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A MACRO REVIEW OF THE COASTLINE OF ENGLAND AND WALES

4: The Thames to Selsey Bill

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ABSTRACT

This report is a review of the coastline of south-east England from the Thames to Selsey Bill. In it are described the various natural and man-made processes which affect the behaviour of this particular stretch of Britain's shoreline. The report includes a description of the major coastal defences, areas of erosion and accretion and various other aspects of beach behaviour. Information is given about winds, waves and tidal currents. Various stretches of coastline which for coastal engineering purposes can be treated as independent or semi-dependent cells are also identified.

This report is the fourth of a series covering the coastline of England and Wales which Hydraulics Research are carrying out for the Ministry of Agriculture, Fisheries and Food.

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1 INTRODUCTION

In 1985 the Ministry of Agriculture, Fisheries and Food commissioned Hydraulics Research, Wallingford to carry out a review of the beaches and coastal defences of England and Wales. The principal aim of this review is to provide information relevant to coastal engineering, the emphasis being placed on identifying the most important processes shaping and dominating each stretch of coast. Inevitably because of the scale of this project the coastline has had to be divided up into regions. The present report is Volume 4 in the series and covers the coastline of south-east England from the River Thames to Selsey Bill.

One of the fundamental objectives of this review has been to identify areas which can be considered as individual coastal units or cells. These cells are judged to be "self contained" when they are dependent on the general coastal processes within that cell regardless of ownership or responsibility. Any beach changes taking place within such a cell are normally independent of change within adjacent cells. Identification of such cells should therefore help planners to determine what length of coastline should be studied or considered, when constructing coastal defence works in any particular area. It is hoped that this type of over view will enhance the understanding of the coastal system and lead ultimately to a more unified and sympathetic approach to the planning and design of coastal defences.

The major points derived from this study are summarised in Chapter 2 and draw together the more important features which characterise this particular stretch of the UK coastline. Subsequent chapters begin with a description of the evolution of the coast (Chapter 3). Chapter 4 contains information on winds, waves and tidal phenomena, while in Chapter 5 coastal processes and a summary of coastal defences are described, including details on the source of sediment supply and areas which are in the process of either accretion or erosion.

2 EXECUTIVE SUMMARY

The coastline from the Thames to Selsey Bill varies greatly in character, from high chalk cliffs to alluvial plains and low lying marshland. As the coastline varies so do the uses to which the coastal strip is put. Coastal facilities range from normal seaside amenities through to fishing harbours, marinas and ports.

There are few absolute boundaries or independent coastal cells with respect to the littoral movement of beach material but more often a series of units of a semi-dependent nature can be found.

First, the south bank of the Thames Estuary from the Isle of Grain to the Isle of Thanet. Here the generally low lying, soft, easily erodible coastline is separated by two large river estuaries. Thus the Isle of Grain can be classed as one unit, the Isle of Sheppey a second and the mainland to the east as far as the Isle of Thanet, the third.

The foreshore along each of these coastlines is largely of mud and sand with the upper beaches (with the exception of the saltings) of sand and or shingle and mud. The nett littoral drift is westwards into the Thames although this is largely interrupted to the Isle of Grain by the outflow of the River Medway and to the Isle of Sheppey by the River Swale.

On the mainland the coastal strip between the River Swale and Thanet in the east, alternates between low lying land and clay or clay and sandstone cliffs up to

30m high. The muddy foreshore changes also to mud and shingle and then to shingle to the east. The increasing quantities of shingle reflect the increased wave exposure in an eastward direction. The beaches themselves are now becoming starved of shingle, primarily as a result of the reduced supply which was once derived from eroding cliffs. Shingle is added by local authorities on a fairly regular basis to redress this imbalance.

The Isle of Thanet can be classed as one unit. From Birchington through Margate and Broadstairs to Ramsgate, chalk cliffs predominate. The foreshore consists of a wave cut chalk platform overlain by deposits of sand. As mentioned above the nett littoral drift on the north facing coast is westwards into the Thames from the North Foreland. There are some localised reversals near Birchington where indentations in the rocky coastline (revealing small sandy coves surrounded by steep chalk cliffs) are evidence of small independent cells. With the strong indentation the drift is low along the whole of this coastline.

On the east-facing coast, south of the Foreland, nett drift is generally southwards and at Cliffsend, south of Ramsgate, the high chalk cliffs give way to low grass covered sandstone slopes. These in turn give way to low lying land at the head of Pegwell Bay. Situated at the mouth of the River Stour, this bay forms a sink for the low, southward moving littoral transport from Thanet and the higher northerly drift into the Bay from Kingsdown. The beaches along the cliffed stretches are sandy, but there are also extensive deposits of mud in Pegwell Bay.

The next area that can be classed as a coastal unit is from Kingsdown to Dover. This is a "hard" coast in that it is mostly cliffed, with little in the way of active coastal processes apart from a small amount of flinty gravel being slowly won from the eroding chalk cliffs. The foreshore is boulder strewn, with isolated pockets of shingle in embayments, such as St. Margarets Bay.

The next cell is the coastline between Dover and Folkestone. Both of these harbours act as barriers to the movement of the shingle on the upper beach, and generally there has been a redistribution of this material from the western to the eastern half of this frontage following the construction of the harbour works at either end. The rate of littoral drift of shingle is now very low, about 3000m^3/year in a nett west to east direction. A thin veneer of sand can be found on the lower foreshore, though this is discontinuous. Wave action at low stages of the tide is reduced by the presence of numerous rock outcrops, reefs etc hence the nett (west to east) littoral transport of sand is also small.

The coastal area between Folkestone and Eastbourne to the south-west, once had a continuous shingle storm beach. This shingle beach is now fragmented as the result of the construction of coastal defences at various times during the last century. Construction of seawalls and groynes at Sandgate, for example, has probably been the cause of declining shingle levels to the eastward. (The rate of shingle build up at Folkestone is now quite low as mentioned above.) The littoral movement has been interrupted not only by the construction of groyne systems over the frontage as a whole but also by the harbour arms at Rye and Hastings. There are also natural features which strongly modify the transport of beach material, e.g. the forelands at Dungeness and at Langney Point. From the past history of the construction of coastal defences, and the subsequent erosion problems over long stretches of coast downdrift (to the east) of such defences, it is clear that coast protection works, particularly large groyne systems, have a "knock-on" effect.

Ideally the whole of the coastal strip between Folkestone and Eastbourne should be treated as one unit for planning purposes. Within this unit several cells can however be identified which have only a weak dependence on each other. The coast from Folkestone to Dungeness, though heavily groyned, can be subjected to major redistribution of shingle during storms. Though the general trend is a nett west to east shingle movement this can sometimes be reversed, especially near Dungeness and to the east where the beaches are partly protected from the predominant south-westerly waves. The Dungeness foreland forms a major change in coastline alignment and beach changes east of it have a minor effect on the coast to the west. Coast protection works west of Dungeness may slow down the rate at which material reaches Dungeness. However since the headland has such a large reservoir of shingle, such works will only have a marginal effect east of Dungeness. It is therefore reasonable to consider the coast from Folkestone to Dungeness as an almost independent cell.

From Dungeness to Fairlight (just east of Hastings) beach movement is only seriously interrupted by the harbour arms at the entrance to Rye. Siltation at the end of these harbour arms indicates that littoral transport continues to take place across the entrance channel. West of Fairlight the foreshore is almost bare, part of the littoral drift being arrested by the western arm of Hastings harbour. Hence the stretch from Dungeness to Fairlight can be considered as another cell. Finally from Hastings to Eastbourne there are no major barriers to block movement and this whole stretch should be considered as one cell.

From Eastbourne to Brighton Marina, near vertical chalk cliffs are the dominant coastal features. To the west of Eastbourne, between Beachy Head and Seaford Head the cliffs are unprotected and their erosion produces pebbles of flint. The shingle beach at Cuckmere Haven is relatively stable. Cliff erosion adds to the littoral supply for the beaches at Eastbourne and to the eastward. The Seaford frontage also once received large quantities of pebbles derived from erosion of the cliffs west of Newhaven. These cliffs are now mostly protected by seawalls and therefore produce little fresh beach material. Beach accretion, due to the west to east littoral drift has built up on the west side of the Newhaven west breakwater. This has stabilised and the end of the breakwater is now in relatively shallow water. It is not known to what extent or in exactly what quantity material now bypasses the breakwater to reach Seaford. The Seaford frontage has been losing shingle for many years though this situation is now being rectified by a massive beach nourishment scheme. From Newhaven to Brighton Marina the cliffs are mostly protected by seawalls and the foreshore in this area is a chalk platform with sparse deposits of shingle. The Marina projects seawards into deep water and hence does not allow beach material to bypass it in any significant quantities. Beach changes at Cuckmere and Seaford are largely independent of any coast protection schemes carried out to the west of the Marina. The coastline from the Marina eastwards to Eastbourne can thus be considered as a cell, albeit a rather fragmented one.

From Brighton Marina to Selsey Bill the coastline is heavily developed and the construction of coast protection works in one area very obviously affects adjacent stretches of coast. This is demonstrated only too clearly by the very wide shingle beach which has developed west of Shoreham harbour and the serious erosion which is now taking place east of the harbour. Given that the amount of material bypassing the harbour is very small, the stretch from Shoreham east to Brighton Marina can be considered a sub-cell or unit. From Shoreham westwards to Littlehampton Harbour, the single beaches are continuous though very variable in size, depending on the effectiveness of groyne systems in any particular area. The foreshore at low water extends almost to the seaward end of the west harbour-arm at Littlehampton and there is clear evidence that the channel becomes infilled with sand and shingle which is then moved eastwards by wave action. At Pagham harbour there are extensive banks of shingle seawards of the entrance and this too does not act as an effective barrier to littoral drift. The coastline from Shoreham to Selsey Bill therefore needs to be considered as one unit. A coast protection policy for this area clearly requires the co-operation of a large number of local authorities.

3 COASTAL GEOLOGY & TOPOGRAPHY

3.1 Geological background

Geological structure and lithological variability have both exerted strong influences on the morphology and the evolution of the coastline of south-east England which is of relatively recent origin on a geological time scale. The English Channel was formed after the end of the Pleistocene Ice Age (1.8 million to 10,000 years ago, see Fig 1) as the sea level rose with the melting of the ice sheets. Since this period, the coastline has undergone rapid change to its present configuration.

All the rock formations exposed at the coast are sedimentary in origin, see Fig 2. They were laid down during and after the Cretaceous period (beginning 135 million years ago) and represent a wide range of differing rock types. Sandstones were covered by various clays and then thick layers of chalk. Further layers of sands and gravels and London Clay were deposited during the Eocene period (35-55 million years ago). Following this period, but preceding the Ice Age, this region experienced folding associated with the formation of the Alps. The rocks of Kent and Sussex form an anticline, or upfold (with the Weald at its apex) aligned approximately along an east-west axis and pitching gently to the west. The Thames Estuary occupies a syncline, or downfold, to the north. As the landscape was eroded so the old sandstones of the Hastings Beds were exposed as a central core surrounded by the Weald clays and greensands with the chalk forming the uplands of the North and South Downs and extending westwards over the Hampshire plain. Along the north coast of Kent and in southern Sussex and Hampshire, the chalk is overlain by younger Tertiary deposits of sands and gravels and London Clay. The English Channel forms an oblique north-east to south-west transect across this sequence and differential erosion of alternating resistant and less resistant strata has led to the development of an irregular coastline of headlands and shallow bays. To some extent this outline has been modified by the effects of geologically recent accretion in areas such as at Langney Point and Dungeness.

Although no part of this coastline was directly affected by the massive ice sheets that covered Britain north of the Thames, changes that took place over this region during and after the Ice Age have played a major role in the development of the present coastline. Under the severe periglacial (arctic) climate prevailing over southern Britain during the glacial phases, the surface rocks were weathered and shattered by the action of frost. Downslope movement of this material was induced by alternate freezing and thawing. These 'solifluction' deposits formed a surface layer of unconsolidated material which in places was mixed with glacial outwash gravels redistributed by meltwater streams. Together these deposits are collectively known as 'head' and typically consist of a mixture of coarse rock fragments embedded in a sandy-clay matrix. An example found on the south coast is the Coombe rock, formed by the weathering of chalk. Brickearth is a mixture of head and fine silts which have been deposited by wind action (loess) and mixed into the head. Where head deposits overlie the bedrock at the coastline, such as in West Sussex, north-west Kent and the Isle of Sheppey, they have been subject to fairly rapid erosion by wave action and mass movement and have provided the dominant source of beach sediment.

During the cold glacial phases of the Ice Age the glacio-eustatically induced lowering of sea level (to about -100m relative to present day levels) caused the periodic exposure of extensive parts of the sea floor. At the time Britain was joined to continental Europe and the coastline was further to the west, probably in a position off Cornwall and Brittany. The Channel was occupied by a large river system draining westwards combining the Seine and the Solent and may have included the outflow of the Thames and the Rhine at times when ice blocked the North Sea basin.

The retreat and melting of the ice sheets resulted in a eustatic rise in sea level. The sea slowly advanced up the Channel and eventually through the Straits of Dover, finally causing separation of the British Isles from the continent about 8,600 years ago. As sea level rose, so the deeply incised river valleys and low lying land were submerged. The drowned river valleys of the Adur, Arun, Cuckmere and the Ouze have since become infilled with alluvium. The rock channel of the Solent off Selsey Bill is 46m below sea level giving some indication of the vertical increase in mean sea level over the past 10,000 years. As the sea inundated the River Solent system so the valley of the River Frome draining from the west became flooded. The sea eventually breached the narrow barrier of chalk between Purbeck and the Needles to form the Isle of Wight, which is now separated from the mainland by the Solent and Spithead. In a similar way the Isle of Thanet became isolated from mainland Kent as a shallow syncline in the chalk of the North Downs was inundated by the sea, thereby forming the ancient Wantsum Channel running between Sandwich Bay and the Thames estuary. However, by the 17th Century, Thanet had been rejoined to the mainland by gradual sedimentation within the channel, aided by the reclamation of the marshland by man.

The post glacial rise in sea level was accompanied by rapid coastal recession. However, the erosion of the cliffs has provided a limited source of permanent beach material, mostly from the weakly consolidated superficial deposits (head) and the Tertiary sand and gravel beds and including flint pebbles eroded from the chalk. Chalk debris is quickly abraded while the finer clays fractions are removed in suspension by tidal currents. The major source of present beach forming shingle is from the reworking of past glacial and periglacial deposits. As a result of the melting of the ice sheets, large volumes of fluvial, fluvio-glacial and periglacial debris were removed by the rivers and washed into what is now the English Channel. As sea level rose, so these deposits were sorted and reduced by the action of waves within the littoral zone as the nearshore zone advanced. Little is known about the mechanisms involved in this process but is believed to be largely complete under present rates of sea level rise and there is now little transfer of beach material from the sea bed to the coastline. Current rates of supply to the beach system therefore depend on rates of erosion at the coastline and rates of littoral drift.

3.2 Coastal processes

Erosion predominates along the coastline from the River Thames to Selsey Bill, as both cliff retreat and beach lowering. The rate of cliff top retreat varies greatly depending on the local geology and the intensity and direction of wave attack. The most rapidly eroding cliffs are those vulnerable to landslips and mass movement in soft Tertiary clays along the North Kent coast. Accretion is localised and mostly takes the form of spit growth, e.g. the Dungeness foreland and in Sandwich Bay, or the accumulation updrift of breakwaters and harbour works, e.g. west of Newhaven, Littlehampton and Folkestone.

The present day beaches, in common with other shingle beaches around the British Isles, are losing material as contemporary sources of beach sediment have become limited. Shingle banks in deeper water are unlikely to supply beach material under present day processes (HRL Ref 22). However, there is some evidence that shingle is brought ashore by wave action from shallow water as at Pagham and Cuckmere Haven. Shingle beaches are also being affected in the long term by the continuing slow post glacial rise in sea level. Along the south coast, the effect of such a rise is compounded by the subsidence of the land relative to mean sea level due to the continued down warping of the North Sea basin since Tertiary times. This gives an overall rise in sea level of approximately 2mm/year generally (Valentin, Ref 48). More recent measurements suggest that this figure is as high as 4mm/year at Dover.

Large tracts of the natural coastal system and the pattern and rate of sediment movement along the South-east Coast have been altered by the construction of engineering works, such that it is now difficult to distinguish between natural and modified rates of erosion and accretion. On a local scale, adjacent stretches of coast are highly dependent on the supply of littoral material from immediately updrift. Coastal protection measures can be shown to initiate and promote downdrift erosion. Cliff protection aimed at reducing erosion has halted the input of coarse sediment to beaches leading to loss of beach volume and foreshore lowering. Groynes and breakwaters designed to retain beach material have interrupted the movement and distribution of sediment alongshore, so inducing downdrift erosion. The net result is an imbalance with beaches generally losing material at a much faster rate than they are receiving it by natural means.

The most important agency for the redistribution of beach material is wave induced transport or littoral drift. The net direction of littoral drift in the English Channel east of Selsey Bill is generally eastwards under the action of the predominant south-westerly waves generated within the Channel and longer period swell waves originating in the Atlantic. The rates of drift vary depending on the degree of exposure of the coast to wave attack. Storm waves from the east may temporarily reverse the direction of actual drift. In the shelter of promontories such as Dungeness, the easterly waves may actually predominate, resulting in a local reversal of net littoral drift. Along the north coast of Kent the south-westerly winds are offshore and therefore beach material moves westwards within the littoral zone into the Thames estuary under the action of north-easterly waves.

The coastline of North-West Kent and the southern bank of the River Thames is similar to that of South Essex (HRL, Ref 18). The coastline is indented by the estuaries of the Swale and the Medway and their tributaries, formed by subsidence during the postglacial period. The coast became fragmented into numerous islands, for example, the Isle of Grain, Sheppey, Elmey Isle and the Isle of Harty, which represent the remains of a former spread of London Clay. The intervening sheltered channels have since become infilled by more recent alluvial deposits and most of the marshes were embanked and reclaimed by the end of the Roman Period.

The gradual narrowing of the Thames estuary and the reduction of all fetch lengths excepting those from the eastern sector, leads to a significant reduction in wave activity and a greater degree of tidally induced scour. The net drift of sediment is to the west but decreases in magnitude upstream within the estuary. Large quantities of fine sediment, originally derived from cliff erosion along the North Kent coast, together with river sediments are deposited as wide intertidal mud flats and as offshore shoals. The present day outline of the southern bank of the river has been defined by man-made clay embankments built during the past century and more recently upgraded to protect the low lying land from flooding when water is funnelled up the estuary due to exceptionally high tidal or surge conditions. Flooding is a particular problem on the margins of Whitstable Bay at the entrance to the River Swale. Sea walls and embankments protect the low lying areas of the Seasalter Levels and the Graveney, Cleve and Nagdon Marshes.

On the north coast of the Isle of Sheppey there is severe erosion of the London Clay cliffs for approximately 9km between Minster in the west and Warden in the east. The cliffs are capped in places by 'head' and Bagshot sands in the west (Upper London Tertiary) and vary in height from 8 to 52m. Erosion proceeds by landslides and slips. The cliff falls are rapidly eroded by high tides. The clay fraction is removed into suspension and moved westwards into the Thames estuary by tidal currents and the remaining sands and gravels are insufficient for the build up of beach material to protect the toe of the cliff. Erosion is particularly severe in the area of Warden Point where a more easterly exposure may lead to greater wave attack at the cliff foot and promote a greater frequency of slips. Most of this coastline has remained unprotected and erosion has proceeded over the twenty year period up to 1982 at an average annual rate of 3m on the highest cliffs decreasing to 1m on the lowest (Swale DC, Ref 46). On the north-east of the Isle of Sheppey and extending south-eastwards into the mouth of the River Swale is an accumulation of sand and shell called Shell Ness formed by a local easterly drift of sediment.

The coastline of north Kent from Whitstable to Birchington is one of general recession both of high cliffs and of low lying marshland. Between Whitstable and Reculver the cliffs are cut in London Clay but east of Bishopstone Glen, older Tertiary sands and gravels are exposed at the base of the cliffs beneath the westward dipping clay. The cliffs are topped by spreads of brickearths and fluvio-glacial gravels or 'head'. The weakly consolidated nature of these cliff materials make them unstable and vulnerable to mass movement and to erosion by weathering.

The principal mechanisms for cliff top retreat along the North Kent coast are deep seated landslips and more shallow landslides accompanied by mudslide activity. The development of major rotational slips is dependent on erosion at the foot of the cliff, the height of the cliff, the angle of the cliff face and the ground and surface water conditions which tend to break down the internal cohesion between the clay particles. Once tension cracks develop along the cliff top, surface water may enter the slip plane and accelerate the slip action. Eventually the cliff face slips forwards and downwards 'en masse' and spreads over the beach. The upper exposed face is quickly weathered back and the gradient lowered while the unstable cliff face is maintained so triggering further cliff slippage.

Slipping occurs at various scales from more or less continuous wastage to major and catastrophic falls depending on the lithology. Rates of cliff recession may be 3-6 times greater on London Clay than the Tertiary sands to the east. The clay cliffs at Reculver are receding at an average rate of 0.68m/year (Ref 3) but this rate may well exceed 1.5m/year in Herne Bay where the cliffs rise steeply to an elevation of 40m (Hutchinson, Ref 5). The occurrence of major landslides may be related to storm surge events such as the Miramar Hotel slide, Herne Bay, in February 1953 (Bromhead, Ref 4; So, Ref 43). High tidal conditions are known to trigger slide activity which occurs more frequently during winter months, when north and north-westerly wind conditions tend to pile water onshore.

In many areas the cliffs now bear little resemblance to their former appearance. Protective works at the cliff toe have been constructed over increasing stretches of this coastline in an effort to curb erosion. This has been accompanied by drainage schemes to stabilise the cliff face and reduce slippage. However, the resultant reduction of input of beach material into the sediment system from the cliffs has caused general foreshore erosion and beach lowering along this coast. The shingle beaches are now regularly monitored and augmented by recycling and recharge of material when necessary (HRL, Ref 28).

To the east of Reculver, the cliffs end and eastwards to Birchington the coast comprises low marshes representing the former western entrance to the Wantsum Channel, which originally separated the Isle of Thanet from the mainland. Much of the area, which now forms the Stour valley, is below the level of high water and is protected from flooding by the Northern Sea Wall.

The Isle of Thanet forms a promontory with a highly indented coastline of vertical cliffs of Upper Chalk stretching east of Birchington to Pegwell Bay. The cliffs are 20-30m high and show much variety of form and rate of change. The chalk is jointed and faulted and these structural weaknesses have been exploited by wave action, undermining the cliff base and causing block falls.

Cliff erosion has been rapid on the north and east coasts with average rates of the order of 0.22m/year (May, Ref 35) to 0.3m/year (So, Ref 43). On the north coast, where the direction of jointing is normal to the coast, the cliffs are irregular as erosion by the waves is concentrated along the joint planes. Arches and stacks have been formed in this way, as in Botany

Bay and Birchington Bay. From Minnis Bay to Foreness, however, almost all the cliffline is now protected by defensive structures to reduce erosion along a built-up frontage. Along the east coast from the North Foreland southwards to Ramsgate, the joints within the chalk lie parallel to the coastline and large cliff falls occur relatively frequently. On the south coast west of Ramsgate, the cliffs are relatively sheltered from wave attack within Sandwich Bay and are receding slowly at a mean rate of 0.07m/year.

The cliffs of Thanet are fringed by a wide rock wave cut platform, varying in width up to 250m at low water. Small sandy pocket beaches occur in shallow valleys in the wave cut platform. These beach deposits are thin and highly mobile over the rock platform. Surveys have shown that there is very little evidence of sand on the seabed at depths greater than 5.5m and that shoreward of this the sand forms a thin layer over the chalk. The movement of sand onshore from the nearshore zone under mild wave conditions and drawdown under storm conditions is reflected by a seasonal change in beach conditions (Kemp, Ref 30).

The North Foreland forms a zone of null net littoral transport and a point of divergence of coastal sediment paths along the Kent coast. Along the north coast of Thanet the prevailing south westerly winds are offshore and therefore net drift increases to the west under easterly and north-easterly waves. These conditions also produce a net movement of material southwards and westwards into Sandwich Bay along the east coast, although actual transport rates are fairly low. Sand has accumulated east of the East Pier at Ramsgate to form a substantial beach. Any fine beach material by-passing this point is likely to be deposited within the shelter of Pegwell Bay.

Sandwich Bay forms a large shallow embayment on the east coast of Kent, south of the Isle of Thanet. It is exposed to fetches from a narrow sector from east to south-south-east but these are also limited by the proximity of the continent and the presence of the Brake Bank and the Goodwin Sands offshore. Waves reaching Sandwich Bay under south-westerly conditions are likely to have a fairly low capacity to transport beach material after diffraction around the South Foreland and refraction over the shoaling contours of the bay. Similarly the effect of the dominant north-easterly and easterly storm waves are reduced by the headland of the Isle of Thanet. Tracer experiments at Deal have shown the direction of littoral drift to vary seasonally with sediment moving northwards in summer and southwards in winter (HRL, Ref 20). However, as the sheltering effect of the Brake Bank increases so the net effect is that beach material is moved northward into Sandwich Bay and Pegwell Bay.

Sandwich Bay acts as a sink for marine sediments transported both from the north and south. Beach material drifting northwards alongshore from Deal has been deposited to form a spit across the mouth of the River Stour. The composition of the sediment changes from shingle with sand dunes up to 10m high at the southern end to sand and eventually shell at the recurved distal end, called Shell Ness. The spit has lengthened at an estimated rate of 5.5m/year (Robinson and Cloet, Ref 40) and provides shelter for the development of marshland behind in the Lydden Valley. Fine muds and sands have accumulated in the wide inter-tidal zone in the most sheltered region north of the River Stour in Pegwell Bay. Robinson (Ref 41) suggests that Sandwich Bay also obtains a steady supply of shingle and sand from the adjacent sea bed and that this sediment ultimately becomes involved in beach drifting.

The bottom configuration of Sandwich Bay and the English Channel is a complex of shoal banks and channels fashioned by the ebb-flood tide system. The Goodwins form a large sand bank system north of the Dover Straits and east of Sandwich Bay. The Sands are elliptical in shape, trending slightly east of north and are 13-14km in length above the 11m isobath. Large areas of the banks are exposed at low water and their bases rest directly on a fairly even chalk surface at a depth of about 24m thus providing little support for earlier theories that the Goodwins originated as an island.

The banks are subject to an appreciable amount of movement but have probably existed in their present location for a considerable time i.e. during the postglacial period. Hydrographic surveys over the past 200 years indicate that the banks have generally increased in size (Cloet, Ref 7). On a shorter time scale, recent volumetric analyses of the South Goodwins over periods of several months (being undertaken by Hydraulics Research Ltd on behalf of the Dover Harbour Board) show fluctuations of the order of one million cubic metres. However, these changes are negligible in relation to the total volume of the banks and represent the movement and redistribution of sediment by the action of waves and tidal streams within the bank system as a whole.

The parabolic shape of the Goodwins is typically formed by the interaction of ebb and flood channels (Robinson & Cloet, Ref 40). The flood channels flow north-eastwards into Trinity Bay and the Small Downs between the coast and Brake Bank. The principal south flowing ebb channels are the Gull Stream separating Brake Bank from the Goodwins and also to the east of the Goodwins. The relative effect of these streams has resulted in an anti-clockwise rotation to a more north-south alignment (Cloet, Ref 7). The Kellet Gut, a channel some 23m deep, divides the Goodwins into the North and South Banks. Similarly a flood channel within Trinity Bay penetrates northwards deep into the Goodwins. Cloet postulates that the extension of these channels may well lead to the separation of part of the North Goodwins, which may then move landwards much in the same way as the present Brake Bank.

The Brake Bank is a submerged sand and shingle bank lying 3km offshore and extending southwards of the mainland of Thanet at Ramsgate. The bank is 300-1250m wide and 6.5km long. It is separated from the Goodwins by the Gull Stream. The bank is moving coastwards, possibly driven by the same anti-clockwise movement as is taking place in the Goodwins or by wave action, such that the central portion is moving at a slightly greater rate and the bank is bending inwards into Sandwich Bay. Given the continuation of these present conditions, the Brake must eventually merge with the shore (Cloet, Ref 8). Robinson and Cloet (Ref 40) suggest that the process of shoreward migration of an offshore bank along this coast has already taken place. They consider that the Stonar Ridge, a shingle ridge lying across the entrance of the former Wantsum Channel from Ebbsfleet in the north to Stonar in the south, represents a bay bar formed by the onshore movement of such a bank.

South of Sandwich Bay, the coast between Deal and Hope Point faces due east. Between Walmer and Kingsdown there is a substantial accumulation of shingle, up to 200m wide in places. However, this bank is now receding as the effects of the interruption, at Dover, of the littoral supply from the south are transmitted downdrift (ie northwards) along the coast. The shingle bank moved inland by 147m in the 50 year period up to 1961 at the Royal Marine Ranges at Kingsdown (Bird & May, Ref 3). This represents an annual rate of recession over this period of 2.94m. Most of the shingle appeared to be removed during south-easterly gales. The sea wall built to protect the ranges has in turn caused the focus of erosion to be transferred northwards on to the open shingle bank. A further stretch of wall was built to protect the town frontage at Kingsdown. General recession is likely to continue with only a limited supply of shingle from the south and rates are likely to vary depending on the coastal protection works.

From Kingsdown to Folkestone the coastline is formed of chalk cliffs. The coast cuts across the dip slope of the North Downs and the cliffs therefore gradually increase in height westwards to 150m at Capel. The general cliffline is broken at Dover by the steep valley of the River Dour. The cliffs recede at a fairly slow rate (0.09m/year) by chalk falls caused by weathering and direct undermining of the cliff toe by wave action. However, the actual rate of cliff recession is related to the degree of exposure to easterly storm waves. Hence, southwards to St. Margaret's Bay the coast is aligned north-south and cliff erosion is effected by frequent rock falls producing a steep, bare cliff face. Along the South Foreland, south of St. Margaret's bay and westwards to Dover, cliff recession is less rapid. The cliffs face south-east and are less exposed to both south-westerly and easterly waves. Debris from occasional chalk falls may remain at the cliff foot for some time and more stable parts of the cliff face are covered by vegetation. At Dover Harbour the littoral drift of shingle from the west has necessitated the construction of longer and more effective breakwaters. As a result a wide shingle beach has accumulated to the west of the Admiralty Pier and there is correspondingly a lack of shingle downdrift on the wave cut platform along the foot of the cliffs of the South Foreland to the east of the harbour.

Just east of Folkestone is an area of coastal landslips, known as Folkestone Warren, affecting 4km of cliffline in East Wear Bay west of the Abbot's Cliff tunnel. The mean rate of coastal recession is of the order of 0.28m/year (Bird & May, Ref 3) although actual cliff top retreat related to any particular event may be far greater. Twelve major slips have occurred since 1765 of which the 1915 slip was the largest known. It displaced the Dover - London railway by 50m. Again in 1937 the sea wall at the western end of East Wear Bay was displaced 30m seawards.

The development of landslips here is due to geological factors (Hutchinson et al., Ref 16). The slips are bounded by a scarp of the Middle and Lower Chalk, 90-120m high, which dips at a low angle inland north and eastwards. The chalk overlies Gault Clay which appears at the base of the cliff in the western part of the bay as an irregular shelf or undercliff which varies in width between 46 and 366m. It slopes gently seawards ending in a cliff about 15m high. The slips are rotational and the slip planes are known to penetrate the Gault Clay. The resistance of the plastic Gault to the normal pressure of the overlying chalk is limited and the clay is seen to bulge and buckle where it is exposed on the foreshore. Most of the slips have occurred after unusually heavy rain and about, or a little after, low water spring tides when there is a reduction in the basal support of the clay undercliff. Thus the form and severity of the slips depend on the the proximity of the Gault/chalk junction to sea level. Hutchinson also cites the progressive development of Folkestone Harbour since the early 1800's as a factor influencing the increased frequency of slips, since the interception of littoral drift from the west has resulted in a reduction of beach material and therefore cliff base protection and support.

The foreshore changes from chalk in the east of Wear Bay to Gault clay in the west. The wave cut platform is often bare of sediment except for a thin layer of sand in places. Shingle placed prior to the Second World War has long since disappeared but some shingle is retained on the upper beach by groynes in the east. Elsewhere shingle has accumulated at Lydden Spout to the east of Abbot's Cliff.

West of Copt Point to Lympne, the cliffs are composed of interbedded sands and clays of Lower Greensand dipping north and east. The cliffs exhibit a variety of form and are fronted by shingle. At Hythe the present coastline forms a gentle curve to the south-west towards Dungeness while the 'old' cliffline continues westwards inland at Lympne. The net drift of material takes place from west to east at a rate that exceeds supply, although at times the direction of drift may be temporarily reversed under the influence of easterly storms. The shingle is rolling landwards and where stretches of the coastline have been walled and groyned this has exacerbated problems of erosion such as at Hythe. This frontage now projects seaward of the natural shoreline position and suffers frequent damage during storms as the shingle attempts to over-ride the wall. Beach levels are variable and are vulnerable to drawdown during storms exposing the wall to wave attack at MHWS (HRL, Ref 24).

The eastern shore of the Dungeness foreland southwards to Greatstone has suffered long term foreshore erosion and beach lowering. There is little potential for littoral drift from the south after diffraction around the ness while direct exposure to easterly and north-easterly storm waves promotes rapid loss and drawdown of beach material. The shoreline has been artificially 'fixed' by the Dymchurch wall. It was built to protect the Romney Marshes in the early 1800's and some form of wall may have been in existence here since Roman times. Much of this foreshore has been depleted of shingle in the recent past necessitating further protective measures and the present walls are subject to undermining and overtopping as a result of the lowering of the foreshore.

Dungeness is one of the most prominent coastal features along the English Channel. It forms an actively prograding shingle plain in the shape of a cuspate foreland stretching from Hythe to Rye. The development of this area is closely related to the draining of the marsh, the changing courses of the rivers and to marine accretion. In the early stages of development, the shingle probably formed a fairly simple spit north-eastwards from Cliff End to Hythe across the mouth of a wide shallow bay so deflecting the course of the River Rother to an outlet near New Romney (Lewis, Ref 31). The 'old', now degraded cliff line is clearly traced inland from Lympne to Appledore. The sheltered area between eventually silted up but may have been reinundated by the sea at various times. This process of sedimentation was assisted by man and the reclamation of Romney Marsh was complete by the end of the Roman Period. During the 13th Century a series of severe storms are thought to have caused a breach in the spit near Rye which was subsequently adopted by the River Rother. Since this time sediment travelling north-eastwards has accumulated to the west of the river entrance to form a series of shingle ridges seawards of Camber Castle (Lovegrove, Ref 32). Consequently the supply of shingle to the main spit was reduced, the shingle bank retreated and become realigned towards the east-south-east, normal to the dominant wave direction.

The Ness today is still accreting on its eastern flank. However, this is matched by a recession in the order of 2m/year along the south face. Material is gradually removed from the south shore by longshore drift under the influence of constructive waves approaching obliquely from the south-west. Once at the Ness the transporting capacity of waves is reduced by refraction and diffraction and the shingle is deposited on the eastern shore where it is built up by storm north-easterly waves into high ridges parallel to the shoreline. The shingle stretches 3km inland of the present shore and the 'fossil' ridges clearly show the development of the Ness. The ridges on Dungeness form distinct groupings enclosing marshland areas. The Midrips, the Wicks, Holmstone Beach and Lydd Beach along the south coast are all formed of lower ridges trending north-eastwards. These older ridges are truncated at their southern end while at Dengie Beach more recent ridges are aligned approximately parallel to the eastern shore.

At Walland, to the east of Camber on the south coast of Dungeness, shoreline recession and foreshore lowering have been exacerbated by the interception of the littoral supply from the west by the piers at the mouth of the River Rother. Sea defences and groynes have failed to remedy the situation. The beach is now maintained by a programme of shingle recycling from the eastern shore of Dungeness at an annual rate of

31000 cubic metres. A similar situation exists along the Pett Foreshore for about 8km to the west of the River Rother to Cliff End. The beach has deteriorated since the 1930's as a result of an inadequate supply of beach material passing eastwards from the Hastings frontage. The shingle beach as now been restored by recycling the material accumulating west of the harbour arm of the River Rother at a rate of 19000 cubic metres per annum (Foxley and Shave, Ref 13).

Sandstone cliffs feature from Cliff End, east of Hastings, westwards to Bexhill. The cliffs vary in height reaching over 75m at East Hill. The cliff profile is irregular and often deeply dissected by small streams. The resistant horizons within the sandstone form steps and ledges and parts of the cliffs are concealed by fans of rockfall debris. At Fairlight Glen, cliffs of alternating clays and sandstone are subject to slippage and are eroding at an estimated rate of 0.36m/year (Bird & May, Ref 3). More recent estimates suggest a recession rate approaching 1 metre per annum (New Civil Engineer. Aug 1987).

Sea defences are almost continuous west of Hastings and much of the cliff face has now been obscured by development. The shingle beaches have been stablised by groyne systems. However, the interception of supplies of sediment from the west by such action has created severe erosion of the foreshore at Bexhill. This beach was maintained artificially by nourishment from both land and sea-borne gravels and by the recirculation of natural beach material from Hastings where a large beach has built up the west of the harbour arm. Prior to this nourishment, the annual supply by littoral drift was insufficient to maintain an adequate beach and during storm conditions any existing shingle would be rapidly removed by wave action to expose the bedrock beneath. Beach recycling has been discontinued. The recent Bexhill coast protection scheme appears to have stabilised this frontage. At Cooden to the east of Bexhill, the low cliffs of shales and clays have been undermined by the sea in the past and here too the beach has been artificially assisted by nourishment. Further beach nourishment is also planned at Hastings (see Page 61).

The coastline of Pevensey Bay from Bexhill to Eastbourne consists of shingle beaches in front of low lying marshland. Langney Point (otherwise known as the Crumbles) is a shingle foreland stretching for 5km west of Pevensey Bay Village to Eastbourne. The shingle has accumulated across the entrance of a large embayment in the Wealden Clay under the action of wave induced beach drifting from the west. A series of shingle ridges is aligned south-west to north-east parallel to the shoreline and accretion has been associated with the movement of the foreland to the north-east. The sheltered area behind the shingle bank became infilled with alluvium and the marshes were eventually reclaimed to form the Pevensey Levels. Much of the foreland is no longer in a natural state. Cartographic evidence suggests that the feature is of relatively recent historical origin, probably later than 16th Century (Steers, Ref 45) but by the late 1700's the promontory already appeared to be eroding. All the Martello Towers south-west of Langney Point have since been destroyed. Erosion seems to have been more evident on the western side of the point and this was accelerated by the construction of groynes along the Eastbourne town frontage. This erosion was eventually reduced by groynes along the west beaches which in turn, however, accelerated erosion downdrift on the east beaches. Groynes have now been constructed along the whole of the frontage and the analysis of beach profiles over the past ten years shows the coastline to be fairly stable (HRL, Ref 27). However, this feature will tend to diminish slowly in the long term as the supply of shingle from the west declines further. It has been estimated that the littoral drift along the Crumbles frontage is in the range of 15-25000m^3 per year (HRL, Ref 27).

From Eastbourne westwards to Black Rock, Brighton, the coastal scenery changes. High cliffs form the major features of this coastline broken only by the valleys of the Rivers Ouse and Cuckmere. At Beachy Head the chalk cliffs form an impressive headland over 150m high. From Beachy Head eastwards along the Eastbourne frontage, Lower Cretaceous rocks such as Upper Greensand and Gault Clay are exposed beneath Middle and Lower Chalk. The cliff profile is concave with a pronounced undercliff where the chalk and greensand have slipped over the underlying Gault Clay. Although the cliffs are sheltered from wave attack from the south-west by Beachy Head, they are receding at a rate comparable with the cliffs to the west (ie. approximately 0.4m/year (Bird & May, Ref 3). At Eastbourne local groyning has retained a considerable beach.

To the west of Beachy Head, the cliffs are predominantly of Upper Chalk, which form the South Downs, and offer little resistance to marine erosion. In general the cliffs are vertical and the top retreats steadily inland by frequent small cliff falls thus maintaining a steep, bare face. The rock debris is quickly removed over the wave cut platform by wave action at high tide. Pockets of shingle at the cliff foot are rarely sufficient to protect the cliff from direct wave attack.

At Birling Gap measured cliff top retreat between 1950 and 1962 averaged 0.99m/year and corresponds to a long term average from cartographic evidence for 1875 to 1961 of 0.91m/year (May, Ref 34). The more recent survey showed that losses were generally greater during winter months and indicates that weathering of the upper cliff face by the combined effects of rain and frost may be an important contributory factor to cliff erosion. The Seven Sisters cliffs run for 3.5km west of Birling Gap to Cuckmere Haven. The cliff crest rises and falls with the truncation of ridges and dry valleys. The chalk is homogeneous in composition receding at an average rate of the order of 0.4m/year (Bird & May, Ref 3).

Cuckmere Haven is a small bay slightly protected from the south-west by Seaford Head. Shingle has accumulated here in sufficient quantities to cause problems at the outflow of the River Cuckmere which is now regulated. It is estimated that the shingle has been accumulating at an annual rate of $2400m^3$ (Beasley, Ref 2).

To the west of Seaford Head, the coastline forms a shallow embayment at the outlet of the River Ouse and originally depended on a shingle bank to provide natural protection for the town of Seaford and the low lying land behind. The initial interception and present diversion of sediment away from the Seaford frontage by the Newhaven breakwater to the west has created severe problems of coastal erosion. Flint shingle has been found in the offshore zone but there is no evidence that it is able to move shoreward across the rock and the platform. It is suggested that shingle passing the Newhaven breakwater is actually bypassing Seaford beach, travelling below low water (HRL, Ref 19).

Other factors also contribute to the persistent erosion at Seaford. The coastline is orientated almost at right angles to wave attack from the south-west. Waves from this direction approach the beach at a small angle and produce a low rate of drift. However, waves approaching from the south and west are capable of transporting shingle at a greater rate although they occur less frequently. The actual direction of drift may therefore be reversed and the net effect is that beach material tends to move away from the central frontage in both directions accumulating at the west end in the lee of the breakwater and at the east end trapped by the long groyne. The deep water near to the shore allows very large waves to break close inshore during storms, and damage at the sea defences was particularly serious along the central frontage prior to recent beach replenishment where there was little beach remaining.

At Newhaven the outlet of the River Ouse is regulated and a stable shingle beach has accumulated to the west of the long breakwater arm. Present beach build up is insignificant indicating that an equilibrium beach plan shape has been attained orientated to the predominant direction of wave attack. The shingle is now transported around the end of the breakwater at an annual rate of about 15000-20000 cubic metres (Beasley, Ref 2). There is an opportunity to recycle shingle from the accretion west of the Newhaven breakwater to the starved beaches in the area. This would avoid future losses of shingle into deep water. However there are no such proposals at the present time. At Castle Hill, Newhaven, some cliff slips occur where the chalk is overlain by Lower Tertiary sands and gravels of the Woolwich, Reading and Thanet Beds providing a local source of beach material. However, west of Peacehaven to Black Rock, Brighton, the base of the cliffs is protected by a concrete sea wall and groynes, thereby reducing erosion of the flint bearing cliffs.

From Brighton to Pagham Harbour the coast of Sussex is characterised by low bluffs of chalk which represents an old marine platform, produced at a higher sea level, and which stretches inland to the South Downs. The coastline is generally retreating but large stretches are now stablised by coastal defences. Thus although for the most part there have been only minor changes in the shoreline over the present hundred years there has been a retreat in the position of low water indicating a general reduction and steepening of the foreshore. The beaches are mainly composed of flint shingle derived from the gravel deposits overlying the cliffs and chalk pebbles from the chalk platform which forms the base of the beach. Coastal protection measures have reduced the supply of material to the beach by preventing cliff erosion. In some places the lowering of the foreshore has exposed the substratum in the intertidal zone such as London Clay at Bognor and Chalk at Angmering. Attempts have been made to retain beach material and stablise beaches by building groynes or by renourishment as for example at Elmer near Middleton.

The drift of beach material to the east under the predominant south-westerly waves is demonstrated by the deflection of the mouth of the Rivers Adur to the east by the formation of a spit feature. The River Adur at Shoreham is diverted 2km to the east and the present outflow is fixed by harbour works. The spit forming the western bank was longer until a cut was made in 1816. To the west shingle has continued to accumulate in 'fulls' or ridges although the shingle banks move landwards during storms. The harbour works have influenced the coast downdrift. Erosion immediately to the east of Shoreham continues despite renourishment and groyning. Further eastwards to Hove and Brighton loss of shingle and foreshore erosion was severe until the construction of sea walls and groynes. At Littlehampton a healthy beach has developed to the west of the pier but in so doing has starved beaches to the east where the shoreline is 'set back'.

The inlet of Pagham Harbour is bordered by twin spit features, one trending north-eastwards from Selsey Bill continuing the line of the coast, while the other trends south-westwards from the opposite shore near the Pagham Beach Estate. Robinson (Ref 39) used cartographic evidence to suggest that the double spit was formed by breaching by storm waves of one spit built by drift across the bay rather than by the effects of counter drifting from the north-east. The evolution of the spit is shown to be closely related to changes which have taken place along the adjacent coast of Selsey Bill to the west. Robinson suggests that material is supplied by frontal accretion from the Inner Owers as well as longshore drift from the west. Thick deposits of shingle derived from cliff erosion at Selsey cover the sea bed in the shallow water east of the harbour entrance. This has provided a reservoir of material to supply the shingle bank under suitable wave conditions. However, now that the supply of littoral material from Selsey Bill has diminished as a result of coastal protection works, the accumulation is much slower and indeed downdrift erosion has been taking place east of the harbour at Pagham Beach Estates. The marshy area behind the spits was once reclaimed but inundated following a breach of the shingle ridge in the late 19th century.

The coastline of Selsey Bill is low lying with a stretch of cliffs at the tip of the Bill formed in various superficial head deposits overlying the

Bracklesham Clays and rising to little more than 8m in height. The peninsula of Selsey Bill itself is virtually an island separated from the mainland by a marshy depression with areas below high water springs and stretching from Pagham Harbour in the east to Bracklesham Bay in the west. The foreshore west of the Bill is wide and flat with sand beaches resting on clay and chalk platforms. The beaches are backed by shingle banks derived from the erosion of the soft unconsolidated cliff deposits while the finer clay fractions are carried offshore by waves and tidal currents. The shoreline has moved steadily inland at a rate of the order of 2m/year (Steers, Ref 45). This has necessitated protection by defensive walls and/or groyning of the beach along most of this coastline except along a short stretch of cliffs to the west of the Bill.

Duvivier (Ref 12) suggests that the direction of drift divides at Selsey Bill, forming a zone of null sediment transport with shingle on the west side generally moving westwards up the Solent and that on the east side moving eastwards towards Pagham harbour. The beaches to the east of Selsey Bill are relatively stable, despite the slow net west to east littoral drift. To the west of Selsey Bill, the actual pattern of drift is more complex. At Medmerry the beach is exposed to attack by the prevailing south-westerly waves. The main movement of shingle here appears to be normal to the shoreline, being drawn down to the lower beach during storms and moving back from the foreshore to the ridge during periods of calmer weather (HRL, Ref 22). During this process some rolling back of the shingle ridge takes place. Flooding and loss of land by coastal recession has been a particular problem at Medmerry where the ridge protects low lying land behind and where the supply of material from the east is now limited due to the coast protection works at the Bill. However there is believed to be a small amount of material brought onshore by kelp rafting. The ridge crest is presently maintained at 5m ODN by the import of landbased shingle.

Further west, the south-westerly waves are diffracted around the Isle of Wight and approach the coast more obliquely producing the expected westerly longshore drift and so removing material from the Medmerry frontage. The coastline terminates in a sand and shingle spit called East Head. The spit is recurved into Chichester Harbour and encloses a large area of saltings and mudflats which are exposed at low tide.

4 WINDS, WAVES AND TIDES

4.1 Wind-wave climate

A Department of Energy report (Ref 9) gives the maximum 50 year extreme wind speeds (over a 1 minute mean) in this area as 36 to 37m/s. These are among the lowest maxima predicted around the UK coastline and they gradually increase both to the west and to the north. Nevertheless parts of this coast, particularly the Isle of Thanet, are exposed to winds from a wide sector, hence calm conditions in these areas are relatively infrequent.

The Department of Energy report gives the maximum recorded wave heights as about 12m offshore for most of this coastal strip (again as a 50 year extreme). However, this reduces significantly to a maximum of about 8m in the outer Thames Estuary. Crest to crest wave periods associated with these wave heights are about 13 seconds off the north and east facing coasts as far south-east as Dungeness. These associated wave periods increase westwards along the English Channel until at Selsey Bill they are given as about 15.5 seconds. This increase is due to the influence of Atlantic swell which becomes increasingly important towards the west end of this stretch of coastline.

There is, as one would expect, a substantial amount of wind and wave data recorded in the English Channel and in the southern part of the North Sea. The following tables give details of wind and wave records and for how long recordings were collected. Table 2 also indicates the type of wave recorder used and the data reference number in the MIAS Wave Catalogue (Ref 33).

Table 1 Wind Records (Ref 36)

Station	Date	Recording Station
Dungeness	1970-1985	Coastal station
East Goodwin	1949-1984	Light vessel
Falls	1972-1984	Light vessel
Galloper	1950-1976	Light vessel
Manston	1970-1985	Coastal station
Royal Sovereign	1949-1984	Light vessel
Thorney Island	1970-1985	Coastal station
Tongue	1975-1984	Light vessel
Varne	1970-1984	Light vessel

Table 2 **Wave Records** (Ref 33)

Station	Date	Recorder Type	MIAS Reference
Brighton	1967	p.g.	128
Dover Harbour	1985	p.g.	1554
Dover Harbour	1985-1986	w.r.b.	1510
Dungeness	mid 83-mid 84	w.r.b.	
Dyke	1966	s.w.r.	700
Folkestone	Proposed		
Galloper	1971-1974	w.r.b.	178
Littlehampton	mid 85-mid 86	w.r.b.	1511
Seaford	mid 83-end 84	w.r.b.	1278
Tongue	mid 65-end 69	s.w.r.	175
Varne	1965-1966	s.w.r.	181
Whitstable	1978 cont	p.g.	116

p.g. - pressure gauge
w.r.b. - waverider buoy
s.w.r. - shipborne wave recorder

As can be seen from the above, the wave data are split fairly evenly between:

1. Pressure gauges

These recorders rely on changes in the pressure of the water column above them due to variations in water surface levels to record wave heights and periods. Usually placed close inshore, they are connected either to a shore station by cable or are self contained with a cassette recorder housed inside them.

2. Waverider buoys

The waverider system of wave measurement is normally used when wave data are required for coastal and offshore applications. The buoy is tethered offshore to an "elastic" mooring and an accelerometer within the buoy measures its acceleration as it follows the changes in water surface movement. This data is fed (via a radio transmitter) onshore to a calibrated chart recorder or a purpose-built magnetic tape recording system. Both wave height and period can be read from the records. The data is transmitted continuously and the receiver is normally programmed to receive at pre-set intervals. Reliable reception is generally limited to less than 20km and the receiver is in direct line of sight with the transmitter. The distance offshore the buoy is deployed is usually dictated by the use to which the data is to be put and by the complexity of the offshore bed topography. This must however be outside the breaker zone. A repeater buoy, developed in 1984, can in some instances be used to relay signals around blocking headlands (HRL, Ref 17).

3. Ship borne wave recorders

Usually installed on light vessels offshore and the data analysed by the Institute of Oceanographical Sciences.

The narrowness of the Dover Strait has a significant effect on the waves, winds and tides. Wave height, wave period and the wind speeds at their lowest here, increasing to the north and west. Any inshore wave predictions require the use of refraction models to take into account the changing bathymetry and waves penetrating from the North Sea as compared with those propagating up the English Channel from the Atlantic.

4.2 Tides and tidal currents

As Table 3 shows, the mean spring tidal range increases westward from Margate (4.3m) towards Sheerness (5.1m) on the north facing coast of the Thames Estuary. The tidal range also increases to the south and west from the Foreland Point at Margate to a maximum at Dungeness and Hastings of 6.8m. From this peak the range decreases westward along the south coast to 4.7m at Selsey Bill.

The difference in tidal range is due in part to the bottleneck at the entrance and exit to the Dover Strait and also to the existence in the vicinity of amphidromic points.

An amphidromal system is a complex tidal phenomenon where high water apparently rotates around points at which the tidal amplitude is zero. There are several such points scattered around the offshore zones of the U.K. and the further away from the centre, the greater is the change in water level.

From the amphidromic point situated off Lowestoft in the North Sea, co-tidal lines of increasing range, spread south to the English Channel and reach a maximum at the southern end of the Dover Strait. The range then decreases until a point is reached to the west of the Isle of Wight where the convergence of the co-tidal lines to a minimum suggests a degenerate amphidromic point.

There are in existence tidal models which indicate both velocity and direction of depth averaged tidal currents plus tidal elevation. Several of these numerical models cover the area offshore of the south east coastline from the Thames to Portland Bill. Based on an H.R.L programme (Ref 23) these are used by both H.R.L and Southern Water. Normally of a fairly coarse grid to cover a bigger area, finer grid models are also used to determine the tidal data in certain localised areas such as at Dover.

Offshore tidal streams often vary considerably both in direction and velocity and reference must be made to relevant tidal stream data in publications such as Reed's Nautical Almanac (Ref 37) or Admiralty Charts and tide tables (Ref 29).

Table 3 Predicted springs tidal range (taken from the Admiralty tide tables)

Station	Spring tide levels relative to CD HW		LW	Range (metres)
Sheerness	5.7	-	0.6	5.1
Herne Bay	5.2	-	0.5	4.7
Margate	4.8	-	0.5	4.3
Deal	6.1	-	0.8	5.3
Dover	6.7	-	0.8	5.9
Folkestone	6.6	-	0.6	6.0
Dungeness	7.7	-	0.9	6.8
Hastings	7.5	-	0.7	6.8
Eastbourne	7.3	-	0.8	6.5
Newhaven	6.6	-	0.5	6.1
Brighton	6.5	-	0.6	5.9
Shoreham	6.2	-	0.7	5.5
Bognor	5.6	-	0.6	5.0
Selsey Bill	5.3	-	0.6	4.7

4.3 Surges

In addition to the tidal variations there are effects due to the fluctuations in the atmospheric pressure. (These can either raise or lower the still water level and are called surges.) These occur fairly frequently down the North Sea coasts propagating southwards down the east coast and increasing in height as they reach the bottleneck in the south. Of paramount importance to the coastal engineer is the prediction of extreme high water levels which are the combination of tide plus surge level.

On the north facing coast of Kent, a 50 year extreme surge would lead to an increase in the region of 2.5 to 2.75m above the normal water level (Dept of Energy, Ref 9). This storm surge elevation gradually reduces to the south. At Selsey Bill in the English Channel, the residual would be in the region of 1.5 to 1.25m above the normal predicted tidal levels, gradually increasing eastwards towards the Dover Straits. A detailed analysis of extreme sea level variations has been carried out by Graff (Ref 14) who has produced frequency distribution curves of extreme tide plus surge level values around the UK coastline, (including Tilbury, Sheerness, Margate, Rye, Dover, Pevensey, Newhaven and Portsmouth). Such information is usually of far greater importance than the prediction of the surge residuals described above.

5 REVIEW OF COASTAL DEFENCES

5.1 Isle of Grain to the Isle of Thanet

Although the coastline bordering the Thames is, in several areas, quite heavily developed, much of it is low lying and many of the developed areas are associated with either the tourist industry or housing. The islands of Grain and Sheppey dominate the coastline on the south side of the Thames Estuary. Wave action on their shoreline is slight, and erosion is due to both tidal currents and wave action. Because of the likelihood of flooding, low lying areas on these islands are embanked while large stretches of boulder clay cliffs are allowed to erode.

(a) The Isle of Grain (the word 'grain' is derived from the old english word 'greon' meaning sand or gravel) (Ref 1).

The Schedule 4 boundary on the southern bank of the outer Thames is situated to the west of Allhallows on Sea. Here low cliffs are protected by a concrete sea wall while the narrow sandy beach at the top of the muddy foreshore is groyned. The sea wall built in the

1970's, is in a fair condition. The only repair work has been to construct a small concrete platform to deter undermining. Rochester upon Medway City Council are responsible for the frontage here (1.4km) and also the frontage at Grain. At Grain some 900m of sea walls of varying construction protect the village. The wall at the north end was built in the 1970's and its condition remains good. The remainder is very old (ex war department) and being repaired currently. Tripod blocks are used as terminal protection and derelict groynes front the wall. Littoral drift is in a nett east to west direction, although the quantity of material is small. The sea wall appears to be as much for the purpose of stabilising the boulder clay cliffs as for preventing wave induced erosion.

Southern Water protect the low lying land east of Allhallows to Yantlet Creek and then east beyond the creek to Grain Marsh, with floodbanks. In some areas these banks are faced with ragstone pitching and they have been raised in recent years to reduce the incidence of flooding. Due to their remote location, some stretches of earth bank have deteriorated and some of the pitching is in a poor condition. Much of this low lying area is designated as an S.S.S.I. North-west of the village of Grain there are unprotected clay cliffs but where these abut to the sea wall, concrete blocks have been used to infill the terminal scour hole to prevent outflanking of the wall. Fronting the village itself there is a small esplanade and sea walls and embankments of various forms of construction. At the north-western end of the village, the walls, built in the 1970's are in good condition. The remainder, which are ex Ministry of Defence walls, are very old and fronted by derelict groynes.

On the west bank of the River Medway on the south-east corner of the Isle of Grain, Southern Water maintain the clay floodbanks which protect a power station and a BP storage Depot. These banks are reinforced by either mass concrete aprons or concrete block revetting. Toe scour is evident in places resulting in the additional placement of riprap and concrete patching. This protection is piecemeal and there is evidence of differential settlement and bulging of the revetment face. Although the coastal defences on the Isle of Grain are generally patchy, this area is mostly undeveloped. The power station is protected by a second line of defences (again earth banks). Except in the vicinity of Grain village, the coastline is well sheltered from wave action, and sea defence rather than coast protection is the major concern. Littoral drift in this area is insignificant and the movement of the foreshore deposits of mud and sand are controlled by the action of the tidal currents.

(b) East of the River Medway is the Isle of Sheppey. The only landward access to the island is from the south via the concrete Kingsferry Bridge which was built in 1960. The island is under the jurisdiction of Swale Borough Council for coast protection while Southern Water are responsible for defence against flooding. The island is mainly low lying marshland but there are also high (73m) clay cliffs on the north facing coast between Minster and Warden Point. The main town is Sheerness on the north west tip of the Island and this is heavily developed. The Admiralty closed its docks here in 1960 and these have now been developed into a car ferry and container terminal.

The town, from the Schedule 4 boundary in the River Medway to the south to Scrapsgate in the east, is protected by massive concrete flood walls (a total length of 7.6km), the responsibility of Southern

Water. They afford a high level of protection to the area against the risk of flooding. The beaches are of sand, shingle and mud and are groyned on the north facing shore to contain the small nett east to west littoral drift. The esplanade here was severely damaged in the storms of January 1978, but has been subsequently repaired. A scheme (Sheppey Sea Defences (Sheerness) Improvement Part IV) incorporating raising the existing sea walls and beach renourishment, was carried out between Barton's Point and Scrapsgate in 1975 (Ref 47). The current nourished beach has since afforded good protection against flooding to the low lying hinterland. The current stability of the nourishment scheme is a further indication of the low magnitude of littoral drift in this area.

East of Scrapsgate where Southern Water's sea defence responsibilities finish in this area, Swale Borough Council have carried out, in their coast protection role, two coastal defence schemes which link together to give a protected length of 1.6km to the village of Minster. These two schemes are complete with groynes, reinforced concrete wave and splash walls and access road. Cliff stabilization has also been carried out.

Eastwards beyond Minster, unstabilized clay cliffs extend to Warden Point. Their erosion is rapid and cliff stabilization and beach protection measures have been ruled out for economic reasons. A partly collapsed seawall at the southern end of the Warden cliffs shows signs of having been displaced seawards by earth movements. Coast protection at the east end of Warden Bay consists of some 500m of concrete sea walls and timber revetment, fronted by groynes. Much of this was renewed in 1986. Between Warden and Leysdown the eroding clay cliffs drop away to low lying land and this is protected by Southern Water who maintain some 1.3km of concrete faced flood embankments (protecting holiday camps and caravan sites) and some groynes.

At Leysdown the town is protected by about 1.4km of concrete sea wall, fronted by groynes, (constructed in about 1953), built as coast protection and maintained by Swale Borough Council. Littoral drift is low and north-west towards Warden Point.

From Leysdown, south to Shell Ness and then up the River Swale, there are about 4.75km of clay embankments which are maintained by Southern Water. These protect low lying land, much of which is still marsh. The foreshore as far as Shell Ness is of sand, shell and mud and is groyned. South-west from here to Sheepwash, the floodbanks are fronted by saltings. Movement of foreshore material here is dominated by tidal currents.

On the mainland, south east of the Isle of Sheppey, along the low lying southern bank of the River Swale, Southern Water maintain some 4.5km of clay embankments bordering the Oate, Nagden, Cleve and Graveney Marshes from the Schedule 4 boundary, west of Faversham Creek, to the Sportsman Inn just west of Seasalter and Canterbury City Council's western boundary. With regard to littoral drift, the Swale Estuary forms a zero transport boundary where the effects of shallow water and estuarine exposure rather than open coast conditions causes littoral drift by wave action to approach zero (Roberts, Ref 38). This area constitutes the South Swale Local Nature Reserve. The foreshore is of sand and mud with shingle, shell fragments, sand and mud to the east. As with the coast further to the east, this area is well protected from wave action and flooding is the major threat.

There is also a stretch of flood embankment, approximately 2km in length, (fronted by a shingle beach) west of Seasalter, the responsibility of Southern Water. The beach is mainly ungroyned although an outfall (built in 1970) acts as an effective interceptor of littoral drift and natural depletion of shingle here could cause flood problems.

From Seasalter to Reculver Towers, a distance of some 16km, the coastal defences are the responsibility of Canterbury City Council. The beach here is of shingle with some sand and the drift is westerly. The main problem along this frontage is that there is a dwindling supply of inflow of shingle from the east to replace the westerly drift. The debris from the Oldhaven and Woolwich sandstone cliffs at the eastern end of the Canterbury City Council's frontage is the only source of naturally occurring beach material within the Council's boundaries. While cliff erosion undoubtedly produced large quantities of beach material in the past, the cliff stabilisation and coast protection measures carried out during this century have now reduced this supply to a very small quantity. Only one area of this coastline now remains unprotected, and that is the stretch between the east end of Herne Bay and Reculver. The rate of erosion of the cliffs (averaging between 0.5 and 1.0m per annum) is far short of that needed to redress the deficit of beach material. As a result, to prevent failure of the sea defences due to fall of beach levels, the local Council is active in redressing this balance by pursuing a policy of beach monitoring and regularly importing beach material. The material is closely specified to match the naturally occurring beach.

From Seasalter north east to the harbour at Whitstable the coastline becomes increasingly exposed to wave activity. Here concrete sea walls and groynes protect the coastline. The sea walls and groynes are the responsibility of Canterbury City Council with the exception of a short length belonging to British Rail (145m). This is where the railway runs close to the coast near the west end of Whitstable. Built over a period from about 1950, the walls are generally in good condition.

It is proposed to commence work in 1988 in upgrading the Sea Defences to the Central Area of Whitstable and thereby reduce the risk of sea flooding to the town. The works will involve sheet steel piling to stabilise the existing wall, and the importation of a large beach, stabilised by new groynes.

From Whitstable to Swalecliffe the coastline is protected by concrete sea walls and groynes with stabilisation of the clay slopes. The coastal defences, built in stages since 1950, are generally in good condition.

Between Whistable and Swalecliffe lies Tankerton where a grassed clay slope runs down to the sea wall and shingle beach. From Tankerton Beach and running at right angles out to sea is the narrow shingle ridge known as "The Street". At low tide this is uncovered for about 1km. Offshore, a wide shallow area known as the Kentish Flats suggests that the coastline was a long way further seawards some time in the past.

At Swalecliffe, where areas are liable to flooding, a sea defence scheme was constructed in 1986. The scheme comprises some 750m of sea wall with shingle beach nourishment protected by groynes. Gabions stabilise the beach, and a clay bund 750m in length, constructed on the west side of the coast protection scheme, joins with the Tankerton sea wall.

From Swalecliffe east to the jetty at Hampton Pier the coastline is backed by clay cliffs. The coastal defences along the whole frontage are concrete sea walls with wave return walls, groynes and slope stabilisation. Again built over a period from 1950, they are generally in good condition. The exception is an older wall at Hampton, built about 1900.

A stretch of coast about 1km long east of Hampton Pier is perhaps the most stable stretch of coast and is protected only by groynes. Herne Bay's north facing foreshore is exposed to wave action which can cause problems during surge tides and floodgates on the promenade can be sealed in severe weather conditions. The sea wall in the Central Area of Herne Bay is very old having been built in the early 1900s. Its replacement, together with the associated groynes, requires to be carried out in the near future.

At the eastern end of the town the ground rises and clay slopes give way to steep sand cliffs which run east to Reculver. The major problem along most of this length is the stability of the slopes, and the safety of the properties at the top. Works of coast protection and to stabilise the slopes have been carried out and a further scheme (at Queens Avenue) is awaiting approval by M.A.F.F.

The sand and clay cliffs east of Bishopstone Glen have been protected at their toe by a rock revetment and the cliffs have been regraded. Known as the East Cliff III stabilisation scheme, this project (Burnett, Ref 6) involved the removal of some 50,000 cubic metres of material from the cliffs. The stabilised cliffs were then further protected (Burnett, Ref 6; HRL, Ref 26) at their toe using some 20,000 tonnes of imported Swedish granite riprap. Much of the cliff material removed during the stabilisation process was transported for use to upgrade earth embankments near Sandwich on the River Stour to reduce the likelihood of flooding by tidal action.

Between East Cliff III and Reculver, a distance of 0.75km, the coast is undefended, there being no economical justification to carry out any works at present.

Reculver itself is fronted by a 200m stretch of concrete sea wall with riprap at its western end. There is practically no beach now at the base of this wall since very little material appears to be passing around the sea wall at the base of Reculver Towers.

Reculver lies to the west of the outfall of the Wantsum Channel and this point marks a major break in the rock types forming the coastline. It is here that the low sandstone cliffs to the west of Reculver give way to the low lying area of the Wantsum Channel which formed a water way some three miles wide between Reculver and Sandwich and until the late middle ages made Thanet a true island.

The storms of 1953 almost completely wrecked the sea defences here and a new sea wall was built. This length eastwards to Thanet is the responsibility of Southern Water.

5.2 Isle of Thanet

Low lying marsh pasture land runs east from the North Stream River to the east of Reculver for some 5km across the Thanet District Council's borough boundary to the west end of Minnis Bay. This low lying land, the responsibility of Southern Water, is protected by a concrete faced embankment. The beach here is mainly shingle and groyned at its eastern end within the Thanet District Council boundary. The general impression is that there is a dearth of littoral material in this area. The nett drift of littoral transport is from east to west although there is a localised reversal in the vicinity of Minnis Bay.

The coastline of the village of Birchington situated 6km west of Margate is fronted by a 3.4km long continuous sea wall with some groynes between the western end of Minnis Bay eastwards to Epple Bay and protects low chalk cliffs. This sea wall was constructed in numerous sections dating from the Epple Bay Wall in 1900. Further works were carried out in Minnis Bay in 1920; two sections were completed in 1962 between Minnis Bay and Grenham Bay, and Grenham Bay and Beresford Gap; partial re-construction and new work was carried out in 1982 between Beresford Gap and Epple Bay; and the final link in Grenham Bay in 1983. Apart from repair works planned for Minnis Bay the wall is in fair condition.

On the foreshore seaweed covered rocks separate small sandy bays. Because of the protection afforded to the toe of the cliffs, the source of new beach material is now negligible. Sand deposits are generally retained within the embayments and these help to reduce the rate of lowering of the foreshore wave cut platform. The nett loss of sand, though taking place slowly, will mean that the amenity value of the beaches is likely to deteriorate. However, since these deposits are already sparse, this loss is unlikely to affect the stability of the coastal defences within the lifetime of the existing structures.

From Ray House at Westgate-on-Sea, east through Margate to Newgate Gap, Cliftonville the coastline is protected by over 6km of concrete and masonry (with some stone) sea wall and occasional groynes. There is now only 0.4km of unprotected cliffs immediately east of Epple Bay. The walls are mostly in fair condition and were built at various times beginning in about 1870, although there have of course been considerable repairs since then. Several lengths of sea wall, interrupted with short lengths of unprotected cliffs stretch along the coast between Newgate Gap and Sacketts Gap, Cliftonville.

Margate Harbour is privately owned by the Margate Pier and Harbour (1984) Company. A stone pier, built in 1810, encloses the tidal harbour and provides protection to the low lying area of Margate Old Town against storm wave attack and flooding. Substantial repairs to the stone pier were carried out during 1974. In view of the coast protection benefit derived from the presence of the Stone Pier, these repair works were financially assisted by a grant from Central Government under the Coast Protection Act. The Victorian Jetty at the Harbour was almost entirely destroyed by a storm in 1978.

Beyond Cliftonville the coastline swings southwards to Broadstairs. It is thus exposed to wave action from the North Sea as well as from the Dover straits. The chalk cliffs here have many bays within which are sandy pocket beaches. Coastal defences are fragmentary, generally protecting the heads of the bays where, as at Kingsgate, the coast road runs close to the sea. Much of this area has private development (eg Cliftonville, Kingsgate and North Foreland) but there is a broad strip of grassland adjoining the clifftop and no coast protection works are necessary. Constructed at various times since 1900, some of the sea walls are privately owned and most are in good condition.

At Broadstairs 2.3km of concrete sea wall, of various ages, protects the town frontage and are in good condition. A small harbour here is protected by a concrete pier. On this east-facing coast, sandy bays are interspersed with rock outcrops but the beaches are more continuous between Broadstairs and Ramsgate than are the pocket beaches to the north.

The town frontage of Ramsgate faces south-east and is protected by about 3.8km of various concrete sea walls which were built starting in about 1890. They stretch from East Cliff in the north to Pegwell in the south-west. Some repairs have been necessary since but generally their condition is good. The piers etc of Ramsgate Harbour are owned by Thanet District Council as is an area of reclaimed land beneath the cliffs immediately to the south-west. The extension of the Port of Ramsgate, which began in 1978, is now approaching completion. This involved the construction of new breakwaters using Scandinavian rock. It also included the reclamation of some 12.2ha of additional land. The main beach, to the north-east of the harbour, is of sand and littoral drift is noticeably from the north-east. Sand can bypass the harbour mouth and indeed tends to accumulate off the East Pier breakwater extension. The groyned beach west of the new port reclamation area is held in place by massive concrete groynes. Any littoral material that continues further southward is dispersed within the wide inter tidal expanse of Pegwell Bay to the south-west.

This wide estuary of the River Stour is fringed on its north side by low chalk cliffs and to the south by the sand flats of the Sandwich Bay Nature Reserve. The Bay faces south-east with largely low lying marshland along its landward edge. There are two short lengths (0.5km total) of concrete sea walls west of Ramsgate, one at the western end of Pegwell and the other fronting the village of Cliffsend. Both walls were built in 1900 or earlier and are in poor repair. A disused Hoverport is situated on the shoreline at the north-east end of Cliffsend. At Cliffsend, the chalk cliffs of Thanet gradually give way to sandstone before they disappear into low lying reclaimed land at the mouth of the River Stour.

Problems on the Isle of Thanet are primarily the result of cliff instability and in certain areas the cliffs have had to be sheathed with concrete or blockwork to eliminate weathering. This problem was particularly serious at Ramsgate.

At Sandwich, material imported from the East Cliff regrading along the Beltinge/Bishopstone Glen frontage (see p 48) has been used in the construction of a 1.5km long earth embankment. Designed to withstand a 1 in 250 year storm, this is a major part of a large £2.5 million flood protection scheme which, when completed, will be continuous from Deal northwards along the coast and then west along the south bank of the River Stour linking in to higher ground downstream of Sandwich. This major flood protection operation also involves the construction of reinforced brick walls and culverts.

Pegwell Bay was once the southern exit to the Wantsum Channel that used to separate Thanet from the mainland. Closer to the mouth of the Stour, sand gives way to saltings at the southern end of the Thanet boundary. The sands of the bay are thought to be eroding (D of E, Ref 10), but the sand deposits are extensive as are the areas of saltmarsh north of the mouth of the River Stour.

5.3 River Stour to Dungeness Point

At the mouth of the River Stour, floodbanks protect low lying areas from inundation and are maintained by Southern Water. The strong indentation of Pegwell Bay has resulted in the accumulation of large deposits of sand and mud at Sandwich Flats, just south of the river entrance. Defences in this area are natural, and composed of sand dunes. These dunes have shown signs of deterioration in recent years despite the obviously large volumes of sand within the inter tidal flats.

Sand dunes give way to a shingle ridge which extends about 5.5km southwards to Sandown Castle. The nett littoral drift of shingle is in a northward direction although little shingle is to be found at the mouth of the Stour. This far within the bay the waves have insufficient energy to move this size of beach material.

From the Castle south to Deal Pier, a distance of about 1.6km, major reconstruction of a concrete wave wall and groynes has been completed. There are no defences south of the pier at Deal, at present the primary defence against the sea is the storm shingle ridge. A concrete sea wall fronted by a groyned shingle beach, stretches some 700m along the Kingsdown Village front to the south of Deal. This wall, is in good condition and has been extended to control outflanking.

To the south of Kingsdown village, some 900m of sea walls of concrete and sheet steel piles (recently renewed) and new timber breastworks, has been extended northwards to protect Ministry of Defence property. This area has a deficit of beach material due to the chalk cliffs being protected against erosion.

Downdrift scour at the north end of the Kingsdown rifle range is now a permanent problem. South of the rifle range the chalk cliffs begin to have a more southerly aspect. The foreshore platform in front of these unprotected cliffs is bare and there is little evidence of the direction of nett littoral drift (the potential drift is northwards).

St Margaret's at Cliffe overlooks St Margarets Bay, an identation into the chalk cliffs fringed by a pocket beach of shingle. Here a 500m long concrete sea wall and groynes protect houses at the base of the cliffs. The sea wall here is in a fair condition and reconstruction of the dilapidated groynes has now been completed. Because of the strong indentation of the coastline the littoral transport is low and groyning is chiefly to maintain a stable beach rather than to prevent losses due to littoral drift. Between St Margaret's Bay and Dover Harbour, the high chalk cliffs are unprotected and the foreshore platform consists of chalk boulders except for a pocket shingle beach (due to local erosion) at Langdon Bay. Clearly there is little or no transfer of beach material from the west beach (updrift) to the foreshore east of the docks (downdrift coast).

Dover is dominated by its large harbour complex, owned by the Dover Harbour Board and protected by some 3.5km of breakwaters, piers, wharves and groynes. Large scale development upgrading and reclamation of both the East and West Docks is in progress and due to be completed in 1990. This is wholly the responsibility of the Dover Harbour Board except for a short stretch near East Docks which is maintained by Dover District Council. Here, some scouring occurs at the junction with Jubilee Way and the promenade (Castle Jetty) where the promenade is protected by sheet piling. West of the Harbour, concrete walls in various lengths and some groynes hold the sand and shingle beach between Dover Harbour and Shakespeare Cliff. The rate of build up has been estimated (in a recent HRL study) at 3000 cubic metres per annum. At the foot of Shakespeare Cliff reclamation work has started on what will be the mouth of the proposed Channel Tunnel. Pockets of sand and shingle appear intermittently along the coast between Dover and Folkestone as far as the eastern outskirts of Folkestone. The sea walls are fragmentary along this stretch and are owned and maintained by British Rail. The total frontage protected by walls is about 4.2km. The area landward of the railway line to the east of Folkestone is known as the Warren and erosion and massive slippage here has been a problem for many years. The reason is that the chalk cliffs overlie a bed of impervious Gault Clay and landslips occurred regularly prior to the construction of toe weighting sea walls. It is believed that over-saturation, after periods of heavy rain, reduce the shearing resistance of the strata. It is also thought that beach lowering in East Wear Bay, probably caused by the building of the Folkestone harbour breakwater in 1875, could also be a contributary factor. In fact the littoral supply has dwindled to such an extent that the shingle no longer enters East Wear Bay from the west. Adjacent and to the east of Folkestone Harbour, is a 300m long concrete sea wall. Built in 1935, its condition is thought to be adequate. This area of East Cliff Sands is the town's main beach. It once had a continuous shingle beach but the shingle has all been transported eastwards by wave action. The cliffs east of the harbour have been eroding for many years resulting in the deposits of large slabs of mudstone on the foreshore at Copt Rocks. This area is the site of the C.E.G.B. twin-cable cross-channel links.

The piers of Folkestone Harbour are owned and maintained by Sealink U K Ltd. The harbour is too small for the large modern vessels and the cross channel ferries tie up at the stone pier. From Folkestone Harbour west to Park Field on the western side of Hythe, coast protection consists of some 7.6km of stone and concrete sea walls, fronted by groynes for most of their length. The walls are of various ages from pre 1940 and are generally thought to be adequate. The groynes however are variable, with some in poor condition. Largely the responsibility of Shepway District Council, some short lengths are private and the Department of Transport are responsible for a length fronting the road at Sandgate. The littoral drift is from the west and the rate of accretion against the west pier at Folkestone is estimated at about 3000 cubic metres per annum. With the heavily groyned foreshore to the west coupled with dwindling beach deposits, the rate of beach build up west of Folkestone will almost certainly reduce in the future.

Hythe was originally on the sea but due to shingle build up over a number of centuries, it is now some 800m inland. The phase of accretion has ceased and erosion is now taking place. At the east end of the town there is now little in the way of shingle bank protection. The low lying land between Sandgate and Hythe is protected by a sea wall. With the shingle beach fronting this wall dropping, the wall is subject to frequent wave overtopping. To the west, the shingle and sand beach is protected by concrete and timber groynes and backed by a long straight promenade. The nett littoral drift is from west to east, the beach material being predominantly shingle. Beach levels in front of the promenade at Hythe have also fallen and there is frequent overtopping and flooding, especially along the western half of the frontage.

From west of Hythe south west to Dymchurch Redoubt, a shingle ridge, breastwork and groynes protect Ministry of Defence property. Flooding has taken place here also and some of the Martello Towers have now disappeared into the sea. The sea defences require a good deal of maintenance.

From the Redoubt to the western end of the district boundary, a distance of some 2.6km, there are various sea walls, shingle and clay banks and sand dunes with some groynes. This stretch which includes Dymchurch, St Mary's Bay, Littlestone on Sea, Greatstone on Sea, Lydd on Sea and Dungeness, is the responsibility of Southern Water who protect the low lying hinterland. The area is not eroding at a serious rate and the dunes at Greatstone are in a reasonable condition. The nett drift is generally from the south, although in the shelter of Dungeness at Lydd, there is a local reversal in drift direction.

Dymchurch itself lies some 2m below high water and is protected by a massive sea wall (known as the Dymchurch Wall). This wall, built originally in medieval times has been reconstructed many times, the last being after the 1953 storms.

The shingle ridge, (with sand at low water), running along the shoreline is continuous as it runs south past Littlestone and Greatstone. North of Lydd on Sea the beach becomes very wide with the low water line being some 800m offshore. At Littlestone on Sea the shingle ridge was re-nourished in 1981 to protect the existing sea wall. The coastal strip, between Pope's Hotel and the Jesson Outfall, was nourished with approx 165000m^3 of shingle and the annual replenishment rate is estimated as $6000m^3$ (Foxley & Shave, Ref 43).

South east of Lydd is Dungeness which has built up out of a succession of shingle ridges developed over the last five thousand years or more. Dungeness Point, the most southerly tip of Kent, became an S.S.S.I. in 1951. The coast to the west of the Point (which is slowly migrating eastward) is liable to erosion whereas that to the east has been steadily accreting. Off the ness, the shingle beach slopes steeply into deep water (the low water line being within 90m of the beach). Drift is from west to east around the ness and a substantial amount of material passes around the headland coming to rest just east of the ness. The Central Electricity Generating Board carry out regular monitoring along the power station frontage and maintain beach levels by recycling shingle from east to west. Most of the material removed from the ness is dumped updrift at the western end of the frontage. Some material is also transported to specific locations where beach levels are low. The shingle is then redistributed naturally by wave action in an easterly direction. The volume of the recycled material varies but Summers (Ref 28) in 1985 has quoted a figure of between 15,000 and 30,000 cubic metres per annum.

5.4 Dungeness Point to Beachy Head

There was once a continuous shingle beach stretching along the whole frontage from Beachy Head eastwards (in the direction of nett littoral drift) to Dungeness. These beaches have since been modified to a large extent by the construction of coastal defences and harbour works. The coastline is now heavily groyned in an attempt to reduce the rate of coastline retreat. There is also a general depletion of beach deposits now that much of the coastline is prevented from eroding by the construction of long stretches of sea wall. The areas of natural accretion at Langney Point and at Dungeness are now no longer building out at the rate that took place in historic times. Indeed there is evidence that accretion at Langney Point has now ceased (Ref 19) although the data on which this premise is made covers rather a short time span (10 years).

Beach erosion cannot be attributed entirely to the construction of coastal defences though these have undoubtedly led to the present fragmentation of beaches. The secular rise in sea level is thought to be higher in this part of the UK than elsewhere. This rise though small in absolute terms (1 to 2mm per annum on average) has a profound effect on the shaping of the coastline. With this gradual increase in sea level, there is a tendency for the beaches to adjust by migrating landwards. Preventing this migration has led to falling beach levels in front of sea walls and a policy of restoring the beaches by artificial re-nourishment has been undertaken by Southern Water. Similar policy will also have to be considered by the small authorities (e.g. borough and district councils). Because of the high cost of nourishment a 'joint approach' may be necessary to tackle this problem.

Southern Water protect extensive low lying areas from the (Kent/E.Sussex) county boundary near Lydd, west to the eastern edge of Cliff End near Hastings.

From east of Lydd to Camber, the frontage which is called Broomhill Sands, has a wide sand foreshore backed by a shingle ridge covering the clay floodbanks. To the west of Broomhill Sands, the sand dunes that back Camber Sands have eroded over recent years and they are now largely fenced off with a replanting (marram grass) scheme in progress. At low water the sea retreats some 800m exposing a large sand beach. To the west is the outfall of the River Rother and Rye Harbour. A problem here is the interruption of littoral drift by the East Pier of Rye Harbour. The coast to the east of the harbour is subject to a recession of about 2m per annum (Southampton Univ Seminar, Ref 47). Recycling is therefore carried out on a regular basis to maintain a continuous shingle ridge. The volume of shingle recycled annually is about 31,000 cubic metres, taken from the east face of Dungeness and deposited on Broomhill Sands (the Walland foreshore).

The Pett Level foreshore between the Rother and Cliff End has also been eroding for many years. Timber breastworks built in the 1930's had to be replaced by a sea wall in the 1950's. Erosion still continued and within a few years the toe of the wall was in danger of undermining. A large re-nourishment scheme was then undertaken involving importing 150,000 cubic metres of shingle from just west of the Rother entrance. Since then annual recycling west of the harbour has been carried at the rate of about 19,000 cubic metres per annum (Ref 47).

At Cliff End, rock fill backed by a sheet steel piled revetment, fronts the village and the very sparse shingle beach still has war time defences of angled concrete blocks scattered along its foreshore. There is also some revement protection using double-wedge concrete armour units at the cliff toe. Unprotected sandstone cliffs then extend east to Hastings. At Fairlight, some 46 houses on the top of the crumbling sandstone cliffs are in danger of disappearing into the sea. Average recession here is about 1m annually (New Civil Engineer, Aug 1987).

The old town of Hastings is backed by steep soft sandstone cliffs (with clay beds) and just east of the town centre there is a rather dilapidated breakwater composed of large concrete blocks with a stone groyne at the east end of the wall. The harbour itself consists of two breakwaters, the western one being in poor condition, having been breached in two places and partly repaired with concrete armour units. There is a wide shingle beach immediately to the west of the harbour as a result of the breakwater having partially held up the west to east littoral drift. A scheme to permit the controlled eastward movement of drift material is proposed for 1988/89, by the construction of a 'notch' in the breakwater (or groyne) on the east side of the harbour. The Hastings frontage as far west as the West Marina, St Leonards (some 3.9km) is the responsibility of the Hastings Borough Council and is protected by a concrete sea wall and masonry and concrete groynes. As mentioned above, the shingle beach gives good protection at the east end of this frontage extending west almost to the pier. Built in the 1930's the wall is thought to be adequate and the groynes variable. The beach west from the pier to St Leonard's is rather narrow, but will benefit from a current major scheme to reconstruct groynes, replace wave "deflectors" over a 1.7km frontage and provide approximately 230,000 cubic metres of beach nourishment during the period 1988/90.

From the West Marina, west to the Hastings borough boundary, protection of this low lying land against flooding comes under the jurisdiction of Southern Water. Coast protection here comprises a shingle bank backed by some 500m of timber revetment (in the centre of the coastal strip) and groynes. This low lying area (called Glyne Gap) is unprotected by sea walls and has been subject to serious beach lowering. Late in 1987 the beach was recharged with almost 58000 cubic metres of shingle over 0.4km of frontage. Groyne refurbishment is also being undertaken.

Galley Hill lies at the western end of this frontage, and in front of this hill and extending westwards to Bexhill is a concrete sea wall. Bexhill beach consists of shingle overlying a wave cut platform of soft silt-stone. The Bexhill frontage has been suffering from a dwindling supply of shingle from the west although no more so than elsewhere along the Sussex coast. It has been estimated that in a period of 10 years from 1975, some 254,000 cubic metres of shingle have been lost out of the frontage (HRL Seminar, Ref 28). The nett west to east littoral drift along the Bexhill frontage is of the order of 15,000 cubic metres per annum. This quantity represents the difference in volume between the material reaching the area and the greater quantity of material being transported eastwards. An estimated 152,000 cubic metres of shingle has been placed in this area as beach nourishment and a massive new groyne system was constructed between 1975 and 1985. The problem has therefore now been transferred to the Glyne Gap frontage to the east (i.e. downdrift) and this area, as mentioned above, is reaching a critical state.

At the western end of Bexhill as far as Cooden, the foreshore is groyned, with a 400m long sea wall to the west and some semi derelict privately owned walls. The beach consists of shingle over a sandy foreshore. Along much of the coastline from Pevensey to St Leonard's, beach levels fluctuate markedly; the situation is quite critical in places. It would appear that Southern Water's beach mangement of the 'soft' coastline extending to Eastbourne is adequate, in as much as the shingle ridge protecting the low lying Pevensey Levels has not been breached this century. The likely need for a major groyne renewal programme, coupled perhaps with a reduction in the natural supply, has led Southern Water into considering a research programme aimed at identifying new beach recycling. This programme has yet to be implemented.

West of Cooden Beach Station the frontage is maintained by Southern Water. Low shale cliffs require protection from erosion and sea defence works have recently been carried out in the vicinity including shingle nourishment. Further west from the golf course to the Rother District Council's boundary (about 1½km beyond Norman's Bay village), Southern Water protect the low lying land with timber revetments along most of the 3.8km backshore and these are fronted by groynes. Southern Water also look after the Wealden District Council frontage beyond this point, around Pevensey Bay. This consists of some 3.5km of shingle bank, groynes and some timber revetments. Southern Water's jurisdiction extends almost to Langney Point (the ness of the Crumbles peninsula). This shingle beach is groyned and immediately north east of Langney Point, a breastwork prevents the outflanking of the terminal groyne.

Around Langney Point and extending about 1½km westwards the shingle beach and groyne system is maintained by Eastbourne Borough Council. The shingle beach is protected by dilapidated groynes, but is not eroding at a serious rate. Further west, in the vicinity of the Crumbles outfall, the foreshore over about ½km is maintained by Southern Water. In the past Eastbourne B.C. constructed a large terminal groyne (the Tanhouse groyne) just west of the Crumbles outfall, and this gives perennial problems to the Southern Water frontage. The groyne compartment through which the Crumbles outfall empties, which is invariably short of beach material has been improved by frequent strengthening of the shingle bank at the rear.

Eastbourne Borough maintain the foreshore from the Tanhouse groyne to Beachy Head. The frontage from the Crumbles outfall to Holywell at the west end of Eastbourne, is a distance of about 3.7km, and the coast protection consists of a concrete sea wall and groynes. The wall is thought to be adequate and the groynes are generally good although some need rebuilding. The shingle beach gradually narrows from east to west (i.e. an updrift direction).

From Holywell Retreat, west to the town boundary, the beach is held by groynes (no backshore coast protection) and their condition is generally good. However, the beach material contains more chalk pebbles than shingle. The chalk pebbles are derived from the continuing erosion of Beachy Head (as are the flints), where the chalk cliffs rise almost shear to over 150m.

5.5 Beachy Head to Selsey Bill

West of Beachy Head is Birling Gap. Here the near vertical cliffs back a small beach, comprising in the main, flint cobbles.

Cuckmere Haven to the west of the chalk cliffs of the Seven Sisters lies at the outfall of the River Cuckmere. Here a 200m long shingle ridge is cut through by the artificially trained river mouth. The training banks within the river and the shingle banks on each side of the river mouth as far as the cliffs, are the responsibility of Southern Water. The beach west of the river is protected by timber groynes. The river is also the boundary between Wealden District

Council to the east and Lewes District Council. Adjacent and to the west of the shingle ridge, is a privately owned sea wall and further west still, are gabions which look to be satisfactory. Both locally protect the base of the chalk cliffs against erosion. The gross rate of shingle build up at Cuckmere Haven has been measured by Southern Water (Beazley, Ref 2) and found to be of the order of 2,000 cubic metres per annum. This includes a small contribution from the cliffs of Seaford Head and the rest contributed by the nett west to east littoral drift.

The chalk cliffs to the west of Cuckmere Haven are fringed by a rocky foreshore. They are known as Seaford Head and extend round to Splash Point on the eastern edge of the town of Seaford. Southern Water are responsible for the sea defences from here to Newhaven Harbour. A concrete sea wall runs westward from Splash Point some 4km as far as the harbour. The main frontage of Seaford is fronted by what is now an ungroyned beach following a massive renourishment scheme to prevent waves from causing further damage to the sea wall. A recent study by HRL (Ref 26) has estimated that, given a 'full beach', the rate of littoral drift along the Seaford frontage would be 20,000 to 28,000 cubic metres per year. This figure is calculated for a situation in which shingle is allowed to move freely over the central frontage, merely being constrained by the presence of a large terminal groyne at the eastern end and the sheltering effect (reducing the drift to almost zero) of the Newhaven breakwater at the western end. This low rate of drift is because the coastline faces the predominant south westerly wave attack, and hence waves break almost parallel to the beach contours, thereby producing little alongshore movement. Because of the small angle of wave incidence any variation can cause the drift rate to vary markedly from year to year.

The entrance to Newhaven Harbour is protected by two breakwater arms, with the western arm (built in the late 19th century) being considerably longer so as to cut off eastward migrating shingle from blocking the harbour mouth. A marina and small sandy beach lies in the shelter of this western breakwater. Beach accretion, since the construction of the west breakwater, has led to the development of a wide shingle beach immediately west of the harbour. Initially the build up took place here at some 15,000 to 20,000 cubic metres per year but the beach has now become almost stabilised.

West of Newhaven there is a 2.5km stretch of unprotected chalk cliffs, and beyond that almost continuous concrete sea walls protect the toe of the cliffs as far east as Brighton Marina.

Peacehaven to the west has about 1.5km of new concrete sea walls and groynes, and at Telscombe, a concrete apron (150m) serves as protection to a Southern Water sea outfall. To the west at Saltdean, a 200m length of concrete sea wall, built in 1964 and recently rebuilt groynes mark the western end of the Lewes District Council's boundary and the eastern end of the Brighton front. The greater part of this frontage is now protected by sea walls.

Brighton Borough Council are responsible for a total of 8.8km of coastline which is divided into 2 nearly equal lengths by the privately owned Brighton Marina. The eastern length has masonry and concrete sea walls and groynes, protecting the chalk cliffs, which were built between 1931 and 1935. The walls and groynes are in poor condition and subject to a planned scheme to replace them in the near future.

The Marina, which was opened in 1978 and is now owned by Brent Walker, encloses 1km of a masonry and concrete sea wall at the base of the chalk cliff. The Marina breakwaters are constructed with large concrete caissons. From the Marina westwards the 3.7km of coast consists of shingle beaches retained by old masonry and concrete groynes and more recent timber groynes. The west to east longshore drift is estimated at 12,000 cubic metres per annum and this has built up the beaches west of the Marina. Some of this drift, possibly further off shore, is believed to pass around the Marina to the beaches on the east side.

Hove Borough Council cover the Hove front westward to Portslade by Sea, a length of 3.3km. This frontage, from the western end of Brighton to east of Shoreham Harbour has a concrete sea wall along much of its length. The wall, started in 1885, is generally good. Groynes mostly built since 1946 are also generally in good condition. A short section is privately owned and maintained. The shingle beaches from Portslade westwards to Shoreham Harbour gradually deteriorate due to the lack of littoral supply.

East of the harbour mouth CEGB have relinquished their sea defence responsibilities over 2km of coastline which now lie with the Shoreham Port Authority.

Shoreham Port Authority own approximately 900 metres of frontage within the Hove Borough Council area. These defences comprise revetments and sea walls which are in either fair or poor condition. Many of the groynes in this area have been recently refurbished and are in good condition although some have deteriorated to the extent of being redundant. Beach levels are generally low.

Shoreham Port Authority are also responsible for the 2.1km stretch of coast east of the harbour entrance, which lies within Adur District. The shingle beaches at the east of this section are in a healthy state having accumulated against substantial steel sheet piled groyne structures. However, further west beach levels are low exposing the steel sheet piled bulkhead wall and immediately to the east of the harbour entrance where stabit armour units have been installed to absorb the wave energy, beach levels are very low. This latter area has been almost entirely deprived of littoral supply which is blocked by the harbour entrance breakwaters.

The Port Authority have recently commenced a programme of groyne refurbishment in this area and will shortly undertake a beach replenishment scheme. In addition it is planned to improve the sea defences over a length of 500 metres immediately east of the harbour entrance over the next two years. The first phase of this improvement will be a design study which is to be commenced in April 1988.

Shoreham Port Authority are also responsible for the piers and breakwaters at the entrance to the harbour (the outfall of the River Adur), while Southern Water protect about 6.2Km of low lying land to the west of the entrance as far as the Worthing Borough boundary (west of Lancing). Sea defence here is a wide shingle beach, intermittent walls and revetments and groynes. This beach has accumulated at the eastern end following the construction of the present (outer) harbour arm with the initial accretion being of the order of 15,000 cubic metres per year (this being the potential drift rate along this part of the coast).

The whole frontage of Worthing, West Worthing and Goring by Sea is the responsibility of Worthing Borough Council. The frontage is some 7.5km long and groynes (backed by a promenade) retain a shingle beach. West Sussex County Council share some costs where highway protection is concerned. The beaches here, as elsewhere along the coast, are gradually deteriorating and further nourishment is required to make up beach losses.

Arun District Council are the coast protection authority from Ferring, west to Pagham Harbour. The easternmost 300m is groyned and this is maintained by Worthing Borough Council who own the land. Timber breastworks and groynes protect the coast for about 700m west to Ferring Rife. Built about 1960 their condition is rather poor. The shingle beach which is pebble scattered and sandy at Ferring Rife is maintained by Southern Water and protected by timber breastworks and groynes.

From Ferring Rife west to Rustington the shingle and sand beach is protected by groynes (some fairly new) and backed by occasional walls and timber breastworks of varying condition. Much of this area has private estates backing onto the foreshore. The coastal defences in these areas are somewhat fragmentary and the beaches in variable condition. The coastline is very segmental with any hard point resulting in the development of strong indentation downdrift (i.e. to the east) due to the interruption of shingle movement. The plan shape of the high waterline is thus saw-toothed in appearance. It is fair to say that many stretches are currently inadequately protected although much work is being carried out by the local authority, including monitoring of the coastline, determination of wave climate and assessment of shingle movement and flooding risk. The coastal defences along much of the frontage are being presently upgraded, and a programme of groyne replacement is well underway.

On the Arun District Council's frontage where breastworks are still maintained, they are very much a secondary defence with shingle beaches forming the primary protection against the sea.

From Rustington through Littlehampton to the River Arun a concrete sea wall (2km long) and groynes protect the coast and Arun District Council have now taken over responsibility for the whole frontage (West Sussex County Council used to maintain the eastern end). Groynes along this frontage are being replaced as necessary. Some erosion of the shingle beach was taking place in certain areas but the groyne reconstruction has gone a long way to improving the situation. The Littlehampton Harbour Board maintain the piers, jetty and training walls at the mouth of the river.

West of the Arun to Middleton, a length of 4.5km, the defences of sand dunes, a shingle bank, timber breastwork and groynes are maintained by Southern Water who protect the low lying coastal area. At the western end of this frontage, beach nourishment has been carried out on a large scale to prevent overtopping of the shingle bank.

The frontage of Middleton and Felpham (some 3.8km) is protected by concrete sea walls and timber breastworks fronted by groynes. The coastline is irregular in plan shape and there are local problems (due to downdrift erosion) at those points where the coastline has a 'dog leg'. There is still a distinct erosion and flood risk along this frontage (at Middleton and at Elmer).

Bognor Regis is protected by concrete and masonry sea walls and groynes. Their condition is variable and some are in a poor state. The groynes are in a reasonable condition but the beach is liable to get dragged down during storms and the town centre is liable to be flooded. Southern Water maintain 800m at the eastern end in the vicinity of the Aldingbourne Rife Outfall. Total length 3.8km.

From Aldwick to Pagham (3.3km) the beach is groyned and partly private. There are local problem areas, especially east of Pagham Harbour where the beach ridge is receding landwards, following a long period of accretion. Southern Water maintain the shingle banks fronting Pagham Harbour and these also require periodic renourishing or regrading.

Although this volume should finish at Selsey Bill, this area is one of drift divergence and for completeness the coastline description has been extended north-westwards to Chichester Harbour.

From Pagham Harbour and around Selsey Bill the coast protection authority is Chichester District Council. From the harbour entrance to Selsey East Beach, low lying, part marshland is fronted by a groyned shingle ridge. There is intermittent protection to the crest of the ridge in the form of vertical timber breastworks. From East Beach south-westwards to Selsey Bill a concrete seawall protects the low lying hinterland. The shingle beach in front of the wall is variable with a healthy accumulation in some groyne compartments and a lack of shingle in others giving the latter a saw-toothed plan shape with regard to beach contours. Recent coast protection works have included the reconstruction of over 600m of "backwall" with reinforced concrete replacing timber planking at the base of the wall, presumably for added support.

Littoral drift along this frontage is in a nett north eastward direction.

At the Bill 3/4km of frontage consists of a shingle beach backed by eroding clay cliffs. The backshore is partly protected by a dilapidated concrete wall at Bill House, some gabion work further west and a short length of deteriorating timber breastwork at the eastern end. Erosion of the cliffed backshore is severe in places to the west of Bill House. The timber breastwork is frequently overtopped at high water and the backshore has to be maintained by frequent backfilling with shingle at the rear of the breastwork. This frontage probably gets very little feed from the west but is perhaps fed from the offshore shingle banks of the owers, and possibly also by pebbles rafted with kelp and brought ashore in storms. To the west of the breastwork about 1km of frontage is protected with a vertical concrete wall with a stepped toe. This area once had a shingle beach but this has largely disappeared and the sand cover over the clay substratum is now quite thin. Wave overtopping takes place at high water even under low wave conditions. Prior to the construction in the 1950's of the present system of defences (which are now deteriorating) this area had the reputation of being one of the most rapidly eroding parts of the UK coast (Ref 6). The sand beach along this frontage is groyned. Work was recently carried out at Selsey West Beach at the western end of this wall. This included the stepped encasement of 300m length of sloping apron to the existing wall. A number of the timber groynes were completely renewed and a number of concrete battresses constructed to the roots of the groynes. The wall has also been extended westwards, following the set back due to the recession of the adjoining unprotected length of cliff. The area protected by the concrete wall is believed to be a point of drift divergence and any supply from offshore appears to be insufficient to make up the deficit caused by the material being transported both eastwards and westwards out of the area.

There is a short stretch of natural cliff west of the coastguard station and this cliff is fronted by a wide shingle beach. Further westwards the cliffline drops and the shingle ridge extends continuously over a frontage of 4½km maintained by Southern Water, and protecting low lying land. Maintenance consists of groyne repair, addition of gravel from inland sources and regrading of the beach profile (ie. heightening) so as to prevent wave overtopping and breaching.

From Medmerry to Chichester Harbour the frontage is maintained by Chichester District Council and protection consists of concrete sea walls (at Bracklesham) and vertical timber breastworks (at East Wittering). The shingle beach overlying the flat sand foreshore is not substantial and overtopping of both the sea wall and the timber breastworks occurs at high water even under small wave heights.

Further westwards to East Head Spit the shingle ridge is protected at strategic places by vertical timber breastworks and gabion revetments and at the "knuckle" of the Spit, by breastworks and a gabion wall. The beach is groyned in order to retain the dwindling supply of shingle from the east. The volume of drift in recent years has declined and there now appears to be little input of material to Chichester Bar. East Head Spit has varied in size over the years but has gradually recurred northwards into the harbour since about 1898. There are now local fears that the neck of the spit may become breached under sufficiently adverse wave and tidal conditions.

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FIGURES

Time Scale (m years)	Geological Period	Rock Types	Duration (years)
Present day	Quarternary	Holocene - alluvium, dune sands, marsh clays	c 10000
1.8		Pleistocene - glacial till, sands, gravels, periglacial head, loess and fluvial deposits	c 1.8m
36.0	Eocene	Bracklesham and Bagshot Beds - sands and clay London Clay Oldhaven, Blackheath, Woolwich, Reading and Thanet Beds - sands and gravels	30m
66.0	Cretaceous	Chalk (Upper, Middle and Lower) Upper Greensands and Gault Clay Lower Greensands Weald Clay Hastings Beds - sandstones	69m
135			

FIG 1 Geological Time Sequence for the South-east Coast

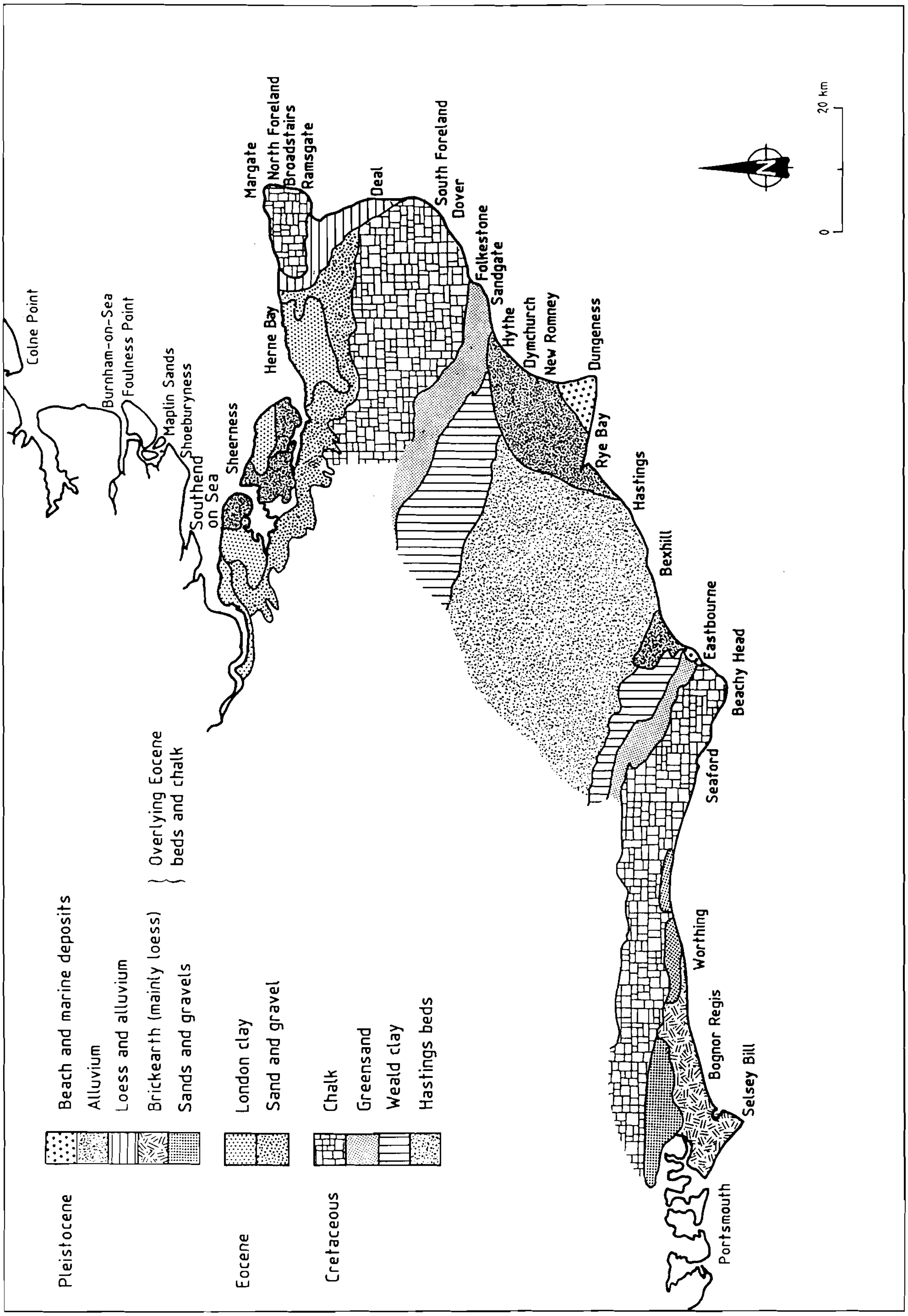

Fig 2 Simplified geology of South East England

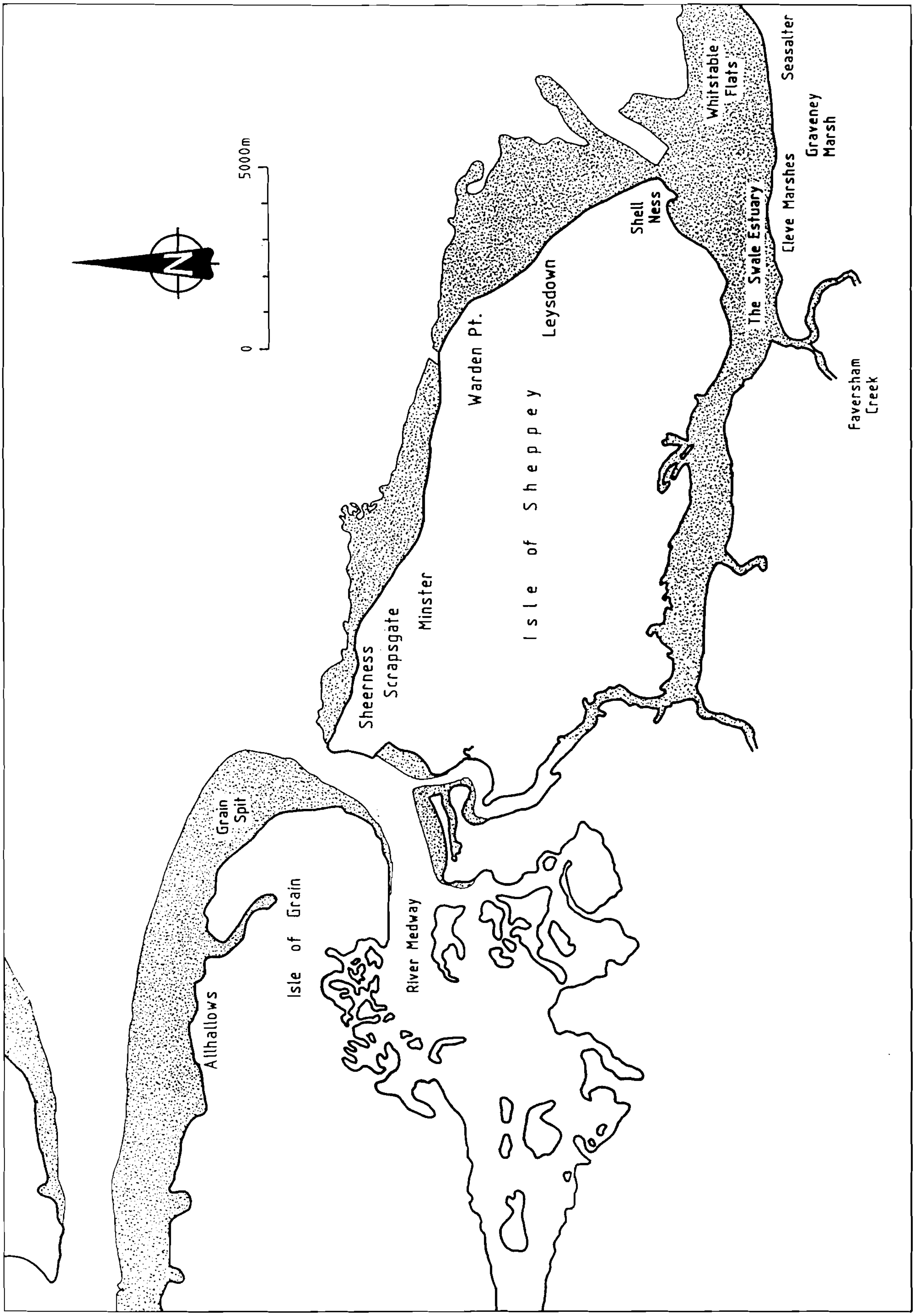

Fig 3 Isle of Grain to Seasalter

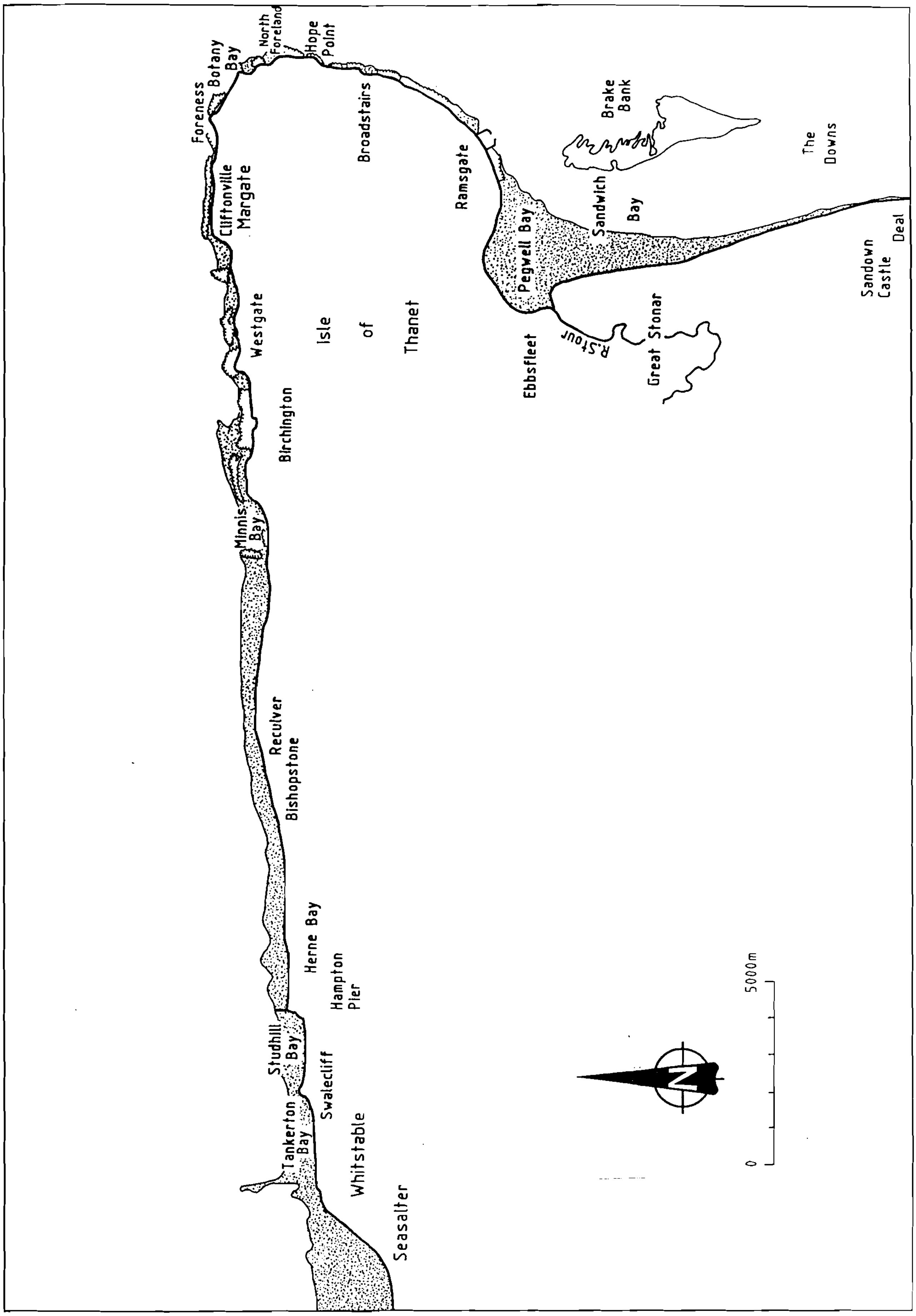

Fig 4   Seasalter to Deal

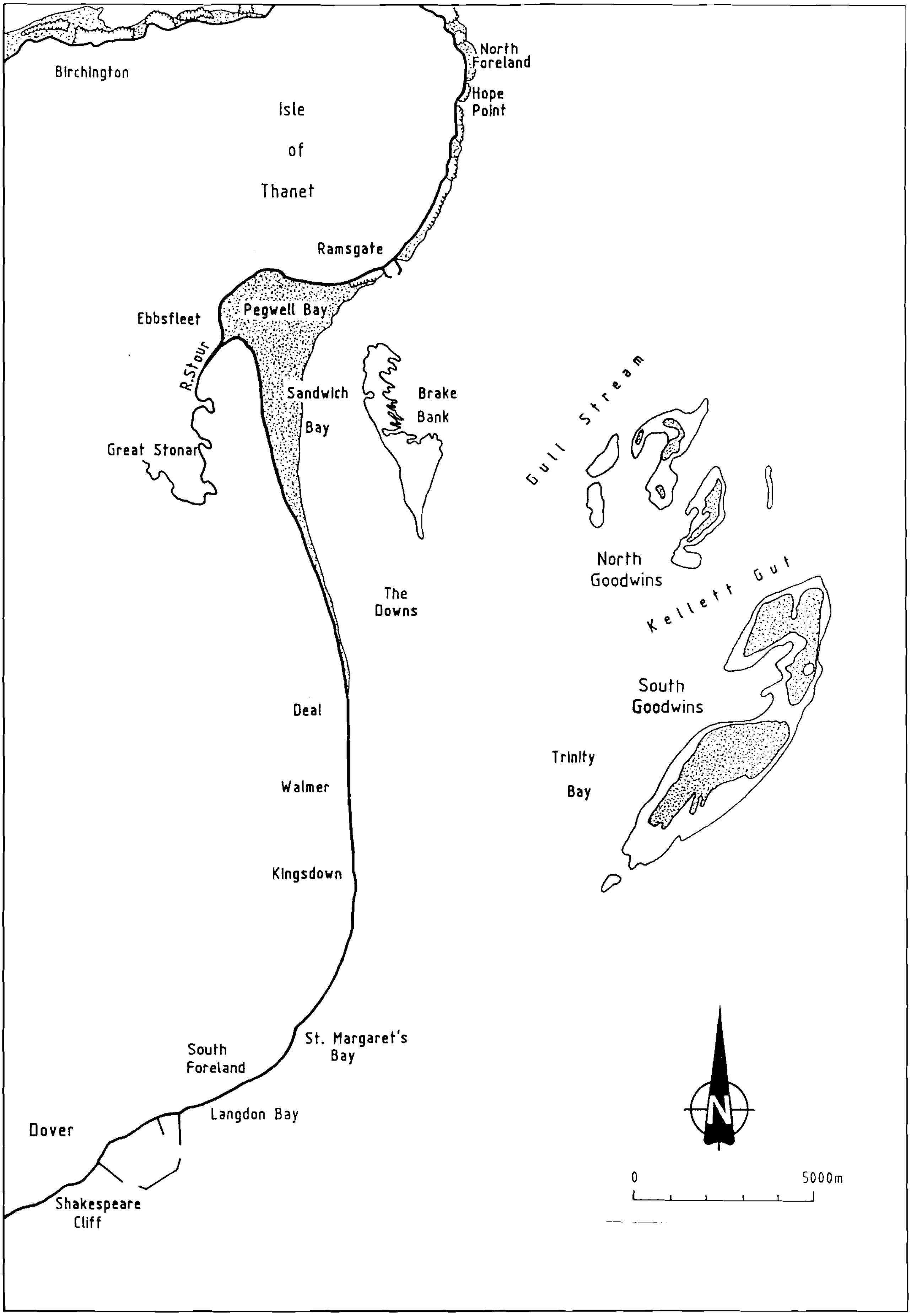

Fig 5 Deal to Dover

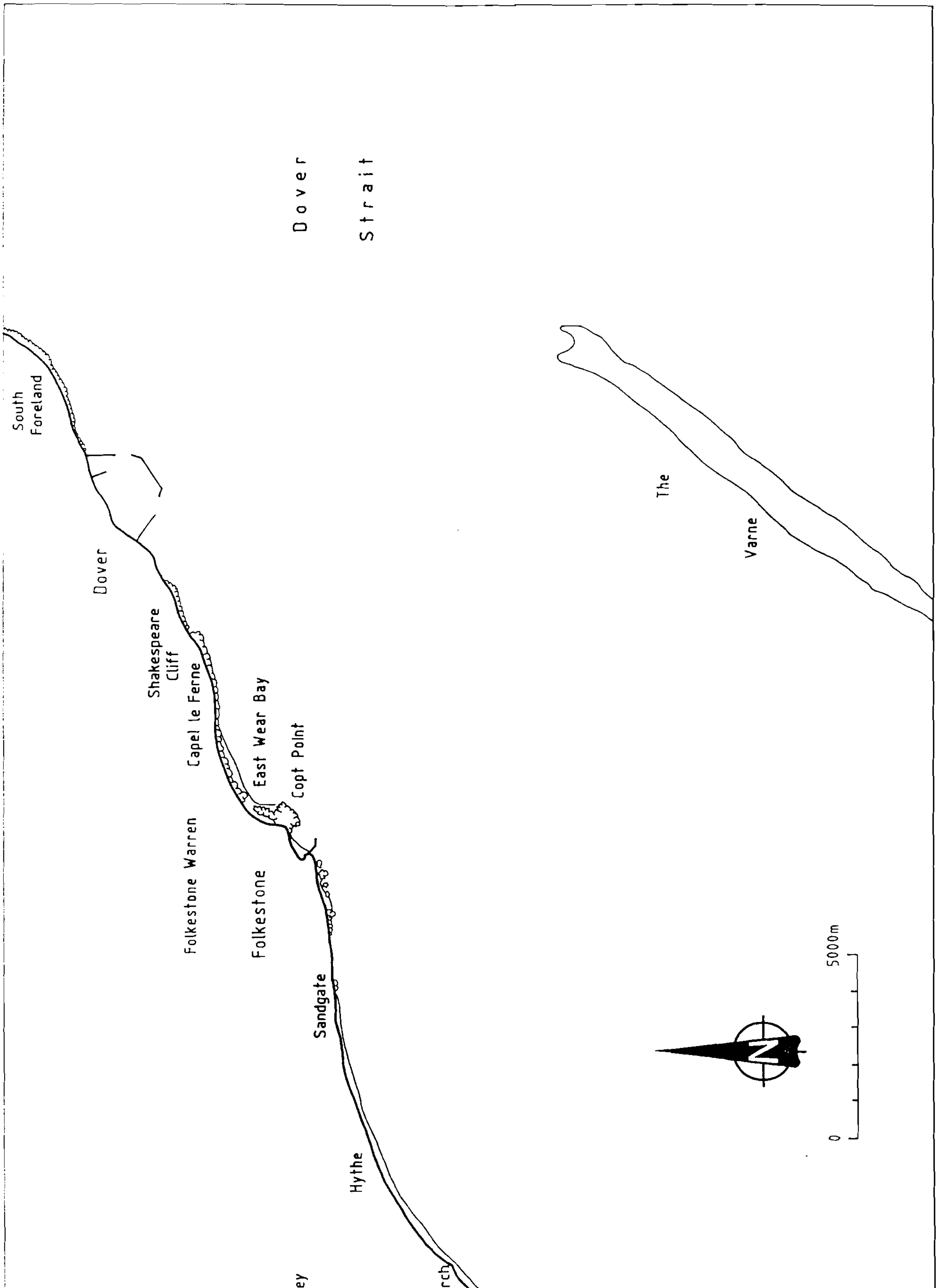

Fig 6 Dover to Dymchurch.

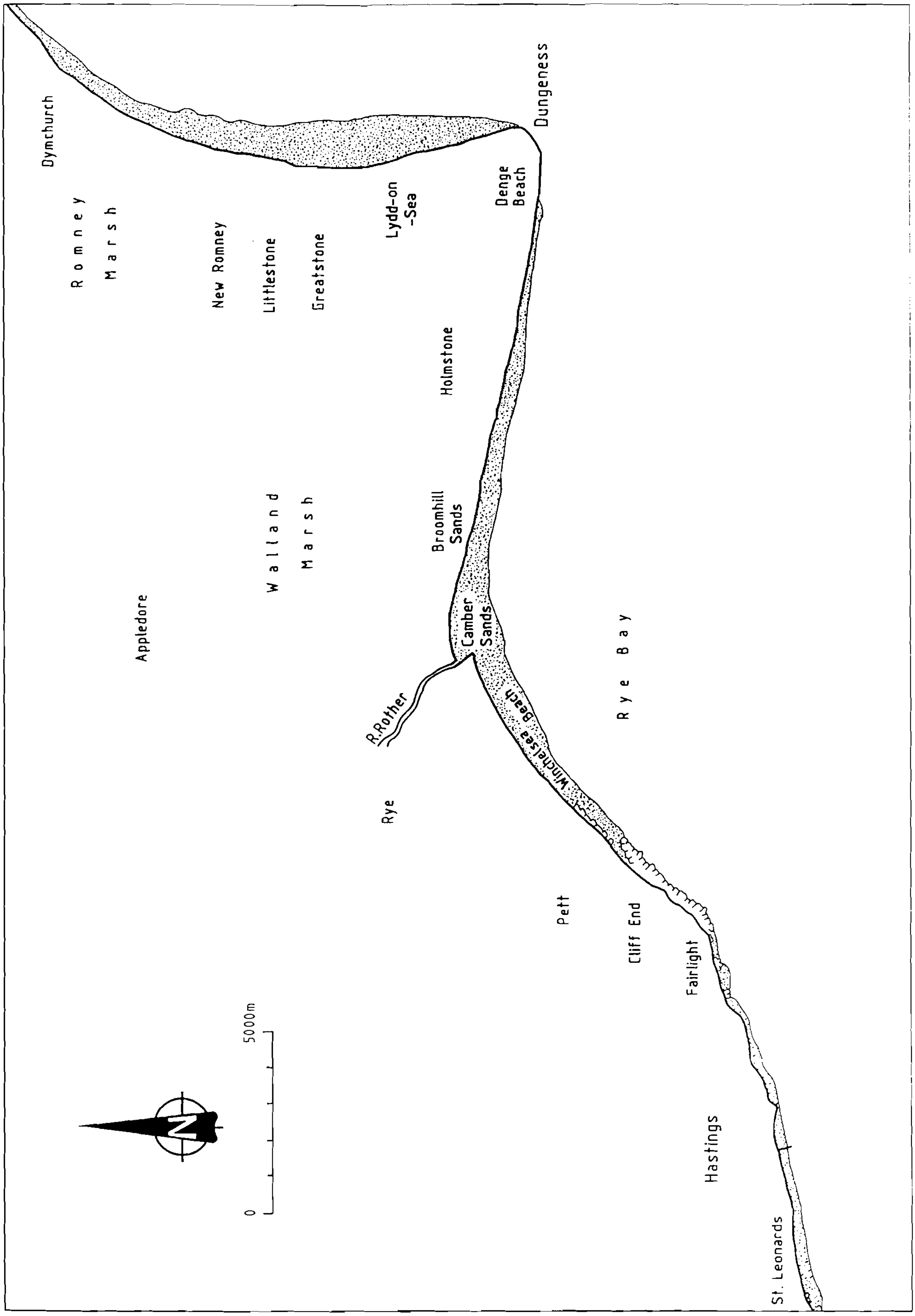

Fig 7 Dymchurch to St. Leonards

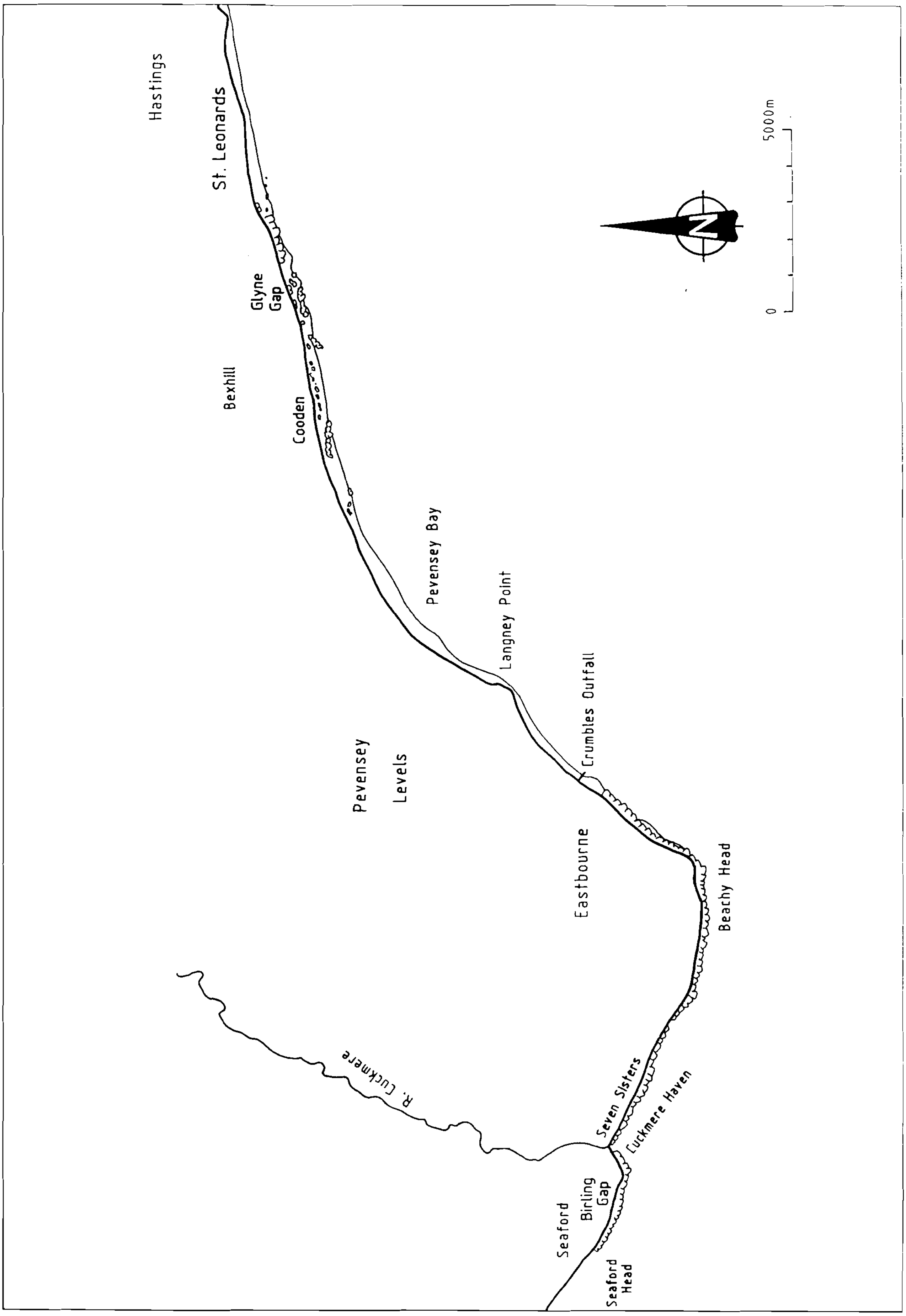

Fig 8 St. Leonards to Seaford

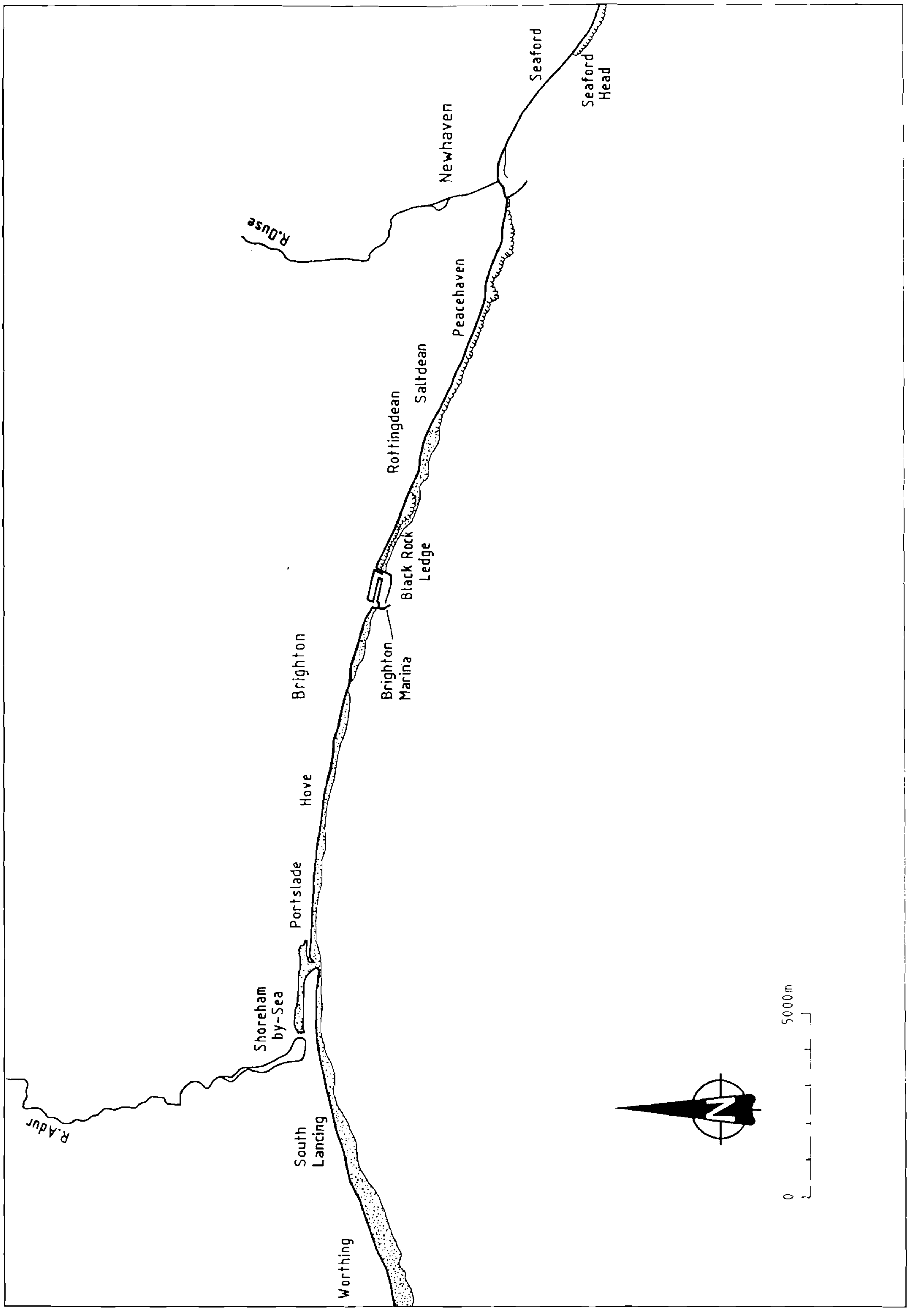

Fig 9 Seaford to Worthing

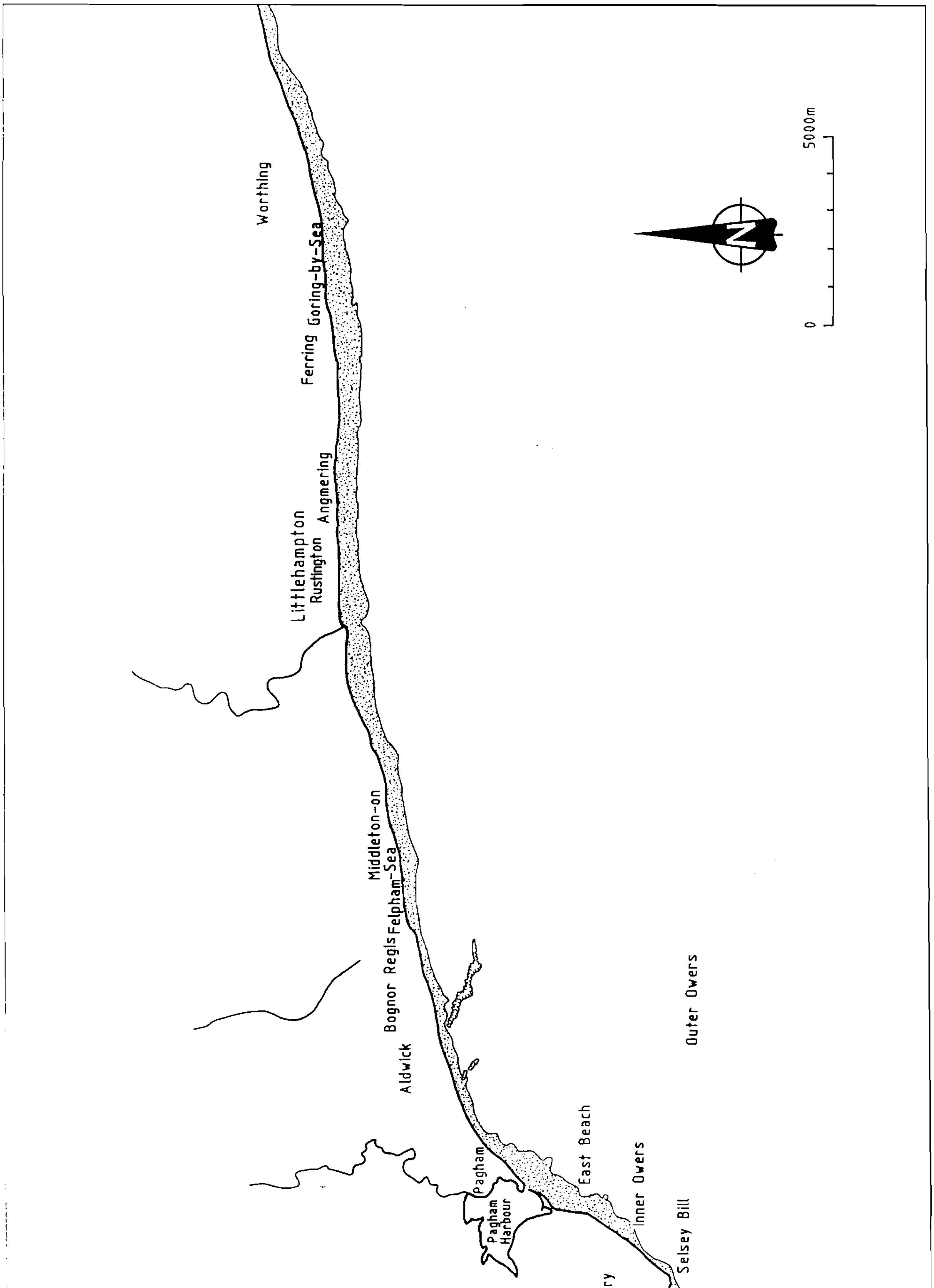

Fig 10 Worthing to Selsey Bill