HURST SPIT STABILISATION SCHEME
DESIGN AND CONSTRUCTION OF BEACH RECHARGE

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ABSTRACT

Hurst Spit is a barrier beach which provides protection from flooding and erosion to an extensive area of low lying land. It has a recent history of spectacular sluicing overwashing and barrier breakdown during severe storm events. The spit has declined I volume over a number of years, due largely to updrift coast protection works causing starvation of the shingle supply. Subsequently, the frequency of wave overtopping has increased causing the loss of large volumes of material from the system.

A beach management strategy has been developed for Hurst Spit, including beach recharge and rock structures. This paper discusses details of the design and construction phases of beach recharge elements of the scheme. The scheme comprises a number of unusual approaches to design. These include:

a) Design of a beach recharge scheme for a barrier beach
b) Design of innovative terminal beach control structures
c) Sourcing and supply of beach recharge materials from a new aggregate production license, from within the coastal cell

The design programme, which includes physical model testing and offshore exploration techniques, is discussed together with implementation of the construction programme.

1 INTRODUCTION

Hurst Spit is sometimes aptly referred to as the “Guardian of the Western Solent”, providing protection to an extensive low lying area from severe wave attack in south westerly storms. The spit protects internationally important wetlands, Hurst Castle, and prevents wave attack from reaching the low flood walls between Keyhaven and Lymington (Figure 1). The declining volume of the spit, which is due primarily to a diminishing sediment supply from updrift beaches, resulted in a diminished defence standard which had become liable to breaching in storms which could be expected at least once per year. An extensive research and monitoring programme was used to examine a wide range of technical, environmental and economic issues, to determine the most appropriate means of improving the protection standard.

The environmental significance of the site provided a design challenge to improve the defence standards to an acceptable level, whilst maintaining the conservation value of the site. A major recharge of the barrier beach using material which matched the indigenous shingle grading, in conjunction with control structures, was considered to provide the most balanced option.

2 DESIGN CRITERIA

Whilst most beaches form part of an integrated defence system, which include solid features such as sea defences or cliffs, Hurst Spit is a barrier beach acting as the sole line of defence to the land in its lee. Hurst Spit is a dynamic structure which can suffer catastrophic failure, leading to extensive damage in a single storm event. Unlike restrained beaches, the changes effected by storm action on barrier beaches are irreversible processes and leave permanent changes and weaknesses within the defence. The beach performance is extremely sensitive to small changes in geometry, wave and water level conditons.

Hurst Spit is an important environmental feature, which has a number of functions apart from those associated with coast protection and flood defence. These include protection of the nearby nature reserve which has SSSI designation in respect of the salt marsh and shingle plant communities, and also as a breeding and feeding ground for birds. The spit itself is also designated as a morphological SSSI, although some of its value in this respect has been lost due to earlier coast protection work in the area. The stabilization scheme has been designed to preserve the conservation and aesthetic qualities of the area in as sympathetic a manner as possible, but without compromise to the safety of the design.

Probabilistic risk assessment procedures have been applied to a range of management scenarios for Hurst Spit using a statistical analysis of joint probabilities of wave and water levels, a wide range of beach geometries, and allowing for a range of levels of investment. These have been analysed by sensitivity testing of a wide range of storm events and storm profiles in varying sequences of events. The scheme design allows for the occurrence of all those events which should statistically occur within the design life.

Various combinations of waves and tides produce alternative design conditions with similar joint probabilities. Each has been considered as a separate design condition, due to the complexity and variation of failure mechanisms that can result in breaching of Hurst Spit. Combinations which lie between extreme combinations were also considered. The conditions given below have a probability of exceedence of 39% during the 50 year design life of the scheme and represent the 1:100 year joint probability return period events.

Tide Level	Offshore Wave Conditions		Inshore Wave Conditions		Probability of exceedence during scheme life
(mODN)	Hs (m)	Tm(s)	Hs(m)	Tm(s)	
2.27	5.84	8.5	3.76	10.0	0.39
0.87	7.9	9.6	9.6	11.2	0.39

Table 1 Hydrodynamic Design Conditions (Hydraulics Research 1989)

Wave conditions shown are for the most exposed western end of the spit. Energy dissipation provided by the offshore banks (Figure 2) reduces the long shore wave energy significantly from west to east and the near shore significant wave height falls from 4.1m to 3.1m within a distance of just 2.5km in the design storm. The scheme has been designed to withstand a 1:100 year return period storm, but the difference in design for a 1:50 year event or 1:500 year event is negligible at this site, due to the very smallchanges in design conditions over the range of extremes.

3 HYDRAULIC MODEL STUDIES

An extensive series of hydraulic model studies were carried out to test the proposed designs and to fine tune designs for maximum cost effectiveness and hydraulic performance. The objectives of the model studies were:

(i) Identify the various combinations of wave and water level conditions that cause overwashing of Hurst Spit
(ii) Determine the rate of loss of shingle from Hurst Spit under storm and "average" conditions.
(iii) Compare the performance of proposed stabilization measures with the exiting Spit.
(iv) Examine the effects of existing structures on shingle transport, such as groynes at Hurst Castle and Milford on Sea.
(v) Identify threshold crest levels and widths to provide alarm levels prior to failure of the shingle barrier
(vi) Evaluate stability and hydraulic performance of existing and proposed structures
(vii) Identify a planned maintenance programme following beach recharge.
(viii) Identify the most cost effective and environmentally acceptable strategy for the maintenance of Hurst Spit.

Analysis of beach profile field data indicated that damage to the Spit occurs most frequently in severe wave conditions associated with storm surges. A range of water levels indcluding extreme storm surges were considered in combination with storm waves, tidal currents and frequently occurring conditions, in various sequences. Beach responses to these processes were examined, by measurement of short term changes to the beach cross section profile and plan shape. The beach was modeled at a scale of 1:40, in four segments which were linked together by mathematical modeling to produce an overall picture of the performance of Hurst Spit. The large model scale allowed the sediment response to waves to be reproduced with a high degree of confidence and also allowed rock armour movement to be reproduced and monitored accurately. Changes in alignment of the Spit and effects of sediment control structures, such as groynes at Milford on Sea and the terminal basion at the eastern end of the rock revetment were also examined.

The test programme was broken down into the following elements:

(i) Mathematical modeling of the nearshore wave climate
(ii) Validation of the physical model methodology for shingle barrier beaches
(iii) Physical modeling of four overlapping segments of Hurst Spit at a scale of 1:40
(iv) Numerical modeling of sediment transport, interavtive with the physical model

4 BEACH RECHARGE DESIGN

The plan location of Hurst Spit can be stabilized only if green water overtopping of the beach crest, which results in crest roll back is prevented. The crest level of the recharged beach must therefore be above the level of maximum run up during the design storm and the beach must be suitably wide to allow the dynamic profile to develop fully within the barrier. Alternatively, the crest width must be both sufficiently high and wide to allow wave events which exceed the crest to deposit entrained sediment at the crest, as opposed to rolling the crest back. The varied wave climate along the length of Hurst Spit results in a differing response of the shingle Spit from west to east. The more severe conditions in the west result in higher wave run up and therefore a higher natural beach crest.

The extensive test programme identified appropriate design crest levels along the length of the Spit. Hydraulic model tests identified that a crest level of 6.3m ODN will not be exceeded by green water under any of the combinations of waves and water levels tested, at any location along the spit. Model tests also identified threshold geometry conditions for each profile beyond which the shingle spit will be vulnerable under the design storm (Bradbury and Powell 1992).

The beach recharge cross section has a crest level of +7m ODN, with a crest width of 12m along much of the length (Figure 4). The design crest reduces further to the east, tapering down to a level of +5m at Hurst Castle, where the climate is less severe. A local bi directional wave climate adds complications to the design at the eastern end of the beach. Design crest levels are higher than the maximum predicted run up levels for any of the conditions tested, to allow for subsidence of the beach into the salt marsh which lies directly beneath and in the lee of the shingle barrier.

A rock breakwater close to the shore was designed to spread and dissipate wave energy across the weak junction of the rock revetment at barrier beach. The structure is armoured with 6-10 tonne rock at varying slope angles, with a crest at 2.5m ODN allowing for overtopping to clean the gap between the breakwater and shoreline during storm conditions. Design for stability of the rock armour has presented a considerable problem, due to the foreshore geometry and the location of wave breaking on the structure. Difficult ground conditions posed a construction problem, with the need for geotextile beneath the breakwater, which is permanently immersed below low water in a minimum water depth of 5 metres, at the toe. The plan location of this structure is unconventional being very close to the shoreline. A wide range of alternatives were tested, but the only cost effective solution found was an angled shore detached breakwater, overlapping the shingle spit and the rock revetment. Hydraulically more efficient structures built further from the shoreline could provide a better technical solution, but the very steep approach beach would necessitate construction of a very large and extremely expensive deep water structure. The compromise solution is a structure in shallower water which will require some periodic beach material bypassing due to predicted formation of a tombolo and starvation of sediment to the east. The structure will reduce the wave attack on the junction by dissipation of the waves before they reach the beach. It will also drive shingle and sand into the lee of the breakwater by diffraction around its seaward roundhead, thus providing a beach of finer material under most conditions.

Longshore transport tests and beach mathematical models suggested that the longshore transport rates will be essentially unaltered by the recharge, as the beach recharge is mainly on the lee face of the Spit. The only likely difference is a reduced supply of the shingle to the western end of the Spit due to the construction of the breakwater.

Design profiles were based upon beach recharge with sediment of similar grading to the indigenous beach material. A total volume of 300000 m3 of shingle material was required to achieve the design (Figure 4).

5 MATERIALS

Wright (1992) discussed the difficulties of obtaining materials of appropriate grading for use in beach recharge at Hurst Spit and outlined a preliminary application to recycle shingle from the Shingles Banks system in Christchurch Bay. The programme comprised the following elements:

(i) Proving the resource
(ii) Engineering options for extracting and placing
(iii) Licensing requirements
(iv) Environmental impact assessment

A geological exploration programme was developed around the NFDC coastal monitoring programme, to investigate the type, distribution and quantity of sediments within the offshore bank system. A reserve of 42 million cubic metres of sand and gravel was identified, some of which had an ideal grading for beach recharge. Analysis of sediment transport patterns, by interpretation of sidescan, wave and current data demonstrated circulations patterns which included sediment transfer from Hurst Spit to the offshore banks; these showed a net accumulation over a period of 100 years and suggested that the 300000m3 required for recharge of Hurst Spit would be naturally recycled back to the bank system over the duration of the scheme life. The studies suggested that the material quality was considerably better than any of the nearby commercial licensed areas and suggested that the material could be produced at a significantly reduced cost.

6 AGGREGATE PRODUCTION LICENCE APPLICATION

Following the offshore exploration programme, a formal application for a marine aggregate production license was made for 300,000m3 of material from the Shingles Banks.

Although an EIA was not a specific requirement for a production licence application it was clear that, because of the nature of this scheme, the Government View procedure would demand one. An EIA was also considered necessary because of the environmental sensitivity of the Spit itself and of its surrounding area. Accordingly, in February 1992, Wimpey Environmental Ltd were commissioned to undertake an Impact Assessment with the following terms of reference. To:

(i) Review the existing environmental information available;
(ii) Examine the potential environmental consequences of extracting shingle from the Shingles Bank;
(iii) Examine the environmental consequences of the Spit and its surrounding area of carrying out beach recharge and construction of the various rock structures;
(iv) Identify areas of poor or non existent knowledge, and make recommendations for further investigation.

Despite the positive views which supported the application arising from the Environmental Assessment and the subsequent independent validation studies, the application for a production license to recycle material from the Shingles Banks area to Hurst Spit met with some resistance, particularly from the fishing community. Following the environmental assessment additional studies were commissioned to satisfy the requirements of the South Wight Borough Council (now Isle of Wight Council) SCOPAC, MAFF (MEPD), English Nature and local fisheries groups. These studies included independent repeat studies of wave climate, sediment dispersion and sampling of benthic communities. Although the scientific evidence, and positive support by most of the consultees, weighed heavily in favour of a positive government view, NFDC were advised by the DOE (now DETR) at the request of the MAFF MEPD, that a dual tendering exercise should be carried out to determine whether the Shingles Banks area presented a more economic source of material for the beach recharge than commercially licensed areas, before a government view was issued.

7 ALTERNATIVE DESIGNS

Discussions with all of the aggregate suppliers revealed that none of the licensed areas on the south coast could meet the specification grading. As it appeared unlikely that commercial licensed areas could supply material of the preferred design grading, the design process was reviewed and an alternative design based on finer wider gradings developed. The basis for alternative recharge designs using materials with finer and wider gradings made the assumptions that these materials would have the following effects on the hydraulic performance of the beach.

(i) The beach will form a dynamic equilibrium slope at a shallower angle for either finer or more widely graded materials than for the indigenous beach grading. This will require a larger quantity of material to form the capital recharge. As the slope offshore of the existing beach toe is very steep (approximately 1:25 at the beach toe) this will inevitably result in the toe of the recharged beach forming further offshore.

(ii) The longshore sediment transport rate will be faster for finer material than for coarsematerial. Losses from the system will be greater, therefore. This will result in a requirement for more frequent and higher volumes of maintenance to be included in the beach management plan

(iii) The use of a finer grading or a more widely graded material will reduce the permeability of the beach

(iv) More widely graded materials will contain a higher proportion of fines which are likely to be lost from the system at an early stage.

The methodology for the alternative designs was developed on the basis of recent MAFF research (Powell 1994) and also empirical examination of nearby beaches with similar gradings. Results of the two methods did not concur and presented a degree of uncertainty about the expected performance of alternative gradings. Despite these uncertainties, an alternative design based on a finer wider grading was developed and tenderers were invited to price three alternative options:

1) Beach recharge based on the original design and supply from the Shingles Banks with material quality at the client’s risk.

2) Beach recharge based on the original design and supply of the indigenous grading of Hurst Spit, from a commercial source, with material quality at the contractor's risk.
3) Beach recharge based on supply of a larger quantity of material to achieve the alternative design, with a wider and finer grading of shingle, from a commercial source, with material quality at the contractor's risk.

As expected, the most economic option proved to be the preferred design using the Shingles Banks as a source. The unit rate for the supply of shingle from the cheapest commercial source was 154% of the rate for the Shingles Banks. An additional 12.5% of shingle was also required to achieve the alternative design to the Shingles Banks from this commercial source. The real cost of construction from this commercial supply was therefore 173% of the cost of the Shingles Banks supply. The unit rate for alternative 2, which was based on the same quantity and grading as Alternative 1, was 189% of the cost of the cheapest Shingles Banks supply. Only one tender was received for this option and could not be considered as it was a non conforming bid. Following considerable debate between MAFF departments, a positive government view was made, the aggregate production licence for the Shingles Banks was awarded, and the contract awarded for that alternative in July 1996.

A series of licence conditions were attached to the positive government view. The costs of these were integrated in the benefit cost analysis and were considered with the application for the scheme by MAFF. Prior to commencement of the contract an extensive programme of baseline monitoring had to be established; this included hydrographic and topographic surveys of the western Isle of Wight and Hurst Spit, monitoring of the shipping channel and sampling of benthic communities. Side scan sonar and trawl surveys of both the dredging area and the discharge sites were also carried out in liaison with local fisheries.

8 SCHEME OUTLINE

The main elements of the scheme are as follows and are shown in Figure 3.

(i) Recharge of the barrier beach with 300,000m3 suitably graded shingle;
(ii) Construction of a rock revetment around the south western flank of the Castle;
(iii) Construction of a shingle nearshore rock breakwater at the rock armour/shingle junction;
(iv) Reconstruction of the existing rock armouring between Milford beach and Cut Bridge

The design and construction of the rock armour elements of this scheme are discussed further in Bradbury (1998).

9 CONSTRUCTION OF BEACH RECHARGE

The supply of beach recharge materials from the client's own dredging area placed the responsibility of achieving material of appropriate quality with the engineer, and ultimately the risk with the client. The contractor's brief was to dredge defined tracks within the area as directed by the engineer, on a cargo by cargo basis. The dynamic nature of the dredging area provided further challenges with strong cross currents, rapidly changing water depths between 0-15m, and a dredging area only 300m wide, adjacent to a shipping channel. These problems necessitated a high level of co operation between the engineer and contractor.

The dredging area is an active sediment sink unlike most of the other south coast production areas, which are fossil deposits. Exploration work had demonstrated that the coarsest fraction of materials was concentrated in certain parts of the area, and that a veneer of sand up to 0.5m thick migrated around the surface of the area, over the main body of coarse sediments. This variability is associated with periods of intense wave activity when most morphological changes to the offshore bank system occur. As fine material was not desirable the licence provided for screening to remove this material, and the contract specified that a dredger with screening facilities should be used for the work. This limited the dredgers available to those normally used for aggregate production work. Most of the dredging was carried out by the 2600m3 trailing suction hopper dredger MV Cambourne.

Additional exploration work was undertaken prior to commencement of the dredging to confirm the quality and depths of surficial sediments, in compliance with license requirements. This comprised vibracoring and sidescan sonar. The project did not have the advantages of detailed production grading data which could be expected from an existing area: initial production relied on geological interpretation of sidescan, sub bottom, grab and core samples. The production quality control process was based upon a rigorous sampling and monitoring procedure. Samples were taken from each cargo for sieving at an on site lab, which provided a 24 hour turn around of results. These were analysed by reference to geological data and the plot tracks of the dredger. Deviations from the planned dredging pattern were provided to the contractor immediately on delivery of the cargo to the beach, in response to the grade of material delivered.

The sediments in the dredging area are unusually coarse for a south coast site, this reflects the low proportion of fine sand material which is winnowed out by the strong cleansing currents of the Hurst Narrows and Needles channel. This effectively reduces the width of the grading, with a lower limit cut off at about 1mm. The sand fraction is similarly unusually small and the grading curve moves correspondingly to the right as a function of this natural screening process. No screening was carried out by the dredger, due to the extremely high quality and low fines content of the as dredged materials produced: further cost savings could have been made if a screening facility had not been specified, but the risk of low grade materials was considered too high to consider this option.

The dredging time frame was restricted by licence to commence after 1 August, to minimize any disruption to fisheries. It was originally intended to let the contract in April to minimize construction risk over the sping-summer period, but this was delayed by the licensing process. Whilst the contractor could potentially have worked in much less favourable conditions, the risk of loss of time due to bad weather was shared by contractor and client, by reference in the contract to defined conditions to be measured at a local wave rider buoy (Figure 4).

In practical terms, the discharge operation presented greater problems than dredging. The narrow channel adjacent to Hurst Spit limited the area for manoeuvring. Depths adjacent to the site and the narrow tidal range limited the location of the dredger to a distance of approximately 200m from the shoreline. Strong longshore tidal currents limited the start of discharge to slack water periods, to permit coupling of the dredger with the 200m floating pipeline. A maximum pumping distance of about 400m was achieved due to the coarse nature of the recharge material, and the pump capacity of the dredger. This required the floating discharge line to be moved to four locations. Strong 2m/s shore currents at the eastern end of the site restricted the deliveries to 2 per day, against the original target of four.

The nature of the recharge presented further unusual problems as the flow of pumped material has to be contained on all sides and the shape of the barrier recharge was unusual in itself. The existing spit was divided to form two bund walls to contain and control the discharge, and limit the flow of water onto the sensitive saltmarsh area immediately in the lee of the spit. The recharge was designed to optimize the current dynamic equilibrium profiles which had developed to seawards of the recharge and most material was placed on the lee side of the barrier beach, directly on top of saltmarsh deposits over which the barrier would naturally have rolled back within a period of 2-3 years: this approach should minimize early losses from the system, since the toe and seaward slopes of the beach would be relatively unaffected by the recharge. The main disadvantage of this approach was the nature of the ground conditions which were variable; whilst pre-contract soils investigations had indicated the sheer strength of the materials should be able to sustain instantaneous loading at full height of the recharge, a buried river channel was found with much lower shear thresholds during construction. This resulted in localized shearing of sediments and rippling of the saltmarsh surface due to mass displacement of materials. Additional geotechnical investigations and revised working methods devised jointly and quickly by the contractor and engineer, by minor realignment and discharge in two layers, overcame a potentially serious problem without delay or additional cost to the contract.

Much of the dredging was carried out in more than 7m of water, but the final stage of the contract was carried out by dredging with a shallow draft trailing suction hopper dredger (MV Sospan), from within the shallow zone of the dredging area above the 5mCD contour. This provided the advantage of production of material from unworked areas of high quality material, which the larger dredger could not work: it also permitted discharge by rainbow spraying onto the toe of the beach in a zone of extremely shallow water which could not be reached by pipeline from the larger dredger. This final stage of working provided a sediment supply at the toe of the updrift rock revetment, ensuring continuity of sediment transport from the west on to the recharged spit.

The nature of the hydraulic discharge resulted in much of the fine proportion of material being immediately washed out of, or through, the recharge. Further trimming and movement of material by mechanical plant resulted in artificial sorting and mixing of the fine fraction and short term reduction in permeability of the sediments.This resulted in the formation of temporary cliffs, above the level of the maximum run up, prior to resorting by wave action. Severe storms have quickly resorted much of the recharge to alow natural dynamic equilibrium profiles to reform.

A considerable quantity of fired ordnance was found within the dredging area, requiring rigorous safety procedures to be adopted. None of the ordnance was found to be dangerous, primarily being practice shells but the whole of the recharge was swept by a specialist team of ordnance experts to ensure no risk to the public. Reduced risks to the contractor of summer working run in parallel with pressures due to increased public demands for access and the safety problems. Careful planning of the recharge operations enabled certain areas of the site to be isolated whilst maintaining public access past the works for most of the contract period. Public relations were maintained at a high level throughout the contract aided by local exhibitions at either end of the site.

10 SCHEME PERFORMANCE

A single severe storm occurred during the construction phase with conditions in line with the design wave conditions. Those areas of completed works performed as predicted by the physical model studies, whilst the zone which had not been completed was breached. The whole of the spit would have been breached under these conditions had the works not been undertaken. A series of relatively severe storms have occurred since completion of the works. The beach response, which has been monitored by topographic and hydrographic surveys in parallel with wave and tidal measurements, has been remarkably close to that predicted for the storm events. It is estimated that the pre storm barrier would have been subject to sluicing overwash leading to barrier breakdown on at lease 8 occasions within the 2 year period on completion of the works. Post project monitoring is ongoing. This is linked with a planned maintenance programme and an extensive five year post project monitoring programme in accordance with the dredging licence requirements.

11 CONCLUSIONS

(i) A shingle beach recharge scheme has been designed and constructed to maintain the line of the Hurst Spit barrier beach.

(ii) An aggregate production licence for the Shingles Banks has been awarded to New Forest District Council for the purposes of carrying out the beach recharge.

(iii) Considerable cost savings have been made and high grade materials have been produced as a result of the dredging licence, by comparison with commercial production sources.

(iv) The beach recharge scheme has performed as predicted by the physical model studies during the first two winters following completion.

12 REFERENCES

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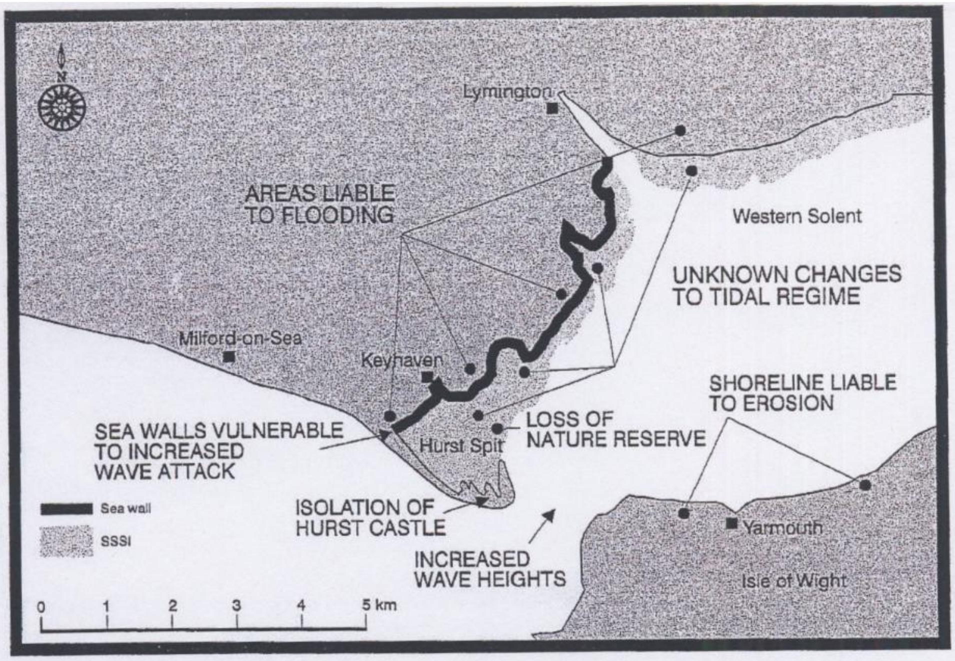

Figure 1 Effects of not maintaining the defence line at Hurst Spit

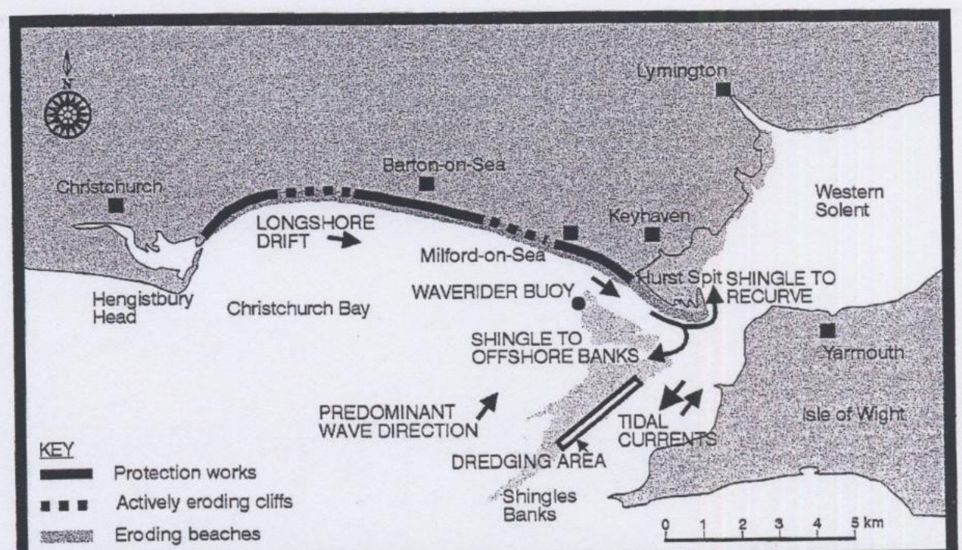

Figure 2 Coastal processes in Christchurch Bay and location of Shingles Banks dredging area

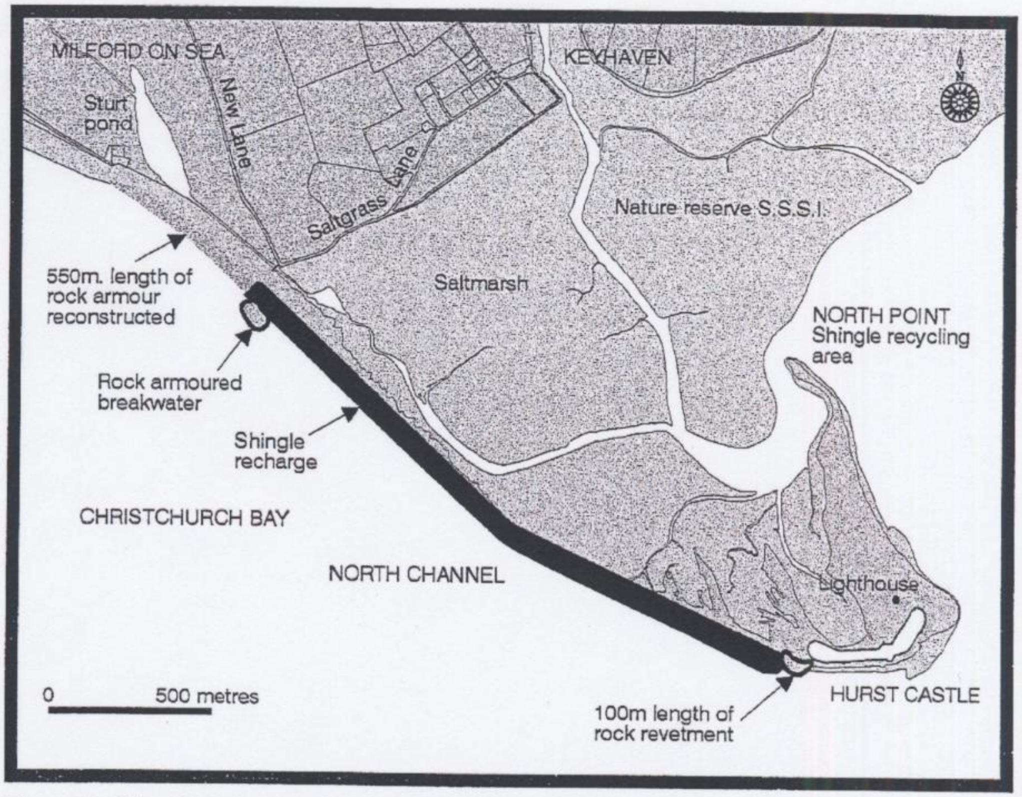

Figure 3 Plan layout of coast protection works at Hurst Spit

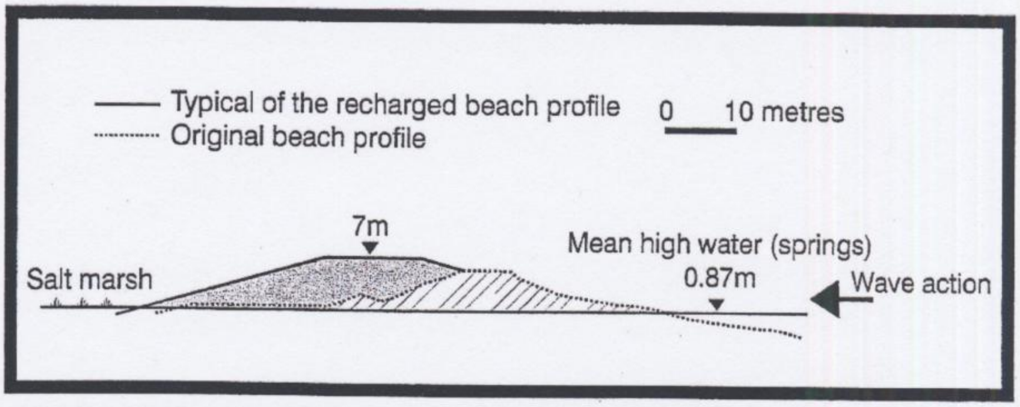

Figure 4 Typical cross section through beach recharge at Hurst Spit