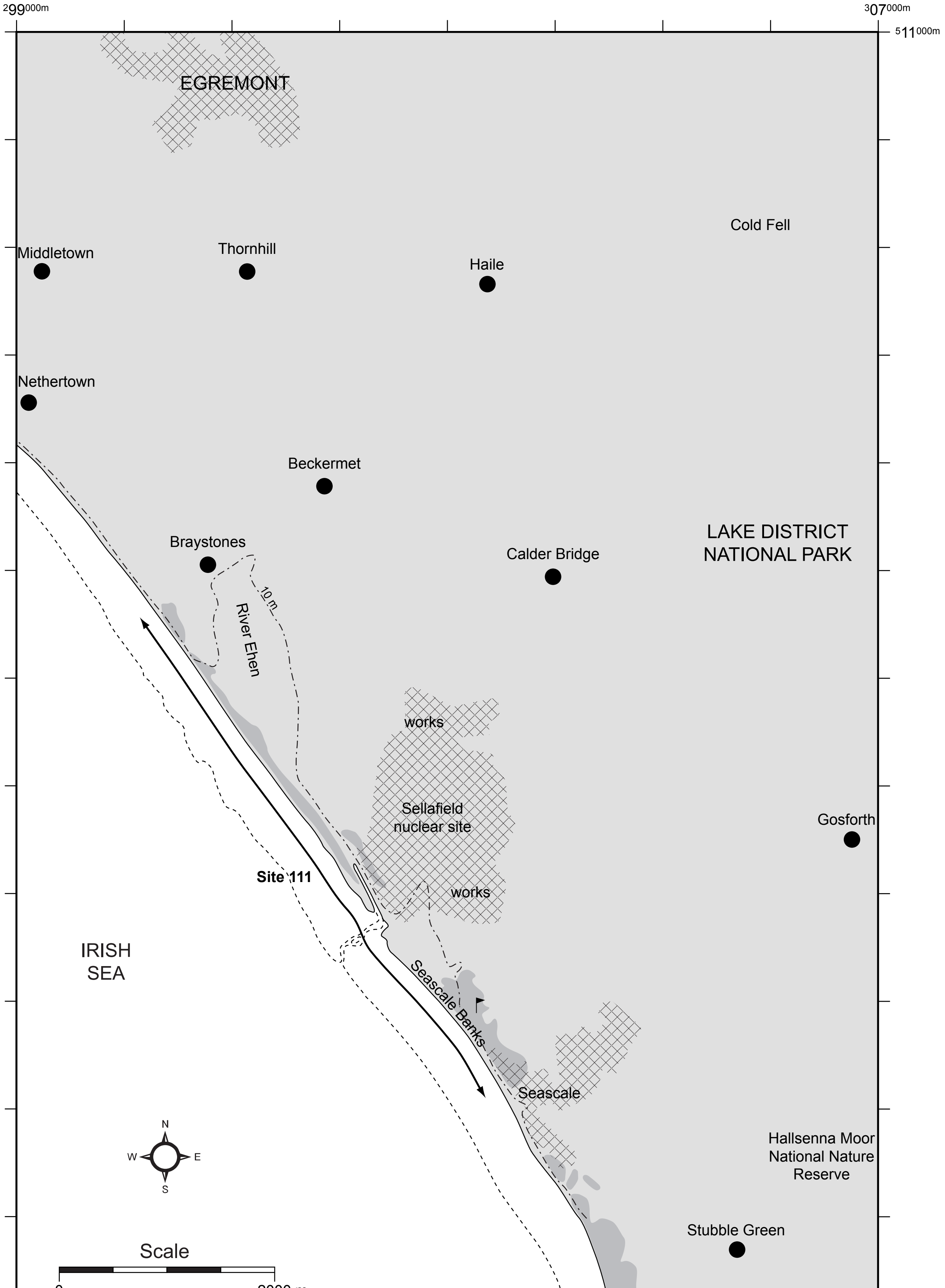


Figure 3.99 Site 111 (Seascale to Braystones)

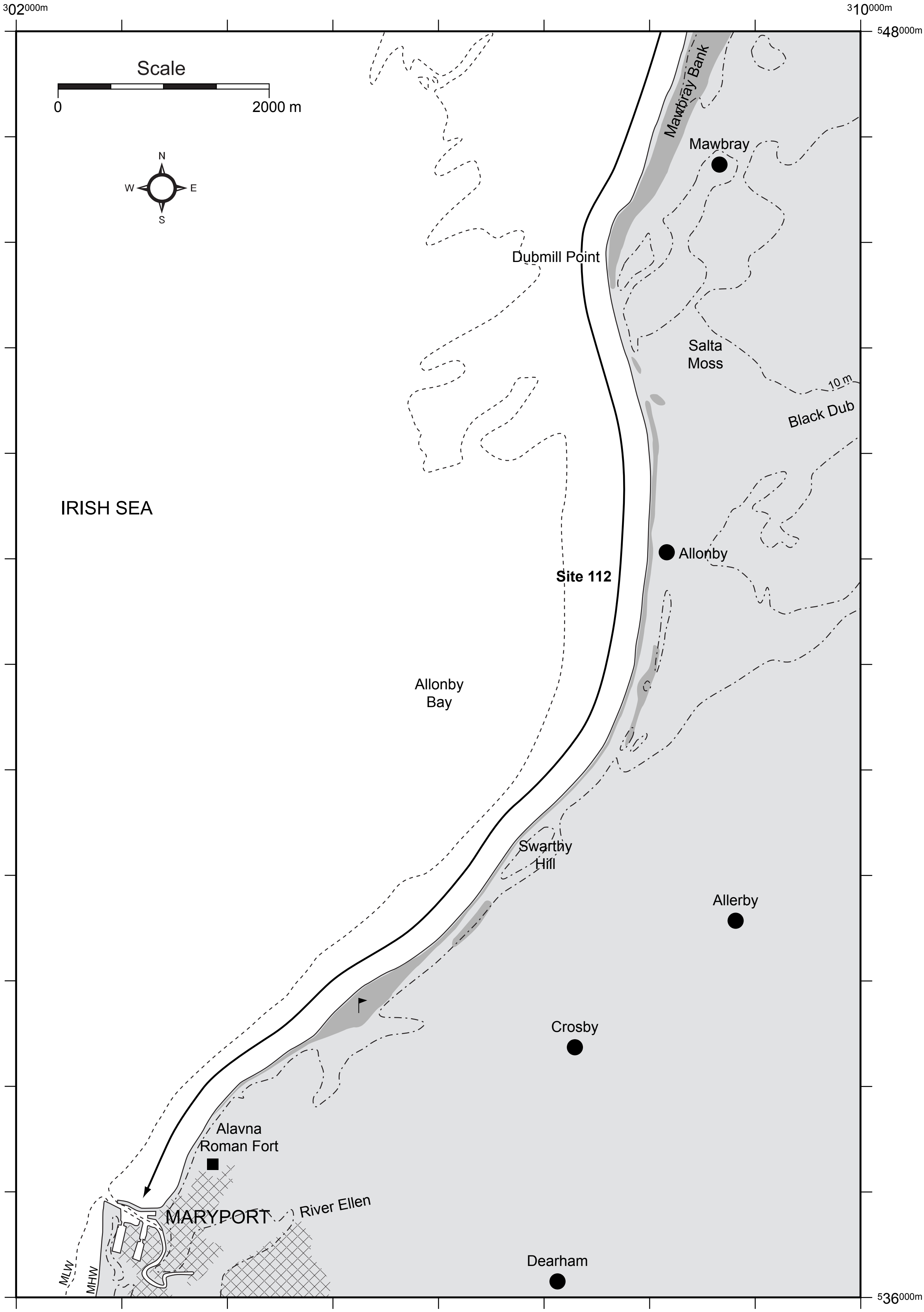


Figure 3.100 Site 112 (Maryport to Grune Point, southern section)

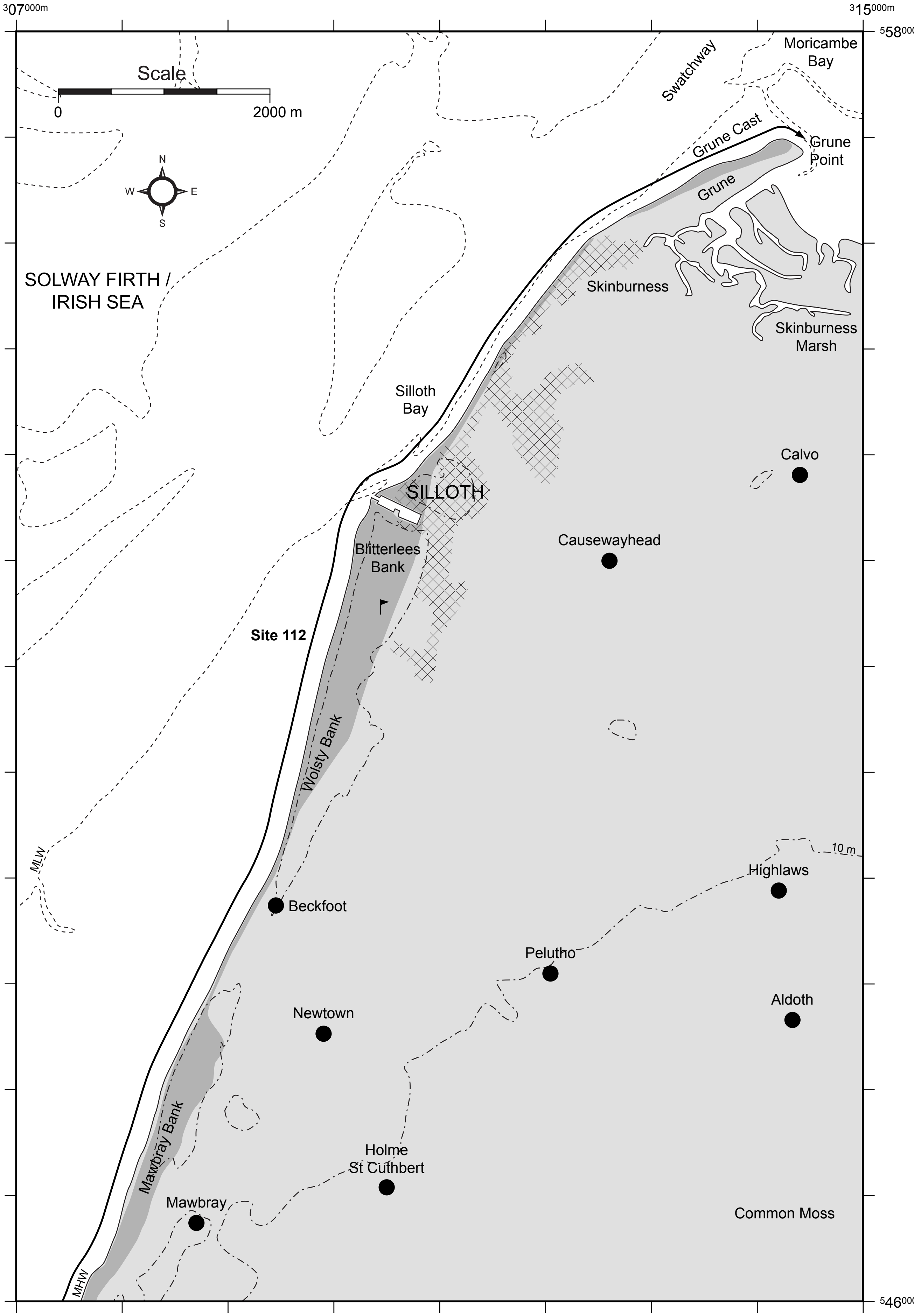


Figure 3.101 Site 112 (Maryport to Grune Point, northern section)

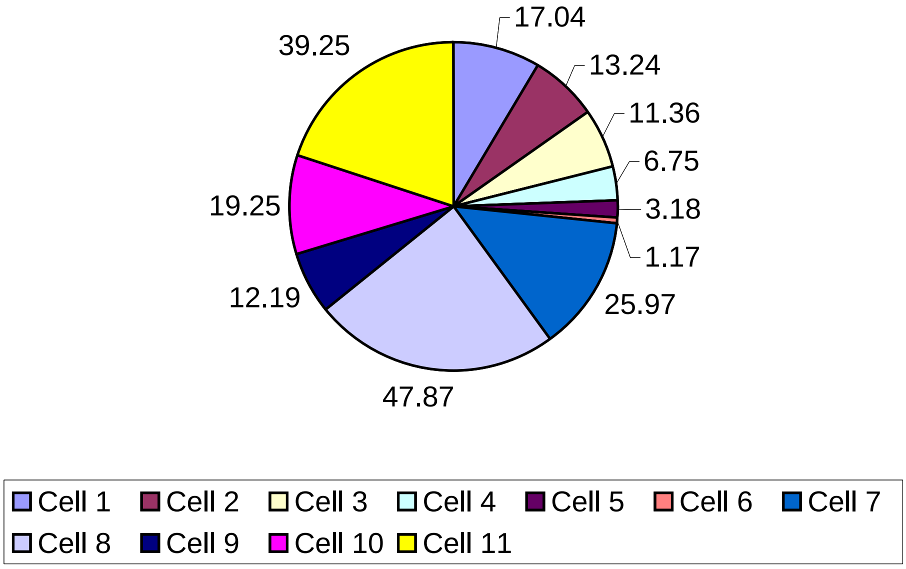


Figure 3.102 Pie chart showing the dune area in km^2 for each process cell. Area values obtained from Radley (1994) & Dargie (1995).

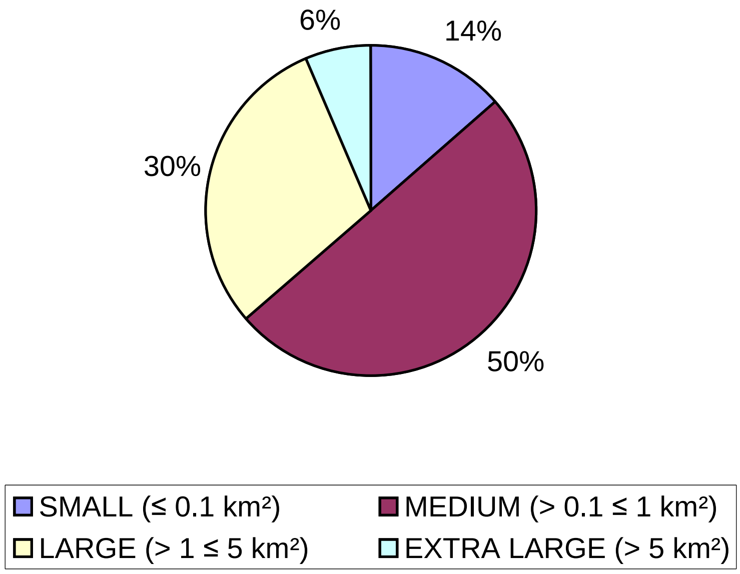


Figure 3.103 Pie chart showing dune system classification based on area values for 124 individual sites obtained from Radley (1994), Dargie (1995) and Posford Duvivier (1996).

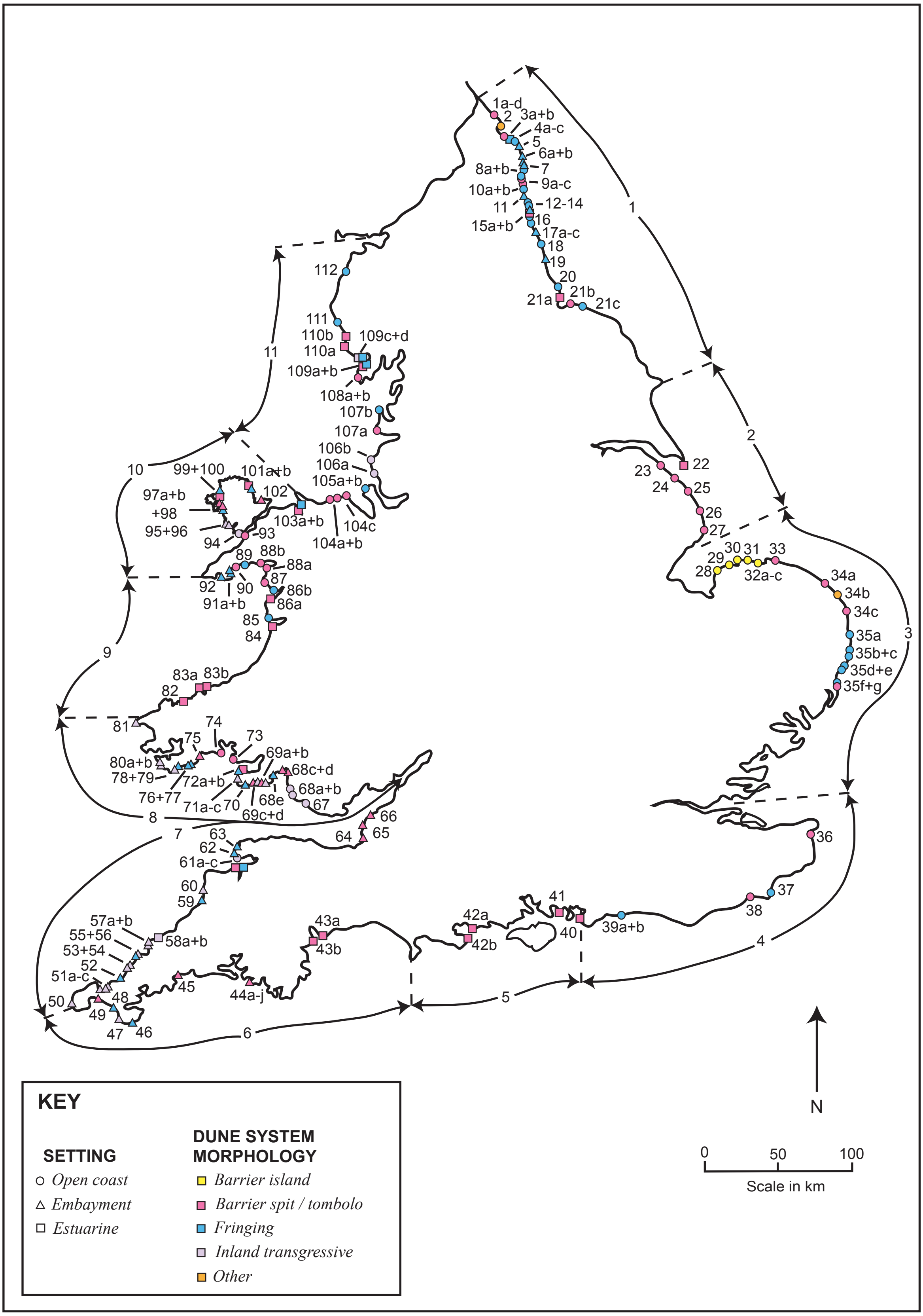


Figure 3.104 Predominant dune system morphology types at dune sites in England and Wales.

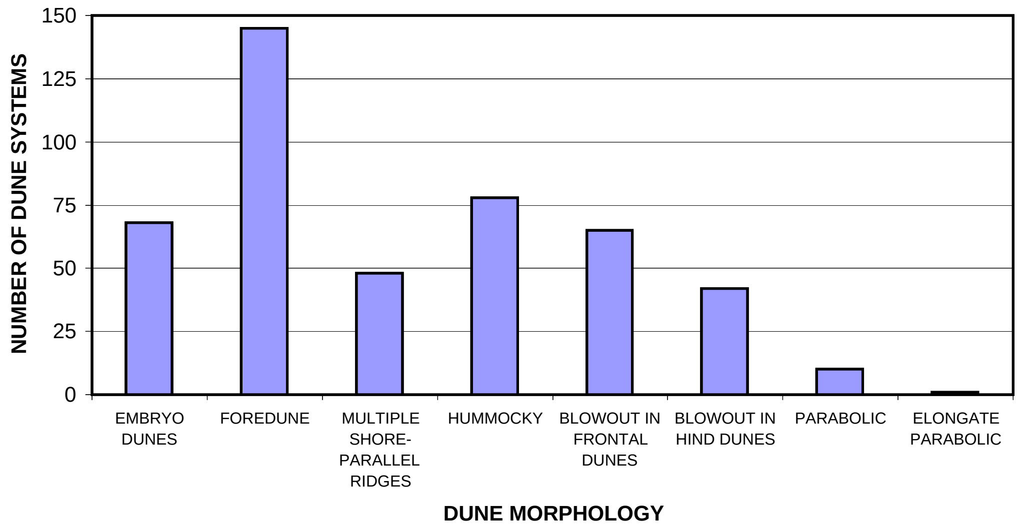


Figure 3.105 Dune morphology types identified at dune sites in England and Wales.

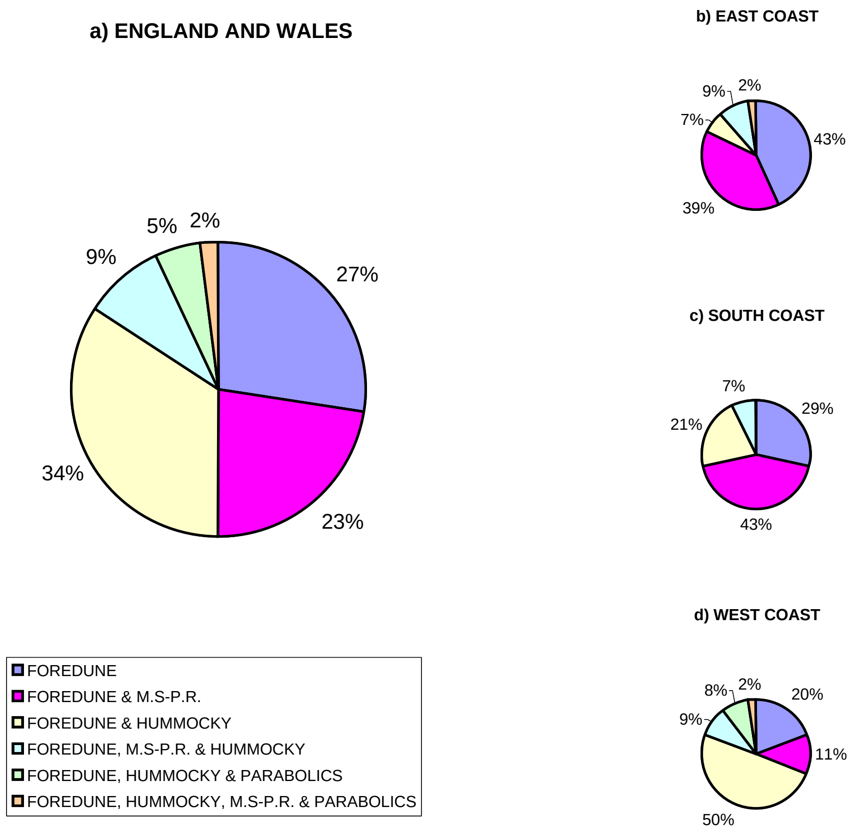


Figure 3.106 Percentage of sites in England and Wales with different combinations of dune morphology types. M.S-P.R. = multiple shore-parallel ridges.

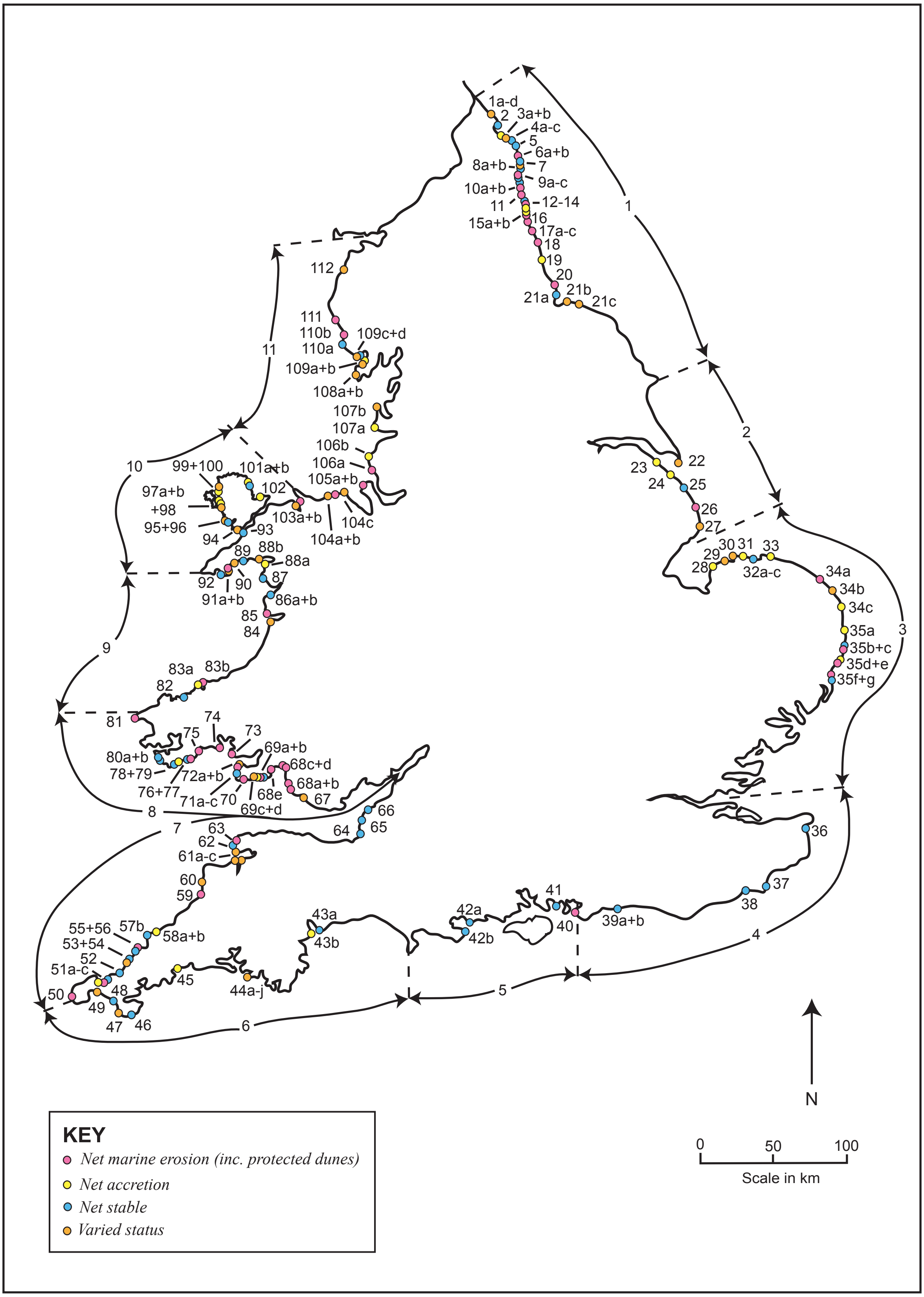


Figure 3.107 Frontal dune erosion/accretion status at dune sites in England and Wales as recorded during field visits between 1999 and 2001. See text for full definitions of each status type.

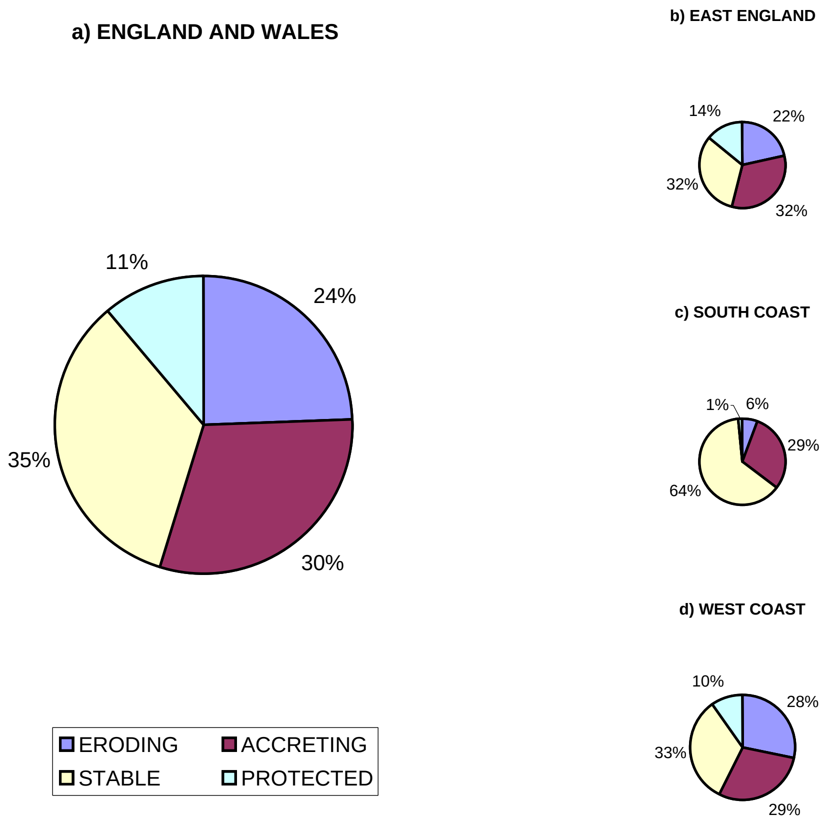


Figure 3.108 Percentage of dune frontage that is eroding, accreting, stable or protected by sea defences for areas of England and Wales.

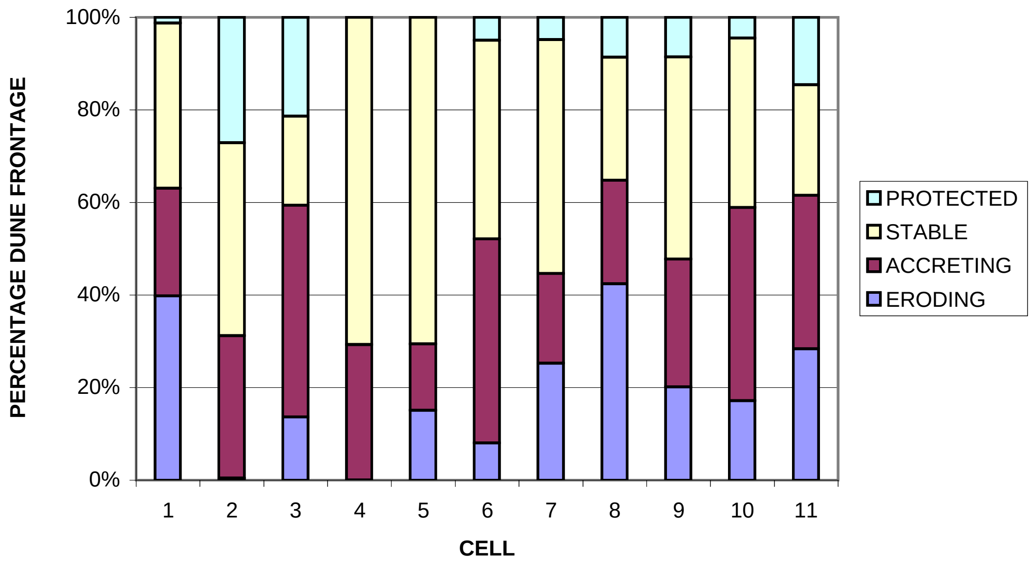


Figure 3.109 Percentage of dune frontage that is eroding, accreting, stable or protected by sea defences in each coastal cell in England and Wales.

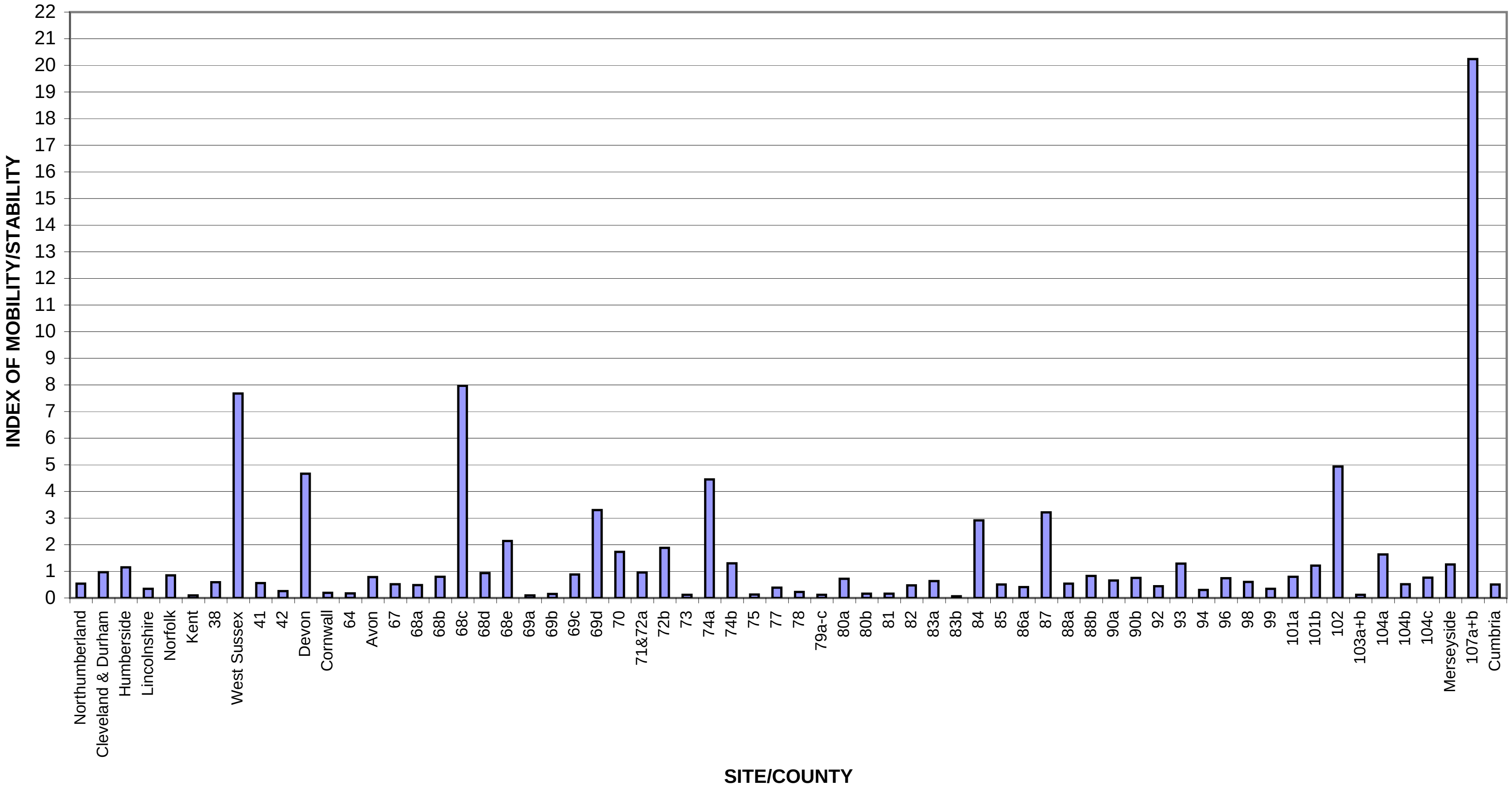


Figure 3.110 Index of mobility/stability calculated using vegetation habitats at each site/county in England and Wales. Table 1 for location of above site codes.

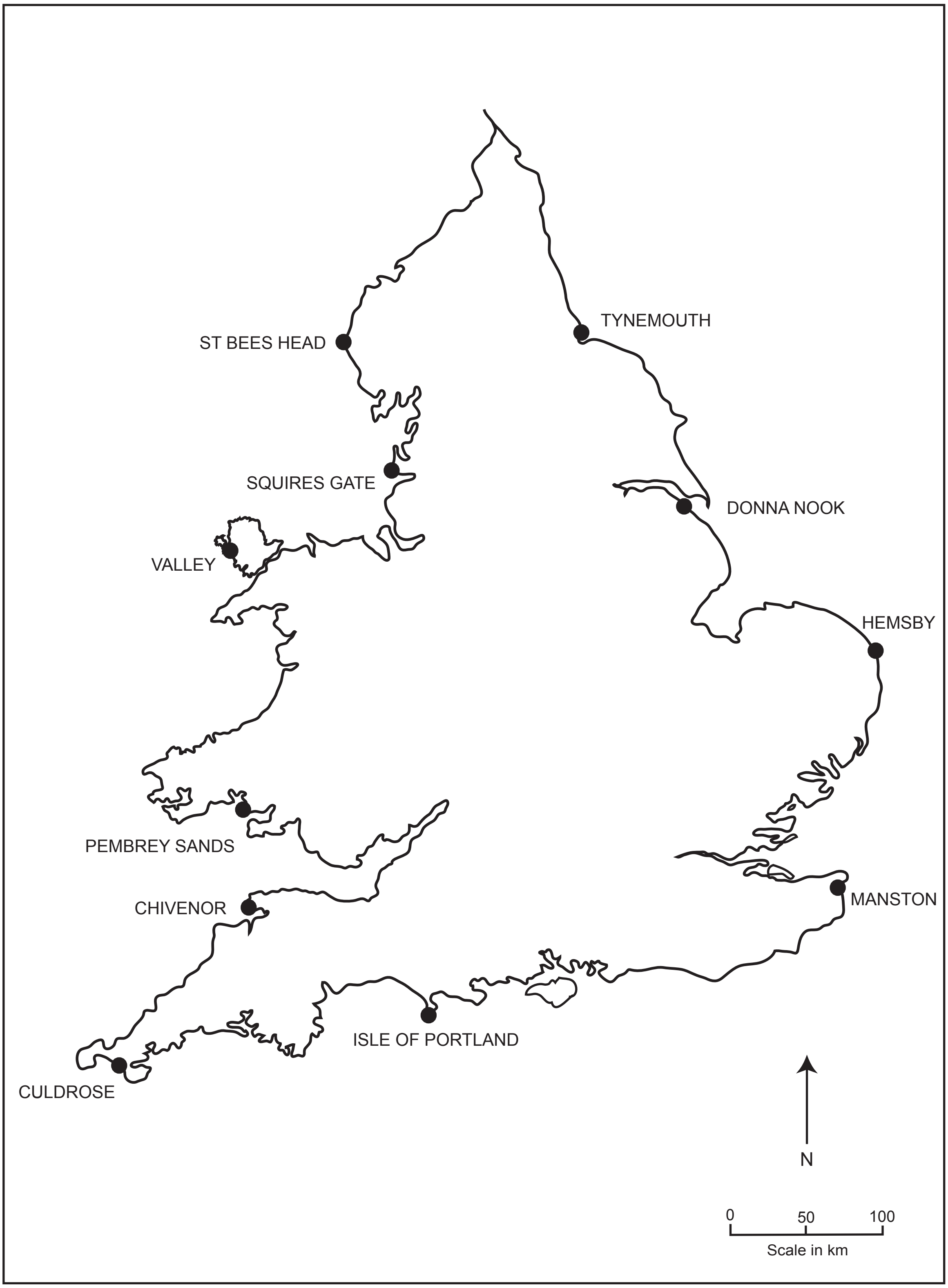
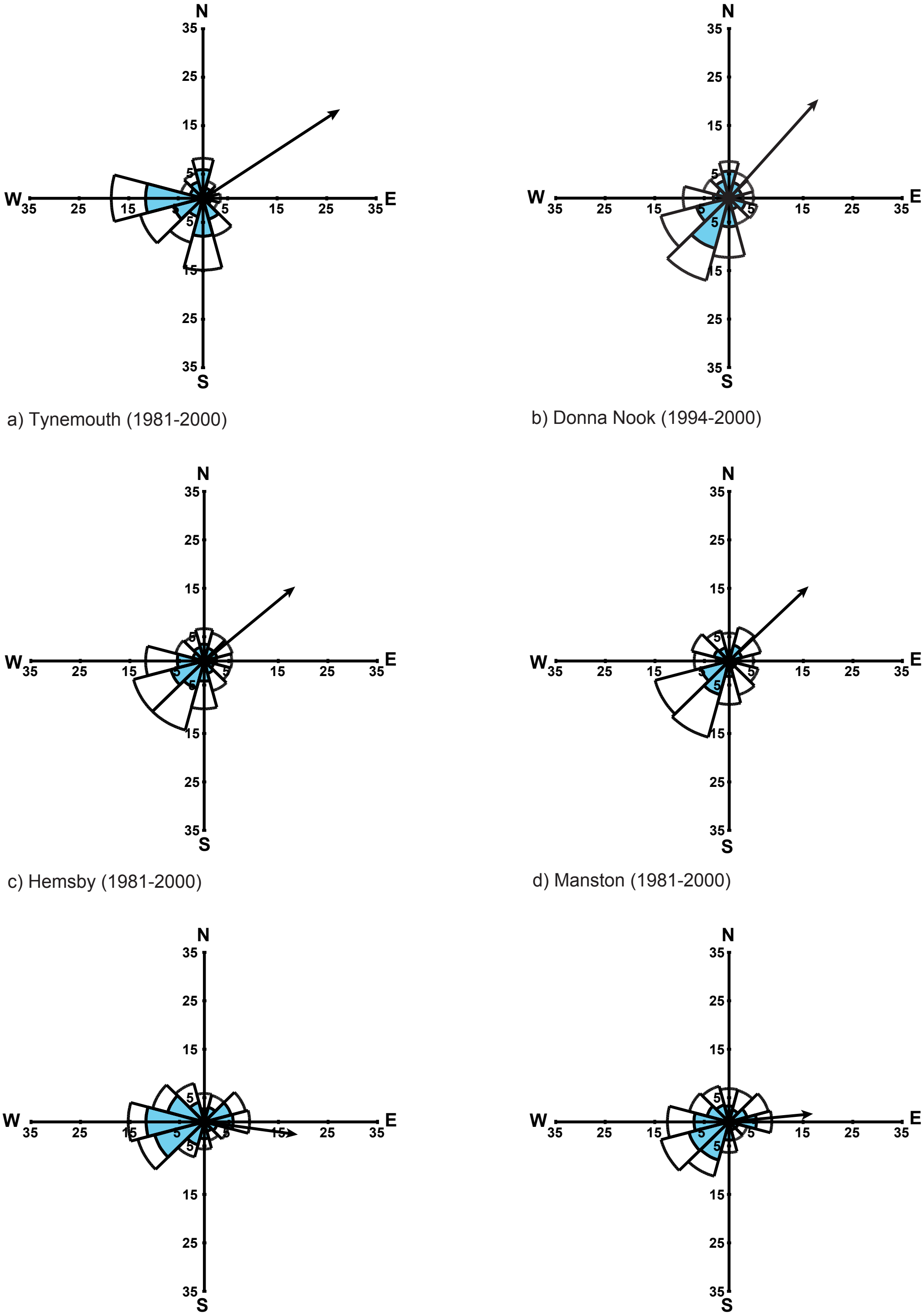


Figure 3.111 Location of meteorological stations used in this study for wind regime analysis.



a) Tynemouth (1981-2000)

b) Donna Nook (1994-2000)

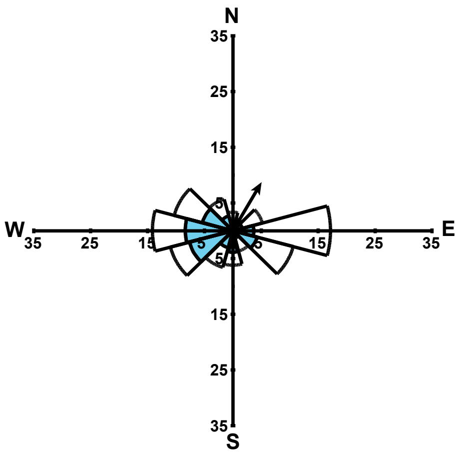
c) Hemsby (1981-2000)

d) Manston (1981-2000)

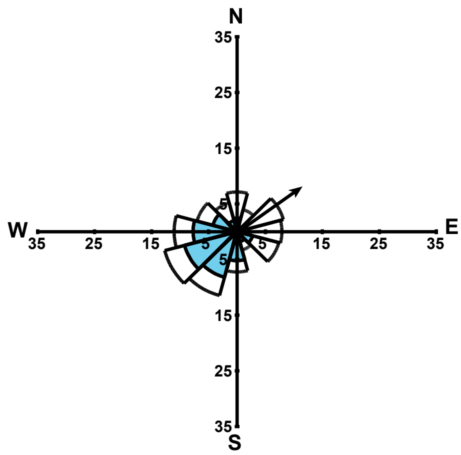
e) Isle of Portland (1981-2000, exc. 1992-1994)

f) Culdrose (1981-2000, exc. 1988)

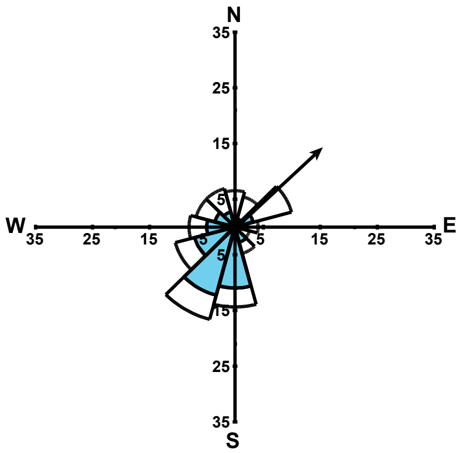
Figure 3.112 Wind rose diagrams for the stations shown in Figure 3.111, calculated from data supplied by the Met Office. Unshaded segments refer to all winds, shaded segments refer to winds > 11 knots. Arrows indicate resultant wind direction for all winds.



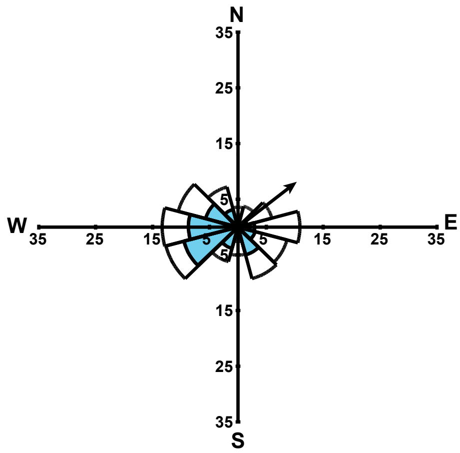
g) Chivenor (1981-2000)



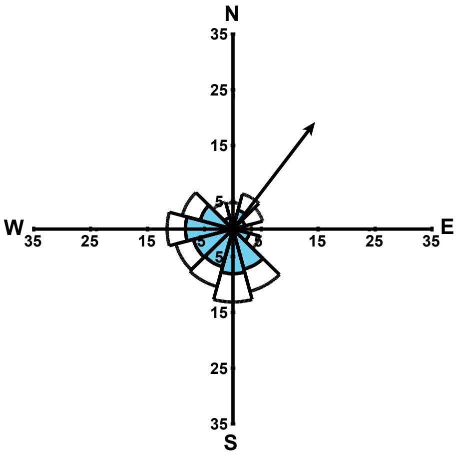
h) Pembrey Sands (1994-2000)



i) Valley (1981-2000)



j) Squires Gate (1975-1995)



k) St Bees Head (1992-2000)

Figure 3.112 continued.

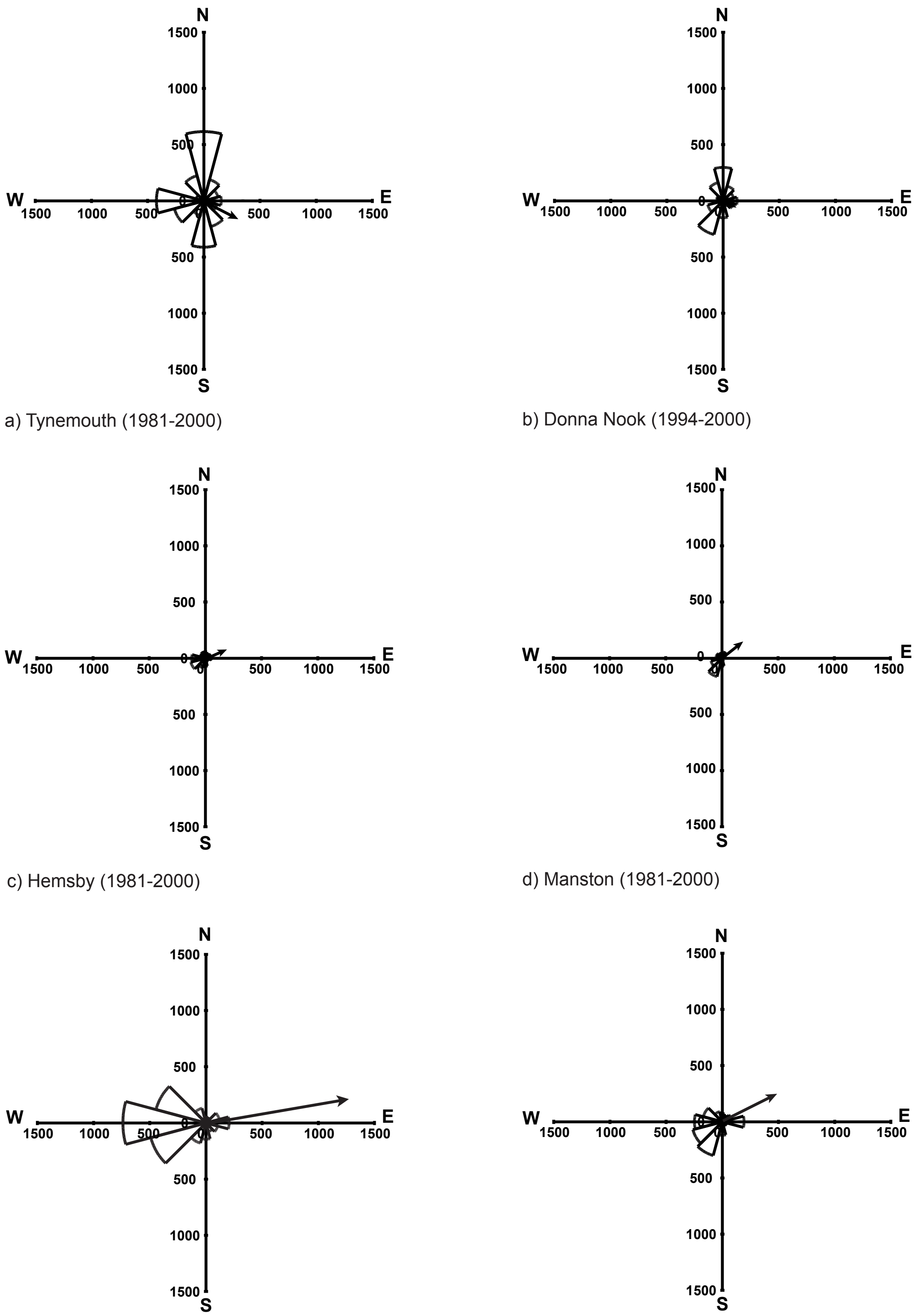
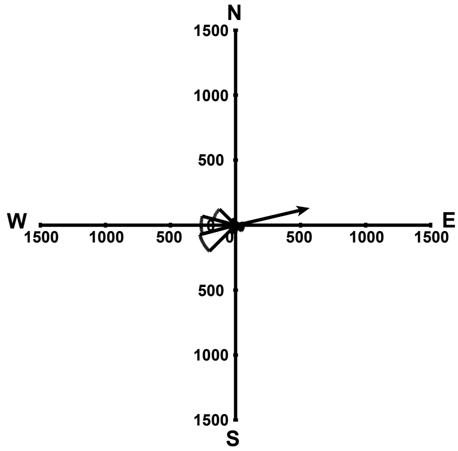
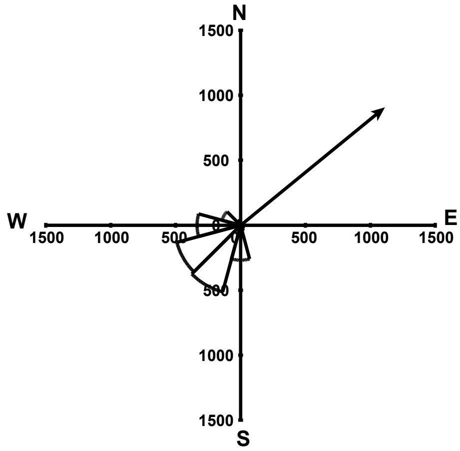


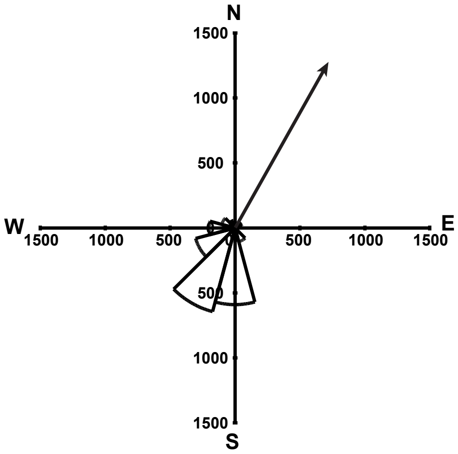
Figure 3.113 Sand rose diagrams for the stations shown in Figure 3.111. Drift Potentials (in vector units) calculated using the Fryberger & Dean (1979) equation. Arrows indicate Resultant Drift Direction (RDD), in vector units.



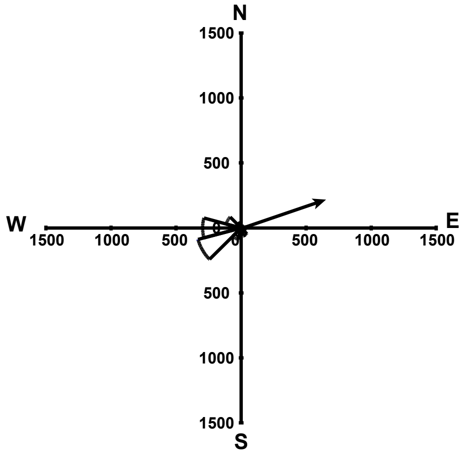
g) Chivenor (1981-2000)



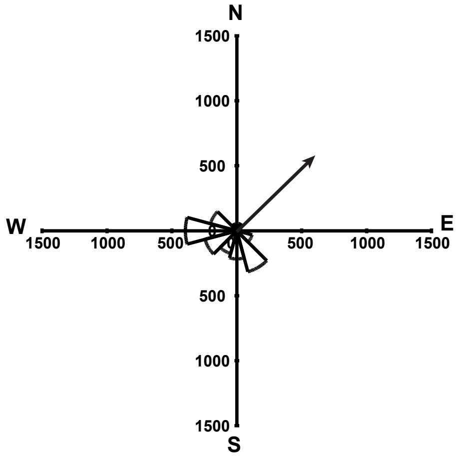
h) Pembrey Sands (1994-2000)



i) Valley (1981-2000)



j) Squires Gate (1975-1995)



k) St Bees Head (1992-2000)

Figure 3.113 continued.

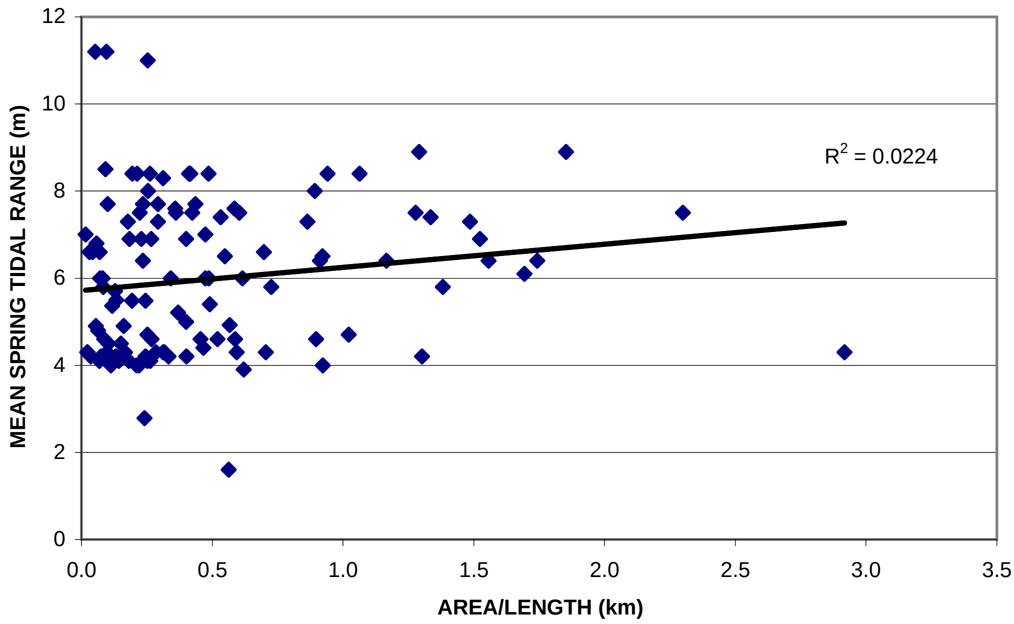


Figure 3.114 Plot of mean spring tidal range against dune area/length ratio for sites considered in this study.

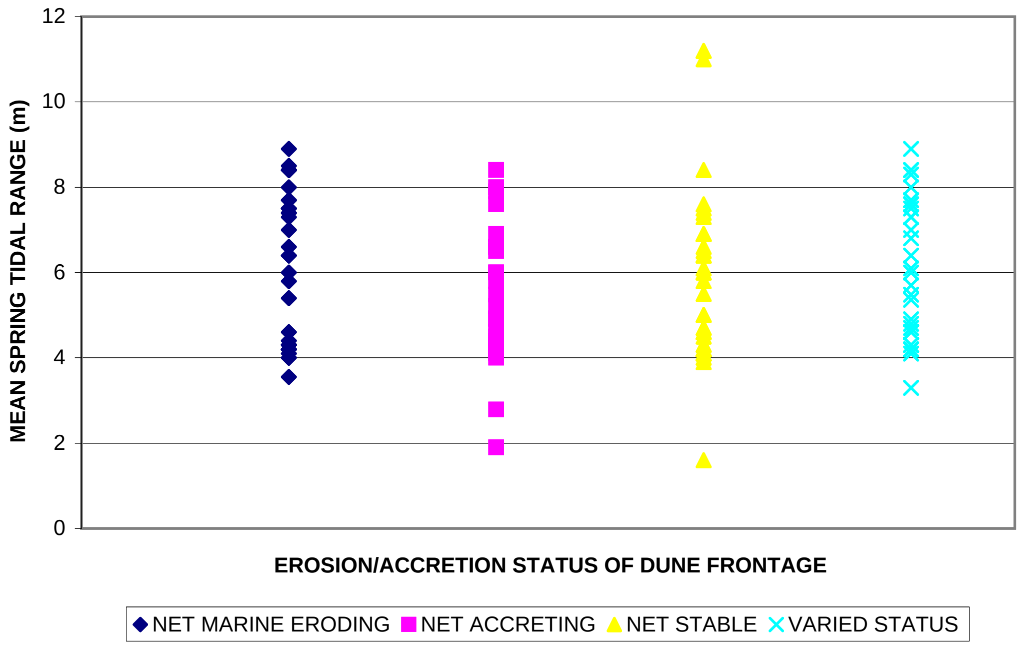


Figure 3.115 Mean spring tidal range and the net erosion/accretion status of the dune frontage at sites considered in this study.

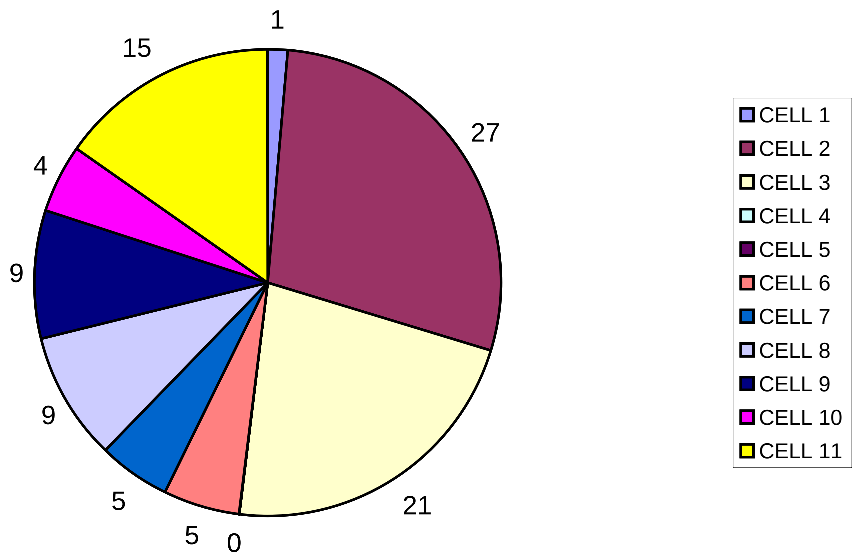


Figure 3.116 Percentage of dune frontage protected by sea defences in each coastal cell.

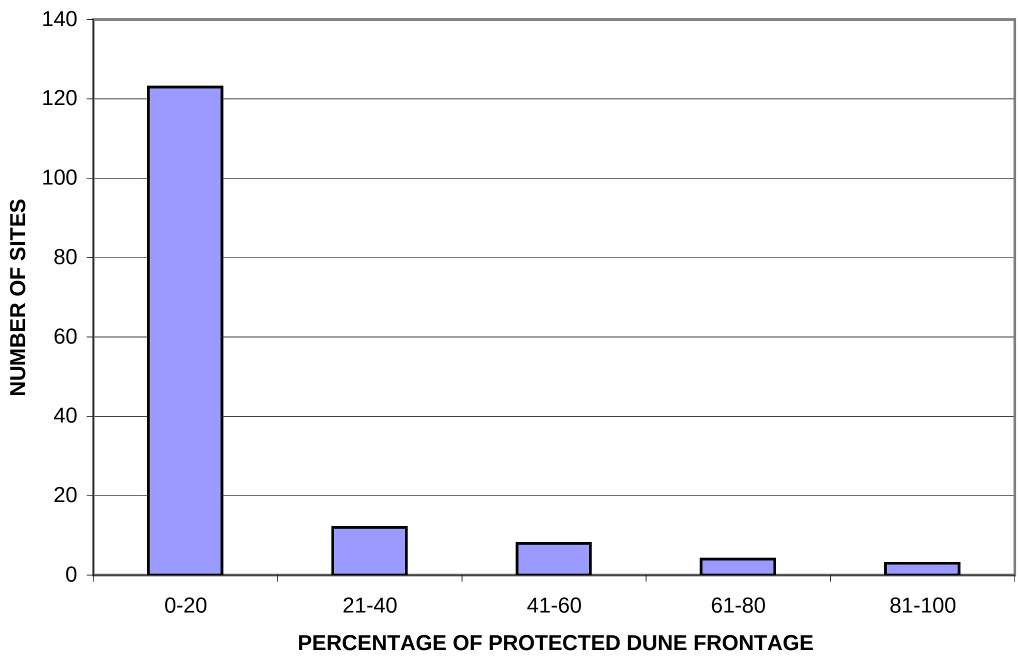


Figure 3.117 Number of sites with varying percentage of frontage protected by sea defence structures.

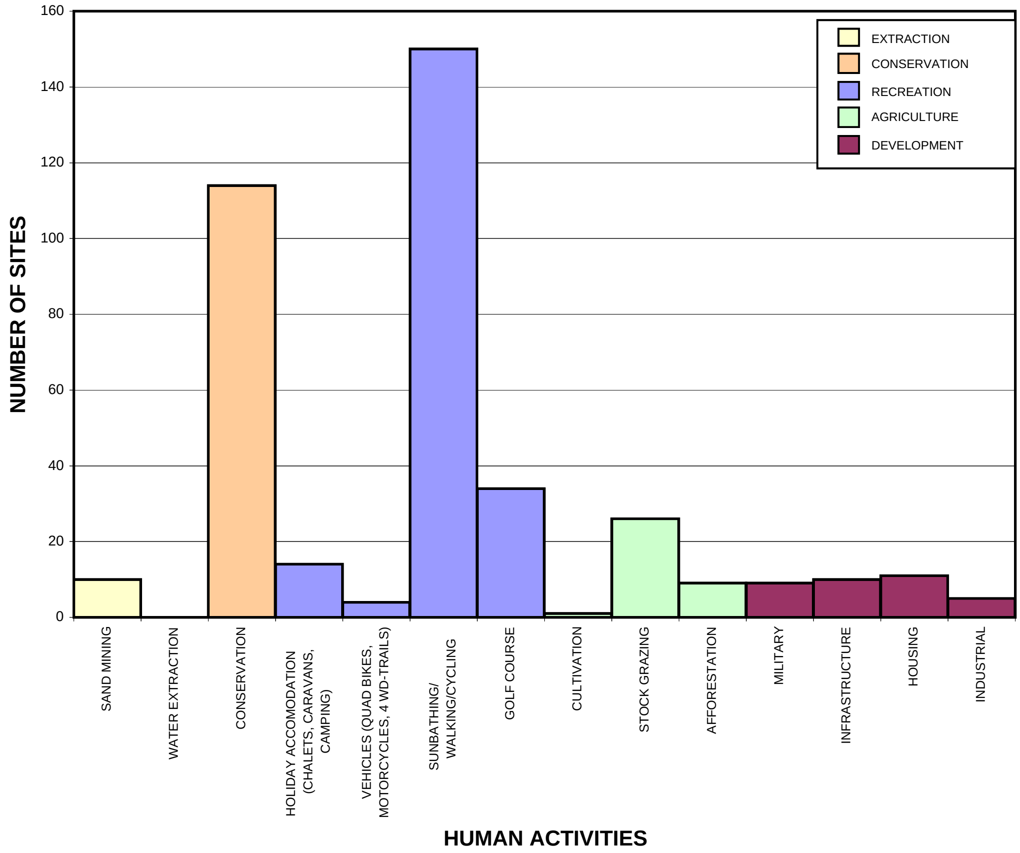


Figure 3.118 Number of coastal dune sites (from a total of 158) where various human activities were recorded.

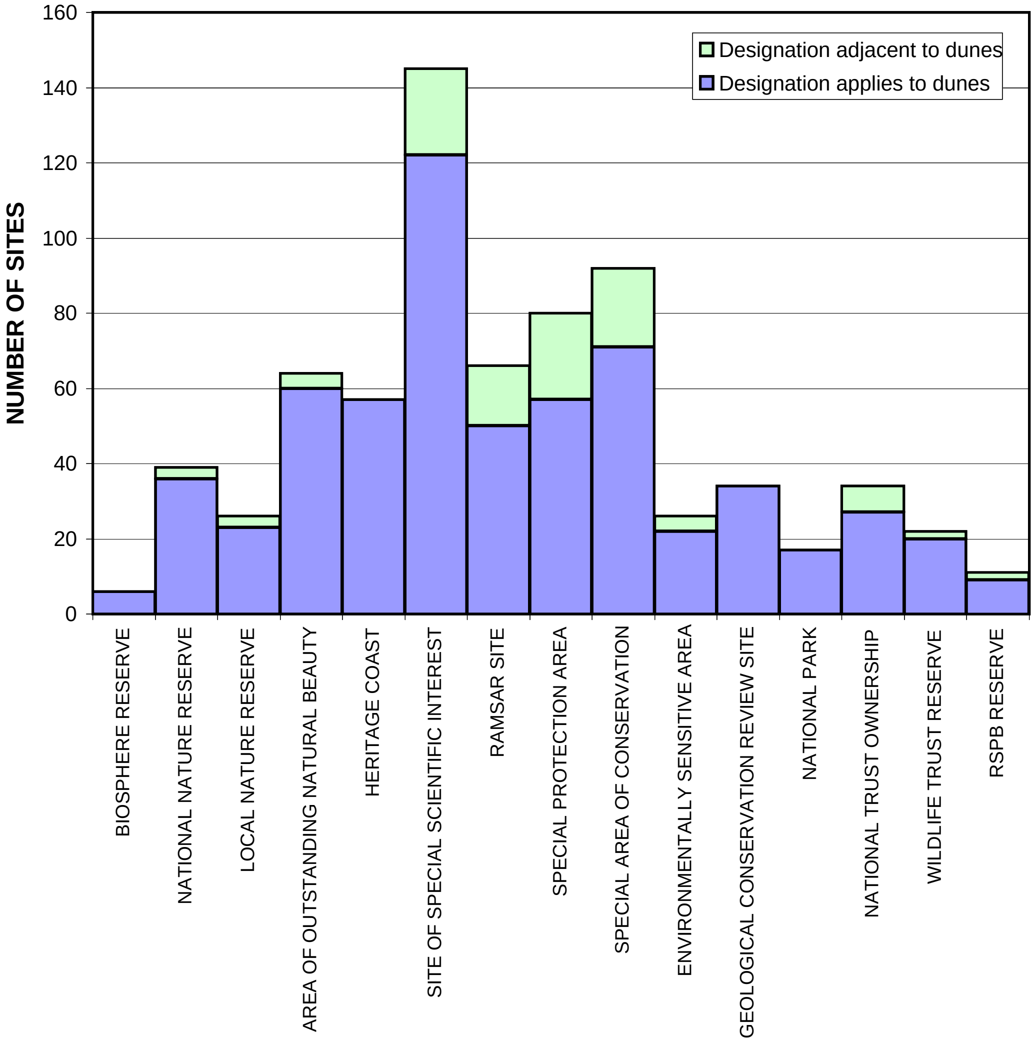


Figure 3.119 Number of coastal dune sites (from a total of 158) with different nature conservation designations.

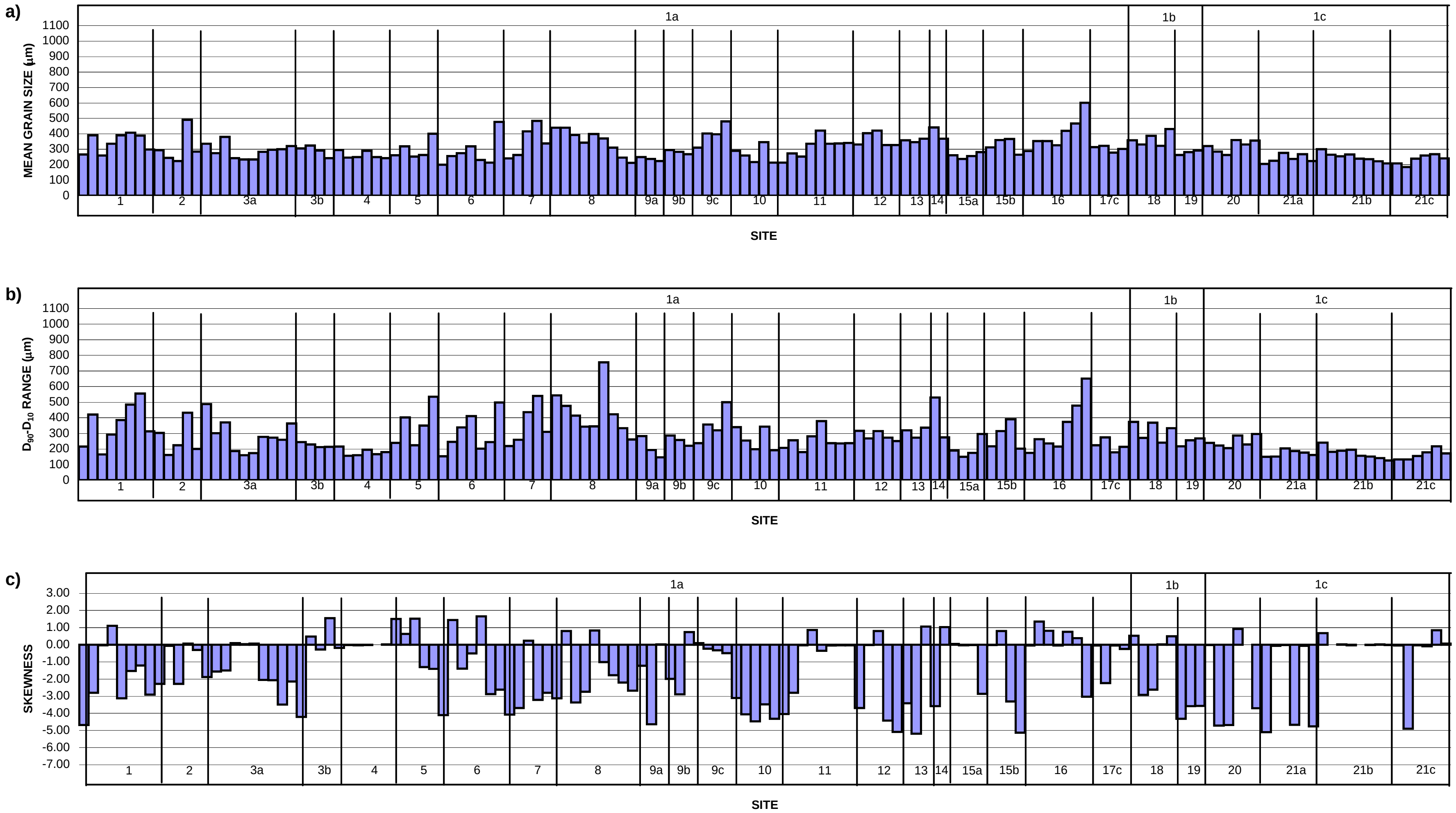


Figure 3.120 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal sand dunes in Cell 1. Site numbers are below and sub-cells above.

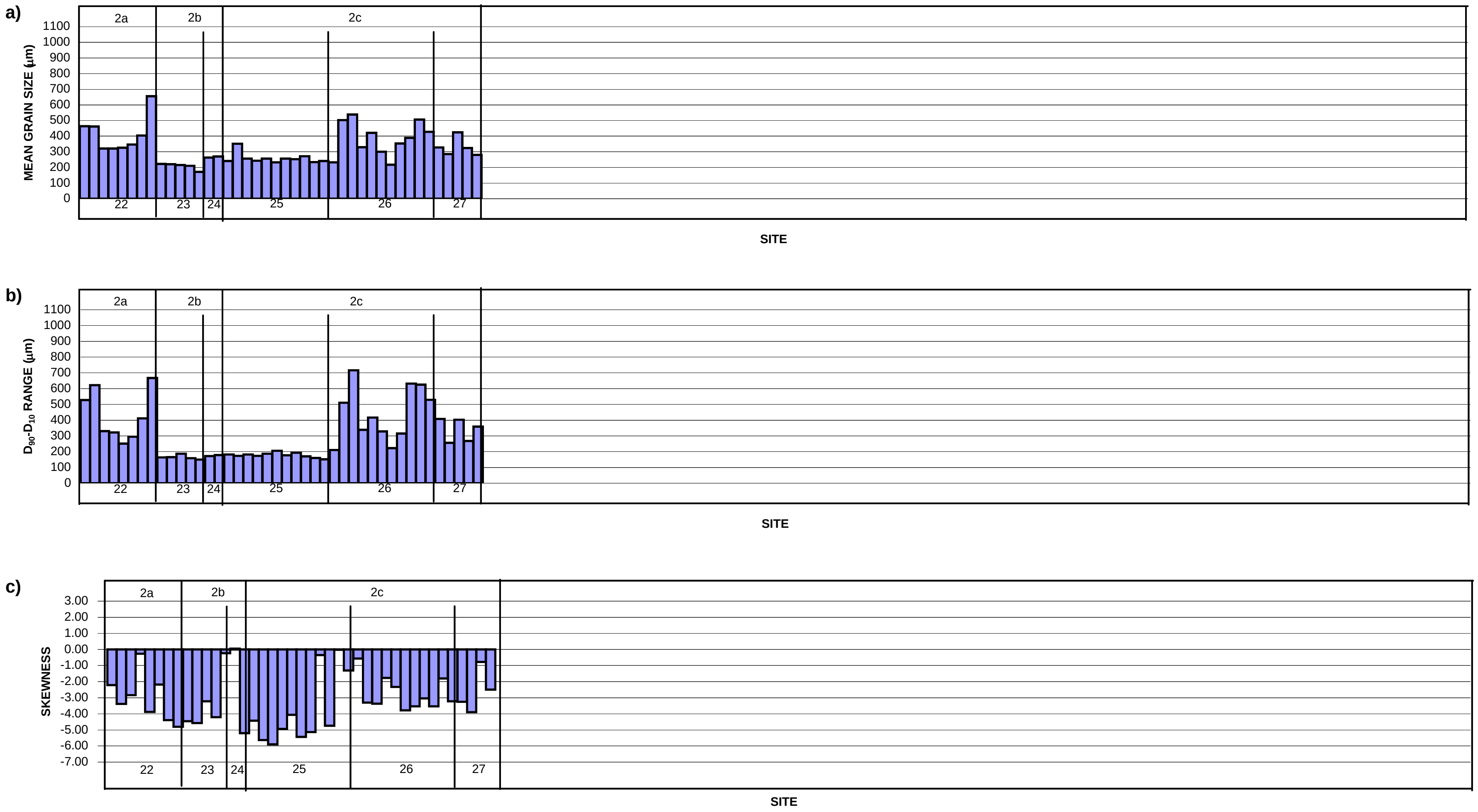


Figure 3.121 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal dunes in Cell 2. Site numbers are below and sub-cells above.

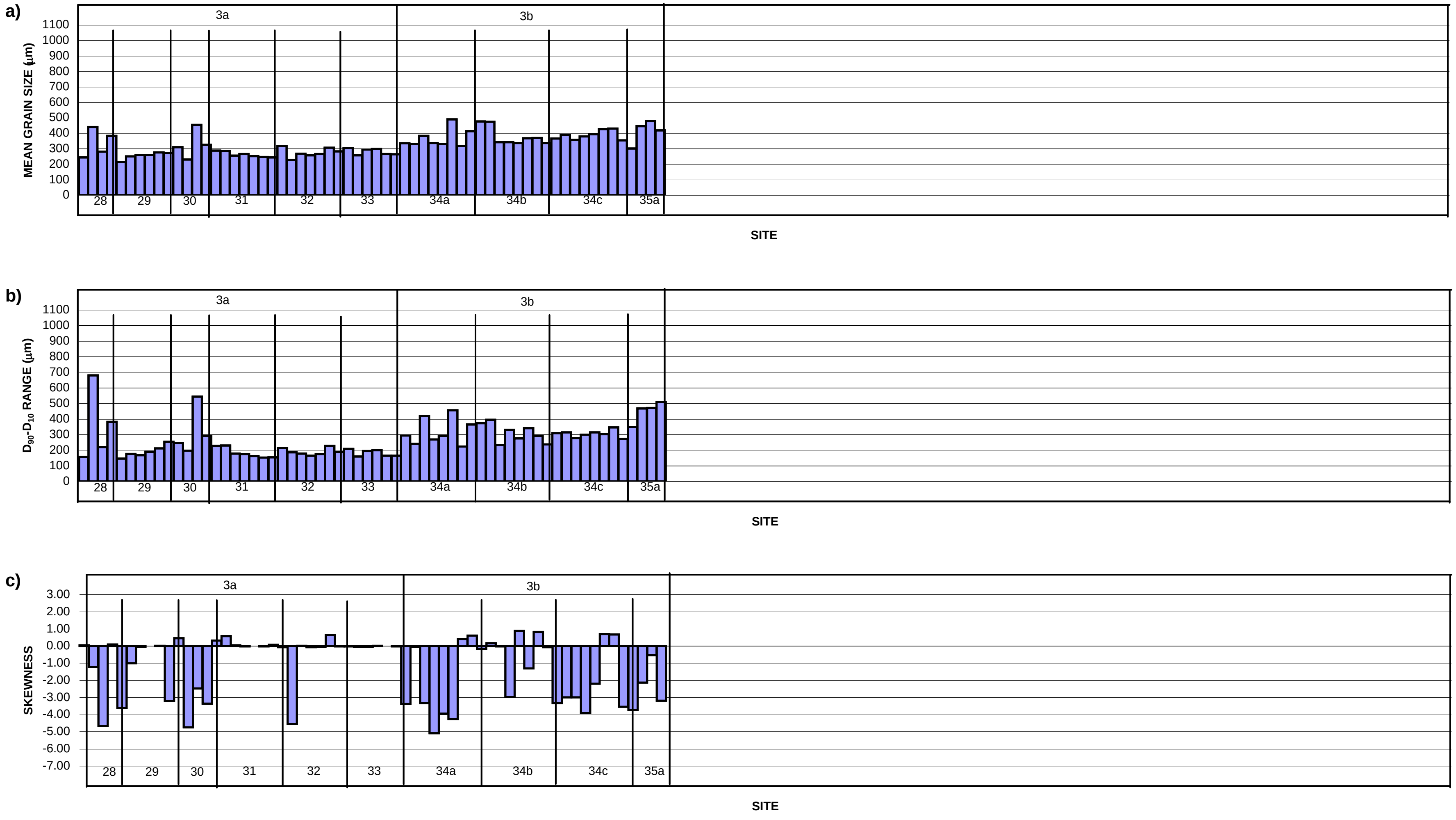


Figure 3.122 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the sand dunes in Cell 3. Site numbers are below and sub-cells above.

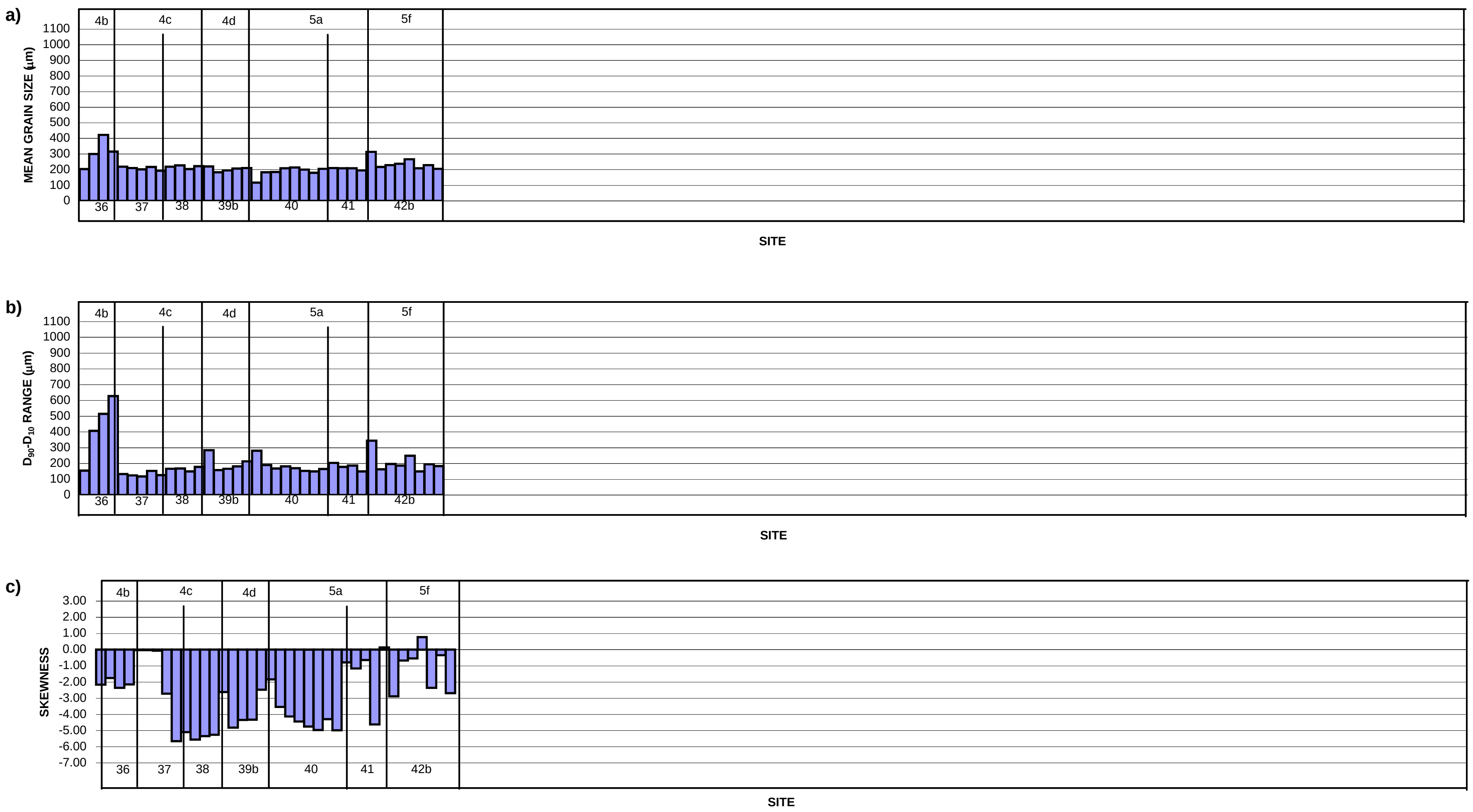


Figure 3.123 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal dunes in Cells 4 and 5. Site numbers are below and sub-cells above.

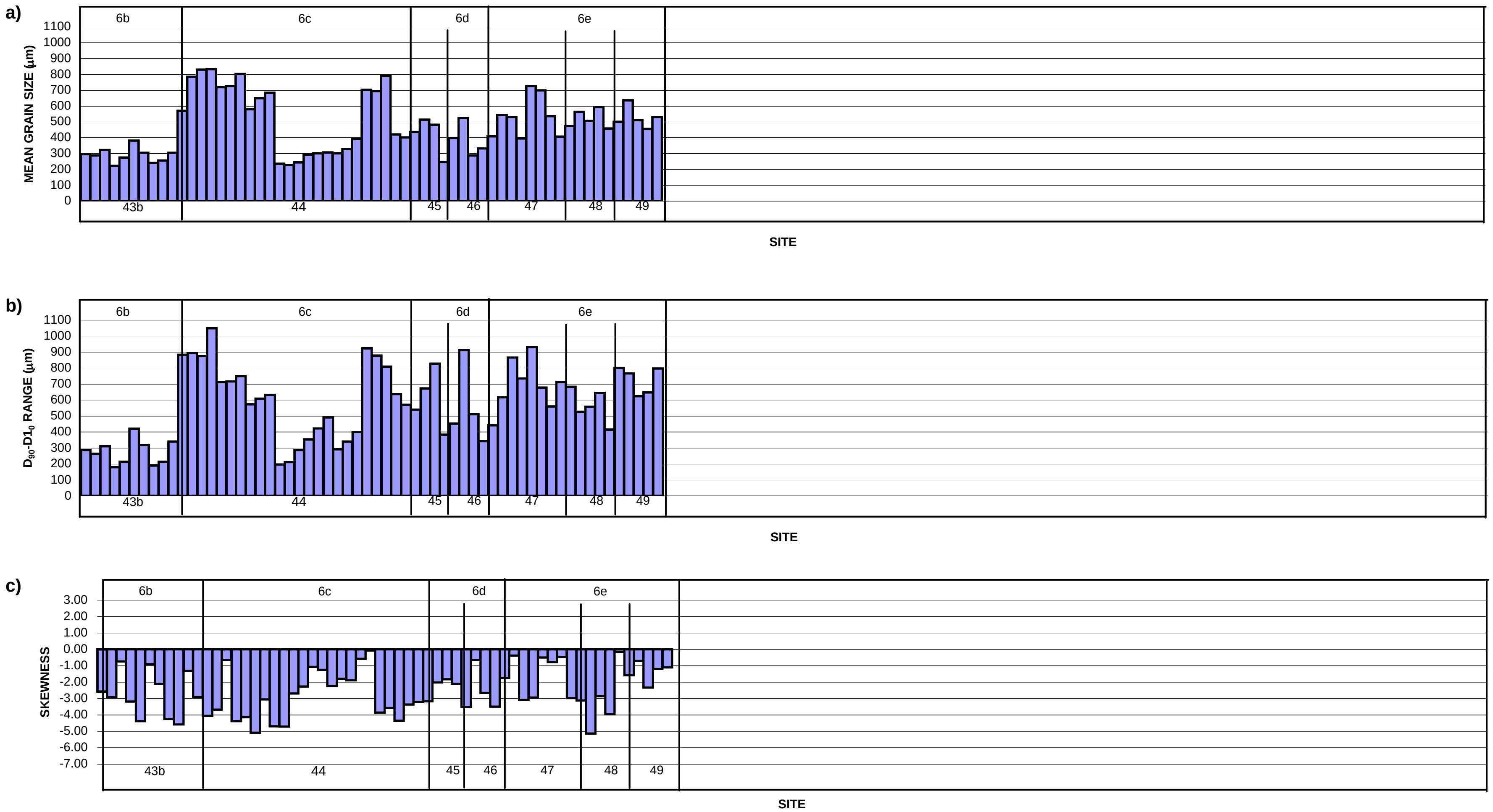


Figure 3.124 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal dunes in Cell 6. Site numbers are below and sub-cells above.

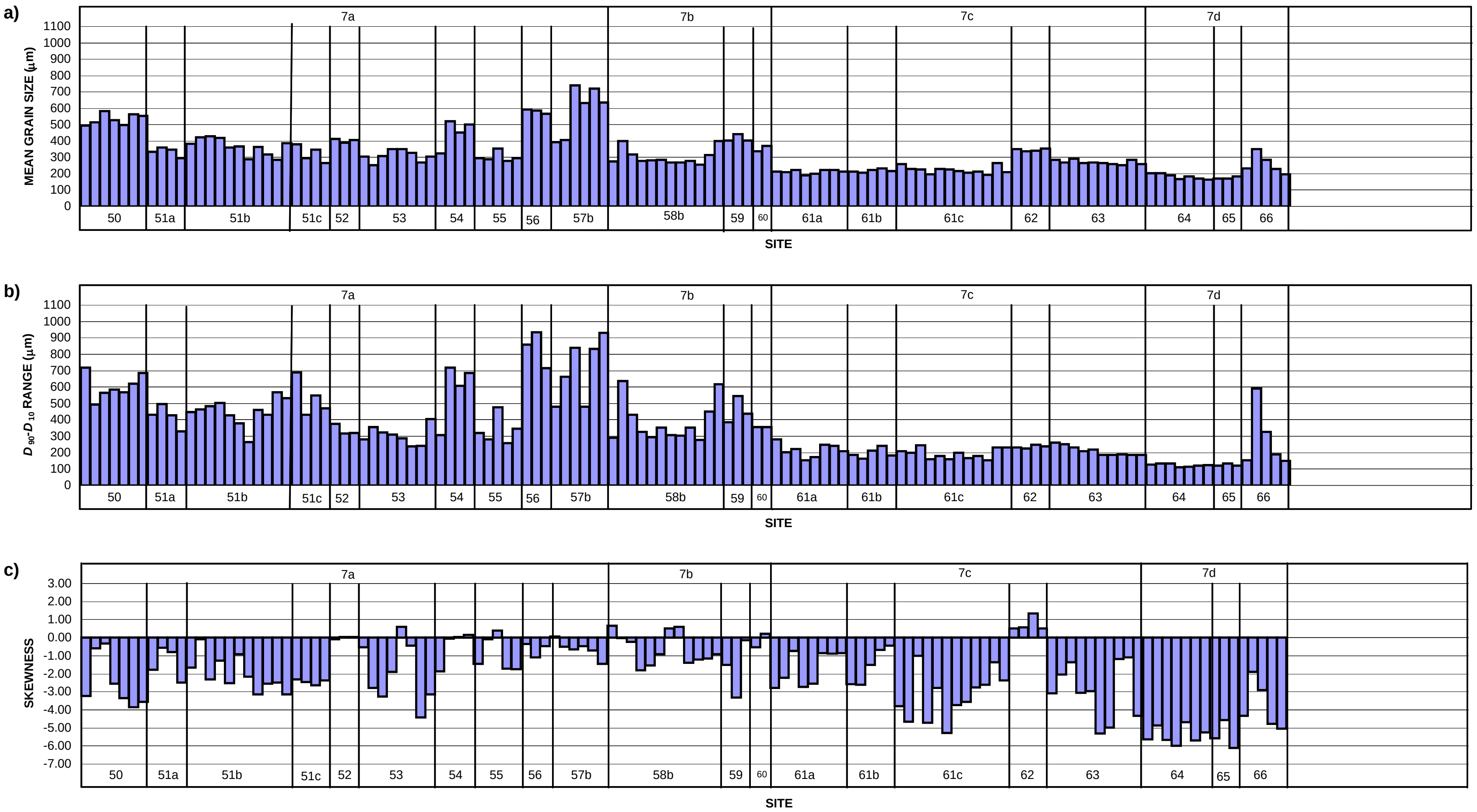


Figure 3.125 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal dunes in Cell 7. Site numbers are below and sub-cells above.

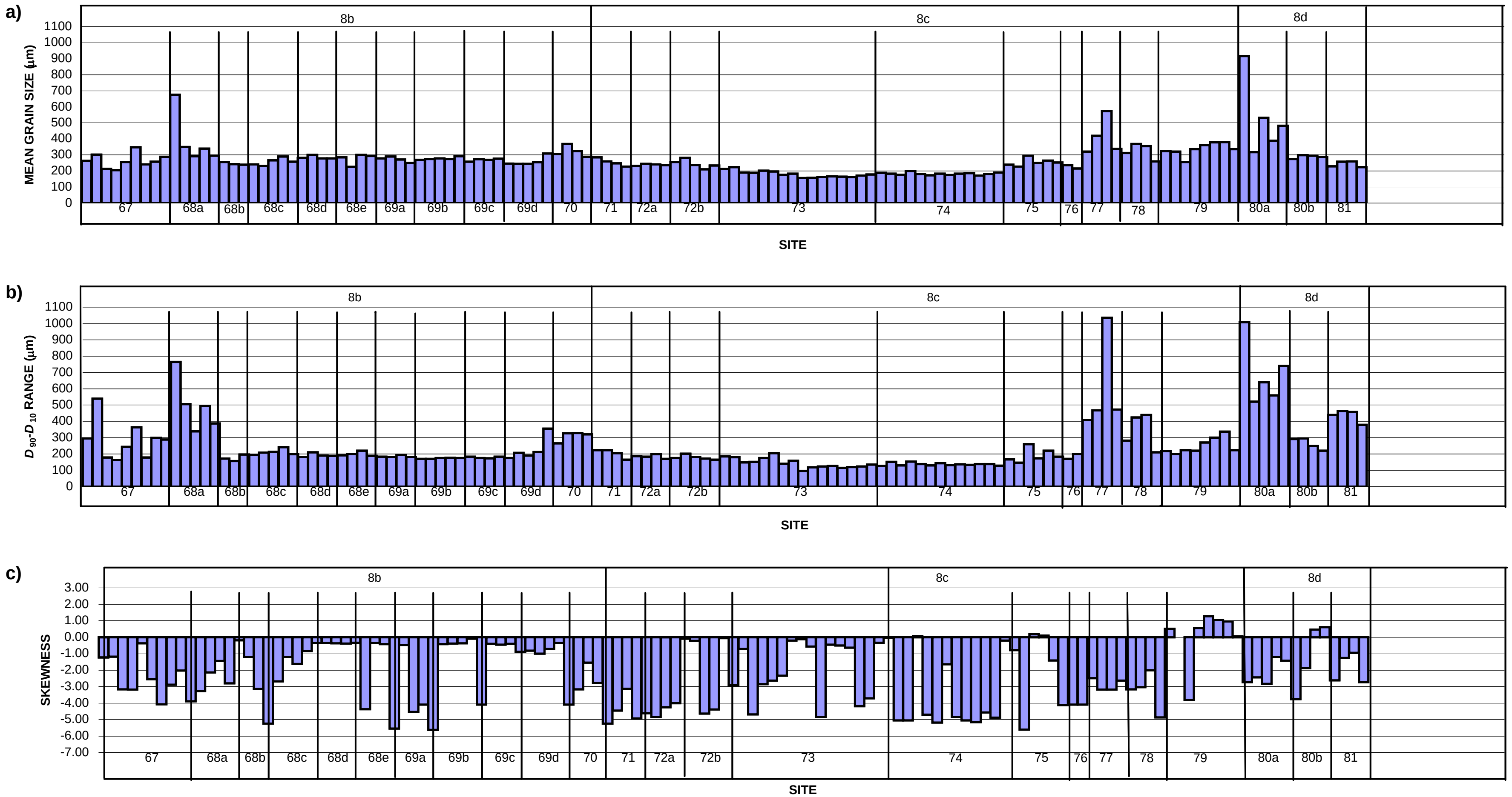


Figure 3.126 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal dunes in Cell 8. Site numbers are below and sub-cells above.

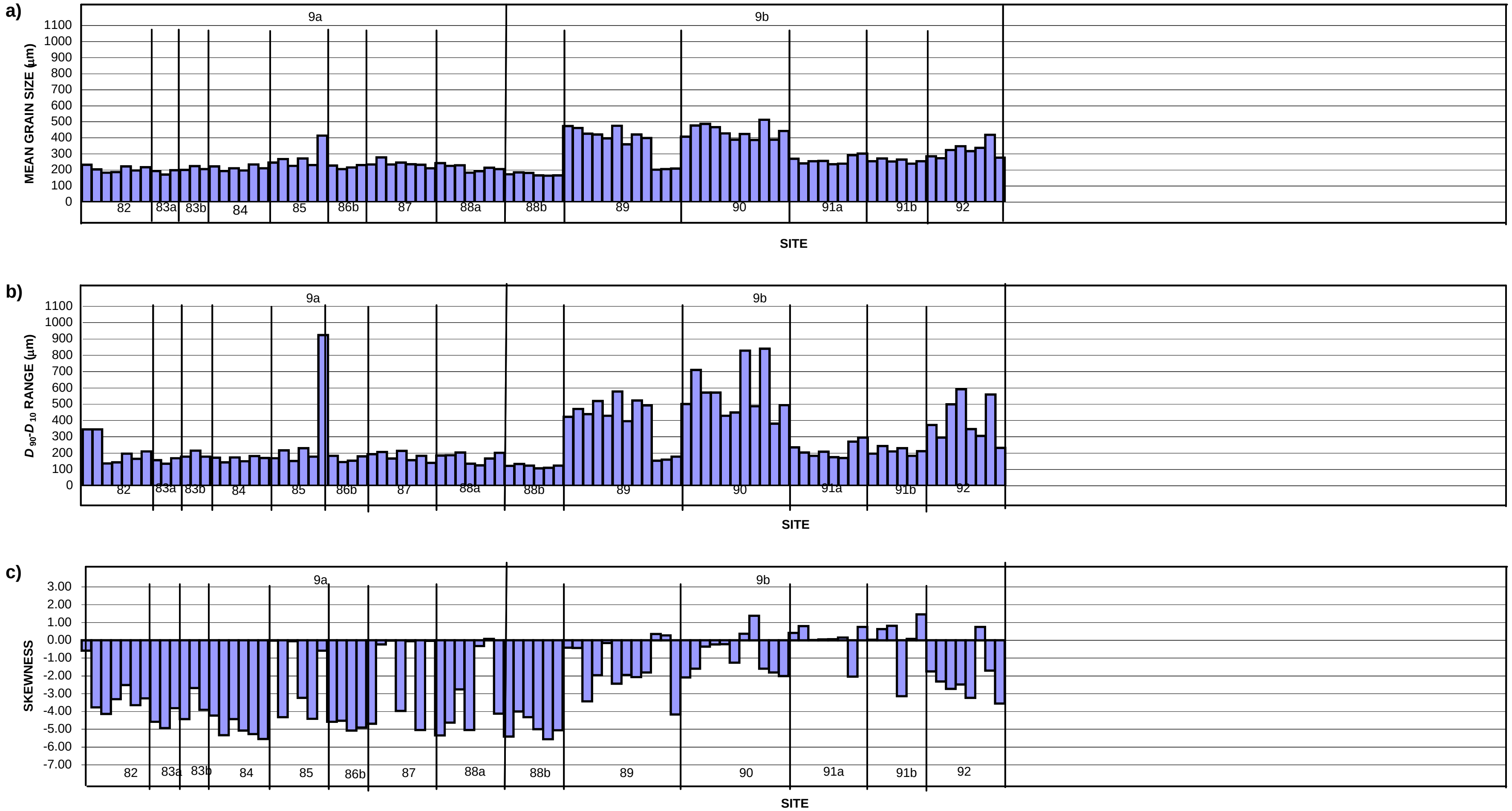


Figure 3.127 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal dunes in Cell 9. Site numbers are below and sub-cells above.

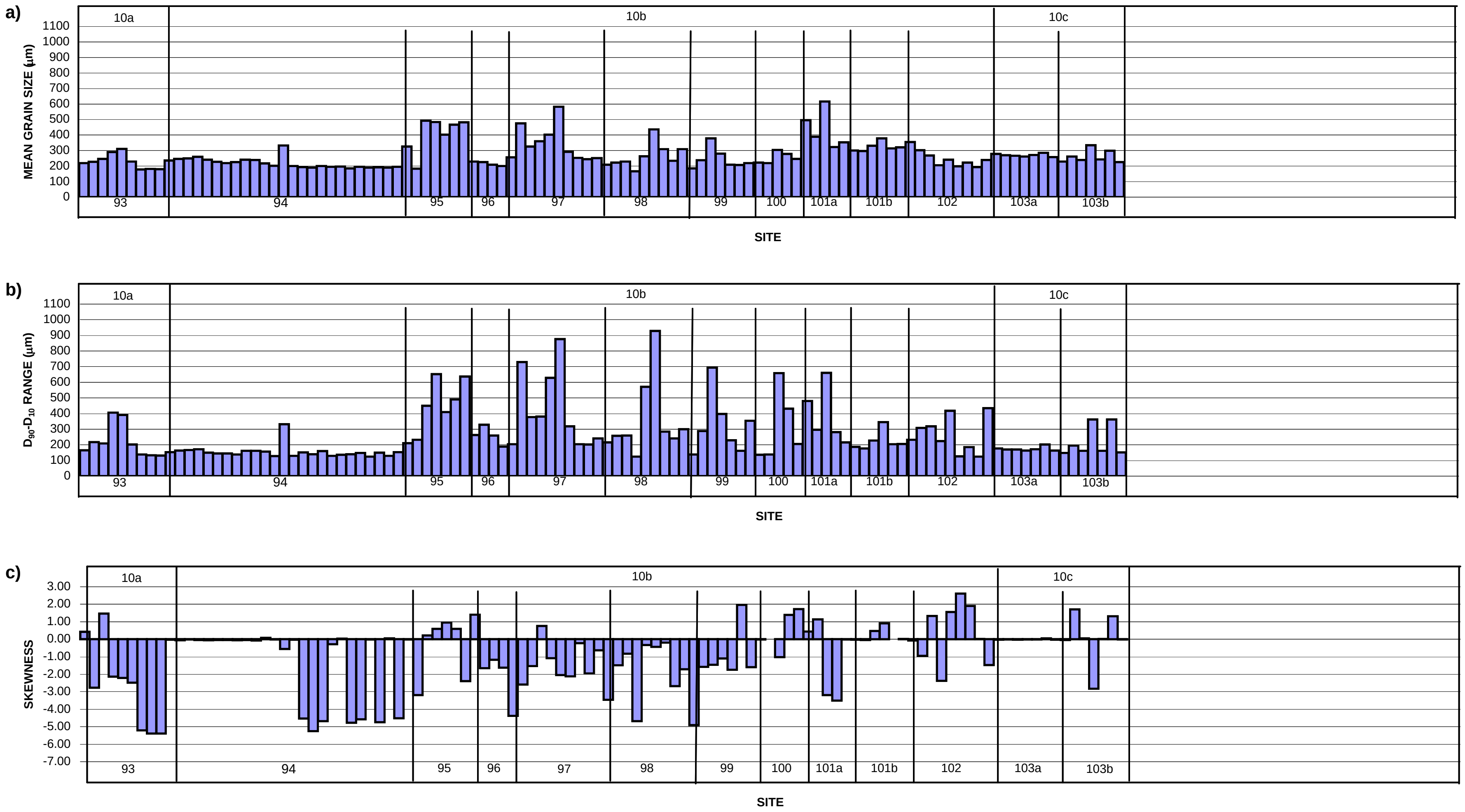


Figure 3.128 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal dunes in Cell 10. Site numbers are below and sub-cells above.

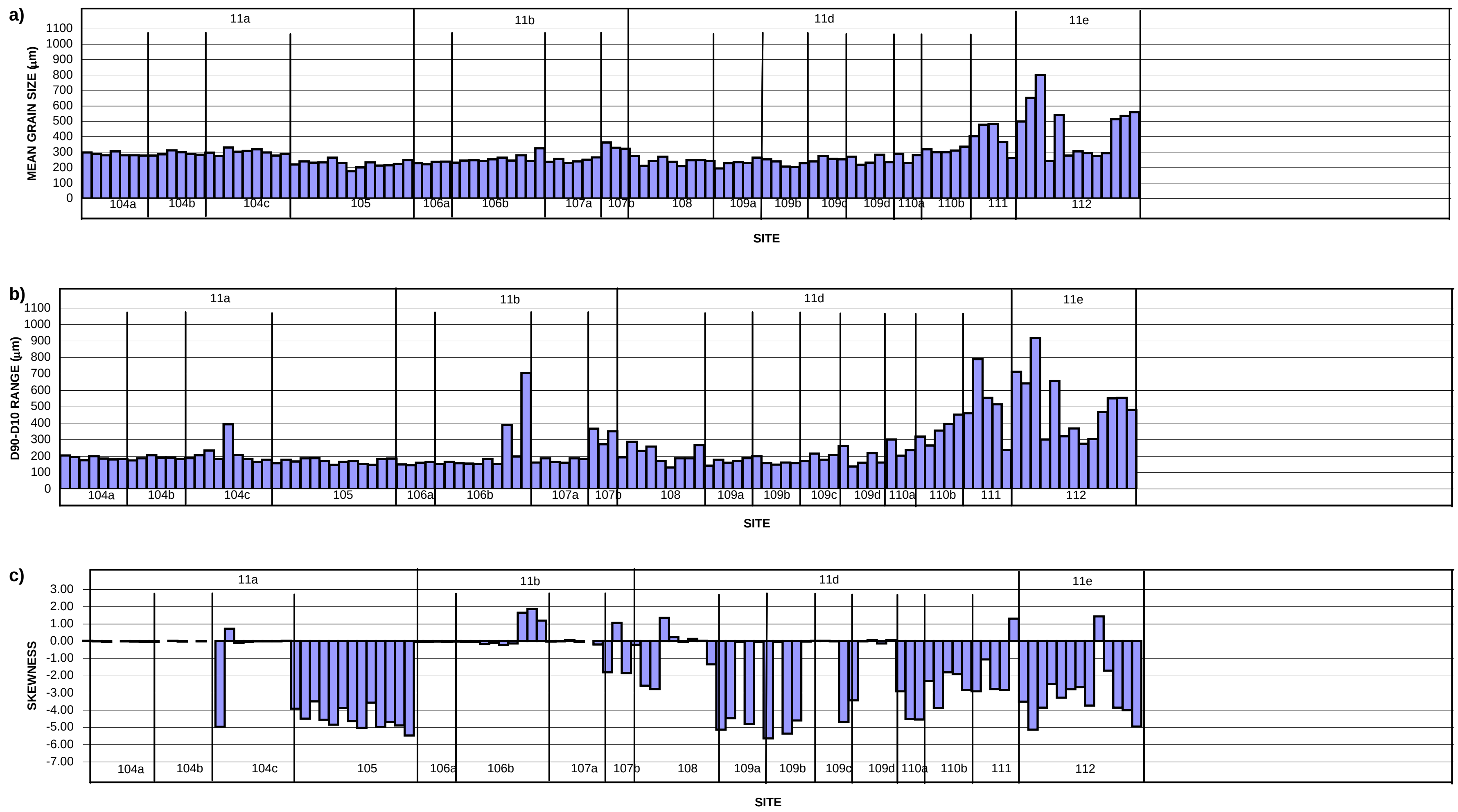


Figure 3.129 Longshore variation in: a) mean grain size; b) D_{90}-D_{10} range; and c) skewness of the frontal dunes in Cell 11. Site numbers are below and sub-cells above.

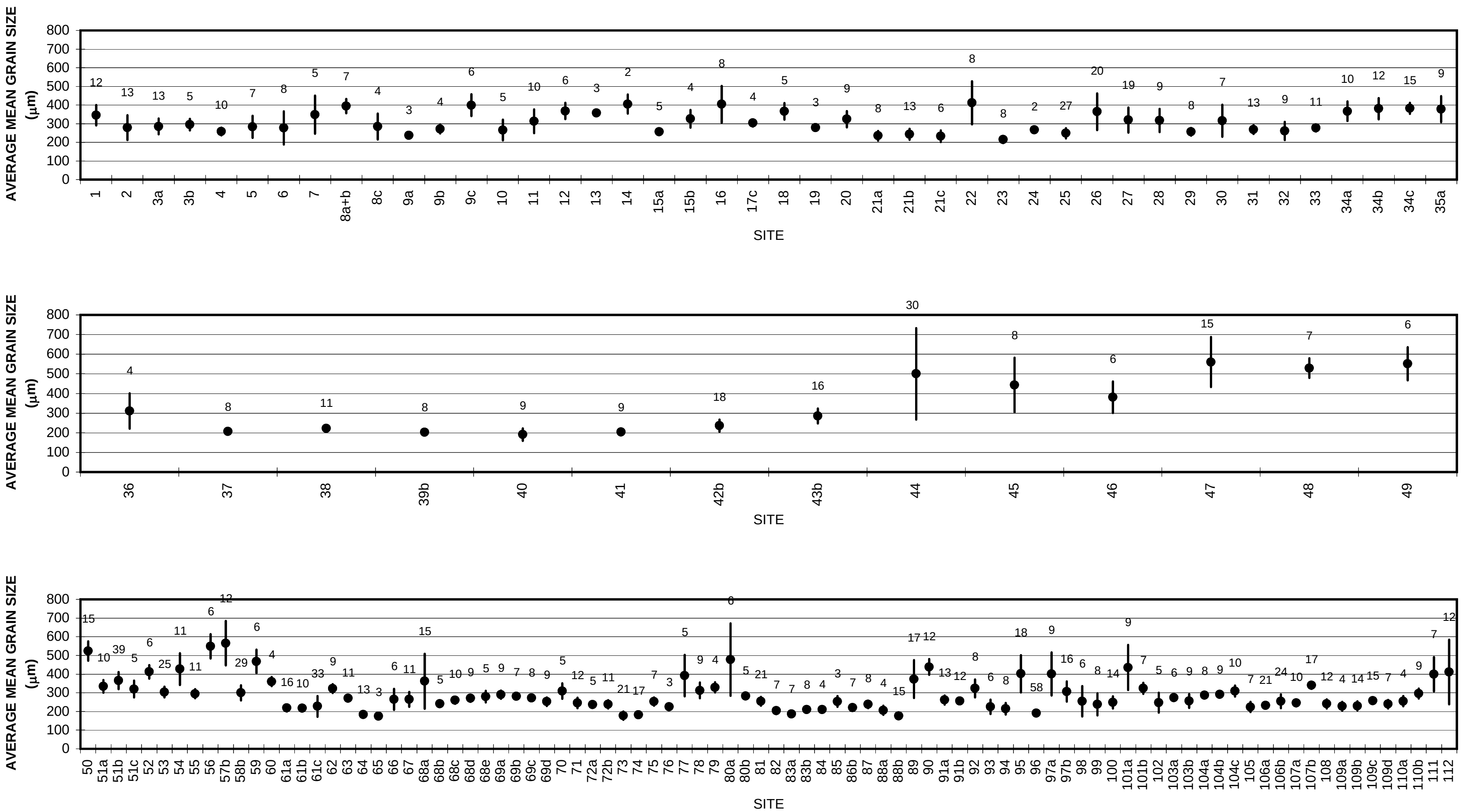


Figure 3.130 Average mean grain size and standard deviation (sorting) for dune systems on: a) the east coast of England; b) the south coast of England; and c) Wales and the west coast of England. The number of samples analysed at each site is shown above the points on each diagram.

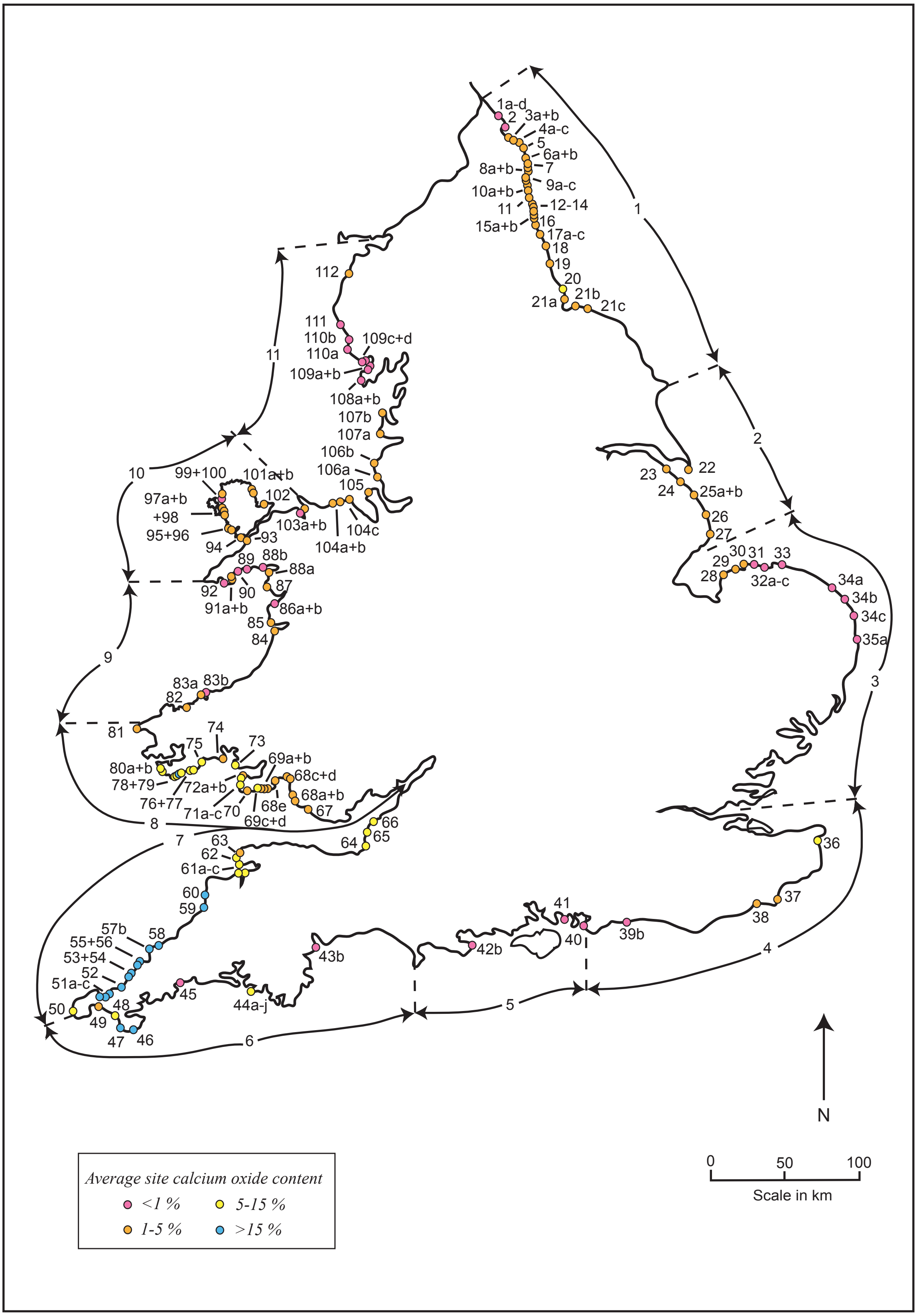


Figure 3.131 Average calcium oxide (CaO) content in samples from each of the dune systems, determined by ICP analysis. CaO provides an indication of the calcium carbonate ($CaCO_3$) content. The calcite form of calcium carbonate contains approximately 56% CaO and 44% CO_2.

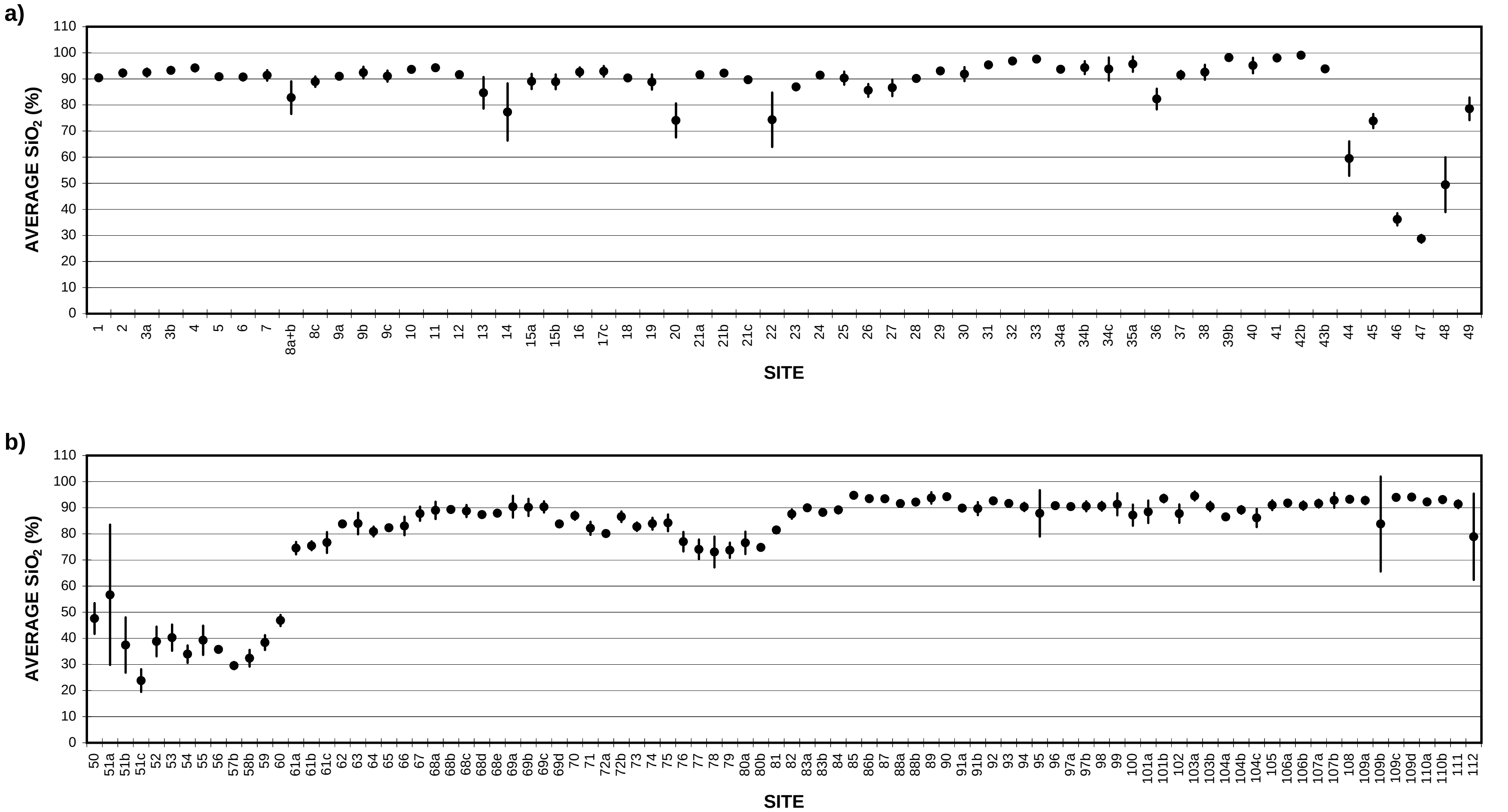


Figure 3.132 Average silica content (plus/minus one standard deviation) for dune systems on: a) the east and south coasts of England; and b) the west coast of England and Wales.

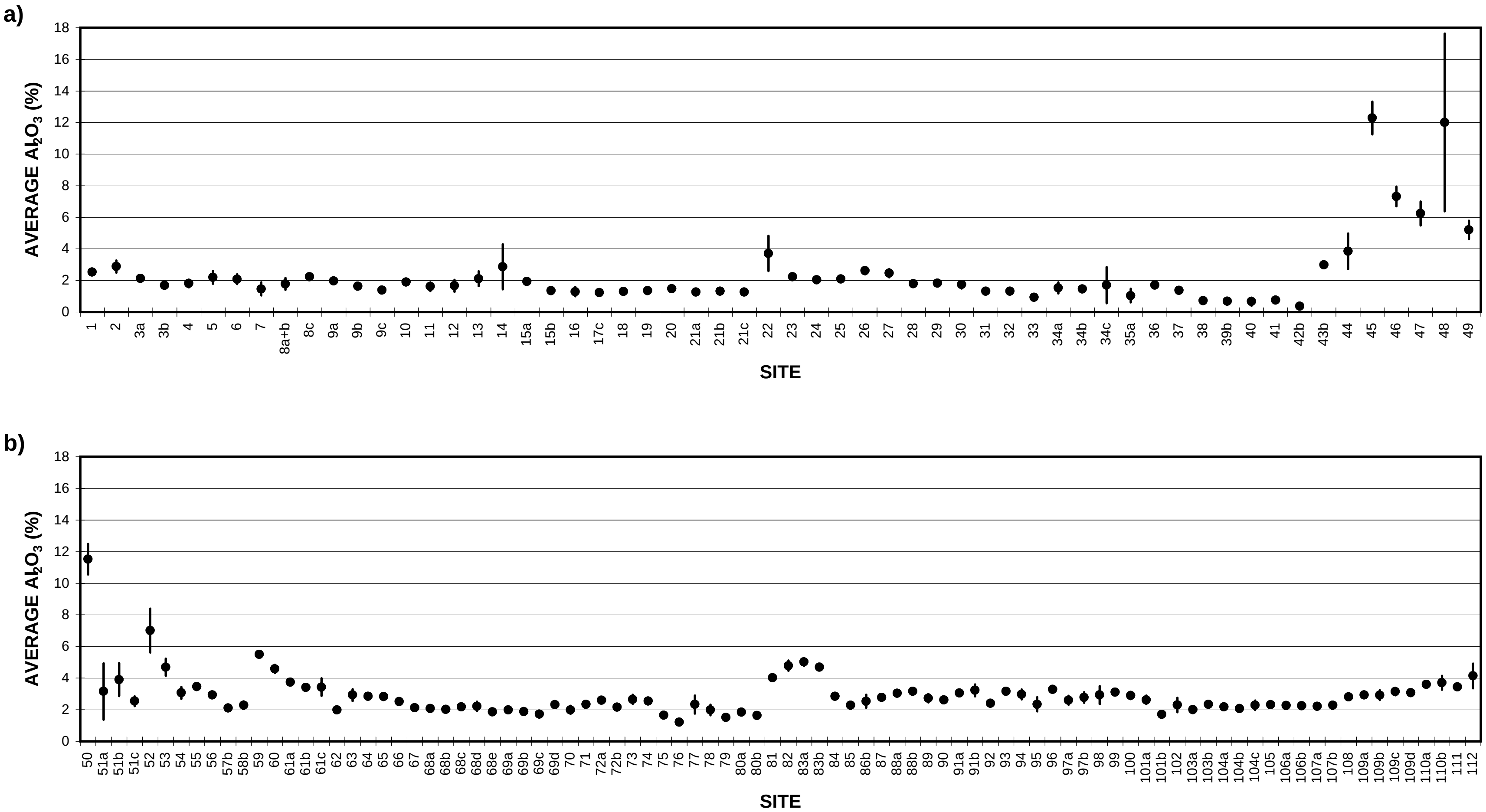


Figure 3.133 Average aluminium oxide content (plus/minus one standard deviation) for dune systems on: a) the east and south coasts of England; and b) the west coast of England and Wales.

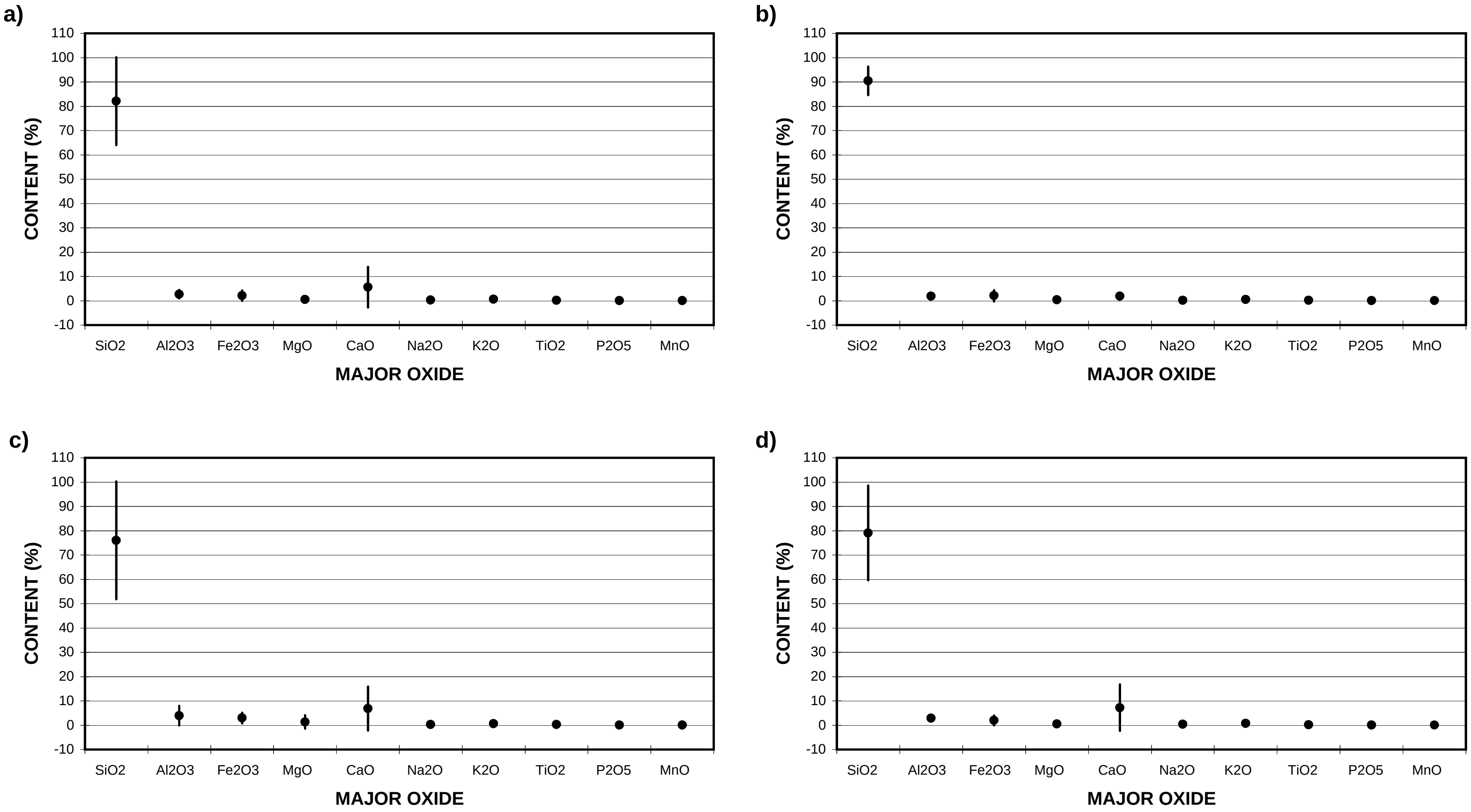


Figure 3.134 Average content of major oxides (plus/minus one standard deviation) for dune systems in: a) England and Wales as a whole; b) the east coast of England; c) the south coast of England; and d) the west coast of England and Wales.

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