The Interaction between Coastal Sediment Dynamics and Coastal Sea Defences at Christchurch, Dorset, England

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Abstract:- This report assesses the coastal sediment dynamics and the impact of coastal sea defences in the Highcliffe, Hengistbury Head, and Christchurch Harbour regions of Christchurch, Dorset, on the southern coast of England. The study combines field observations, expert insights, satellite imagery, and literature to show the intricate interplay between natural sediment processes and anthropogenic interventions.

The study area is characterised by cliffs, sandy beaches, and clay-silt deposits, all influenced by wave action, littoral transport, and geological factors. Two contrasting coastal management approaches are considered. One approach uses rock armour groynes to combat erosion, inadvertently disrupting sediment flow eastward. This illustrates the effectiveness of groynes in beach preservation but highlights their impact downstream. Another approach allows natural erosion, leading to cliff retreat and property relocation. It also reveals the complexities of sediment transport and the depth of closure concept.

This study underscores the intricate nature of coastal dynamics and defence strategies. Human intervention can yield unforeseen consequences, necessitating thorough research and novel solutions to safeguard coastal regions. Continued efforts are essential to find a balance between coastal protection and preserving the dynamic equilibrium of coastal systems to prevent the sea from claiming land.

Keywords:- *Accretion, Coastal Sediment Dynamics, Erosion, Depth of Closure, Groyne, Littoral Drift, Longshore Drift, Sediment Nourishment, Sediment Starvation, Terminal Groyne Syndrome.*

I. INTRODUCTION

The aim of this report is to review the coastal sediment dynamics and the coastal sea defences at Highcliffe, Hengistbury Head, and Christchurch Harbour, as observed during a field trip on November 3, 2008. Specifically, it focuses on how natural sediment dynamics affect the areas involved and how anthropogenic sea defences attempt to influence and control the effects of the sediment dynamics upon coastal features. This review is based on direct observations of the sites, descriptions and comments culled from the field leaders, Google Earth satellite images available online, and readings from the relevant literature.

II. BRIEF DESCRIPTION OF THE AREAS VISITED

The three areas under review are located along Christchurch Bay in the county of Dorset, south coast of England. The geology of this part of England consists of an underlying syncline of Cretaceous chalk filled in with Tertiary deposits (Wenban-Smith & Hosfield, 2001, p. 2). The anticline of the chalk emerges in places such as the Isle of Wight and Isle of Purbeck. The three places visited sit on the Tertiary deposits and later Pleistocene fluvial deposits (Wenban-Smith & Hosfield, 2001, p. 2), contributing to the sediment sources that form their beaches and coastal features. Highcliffe is located just west of the boundary between Dorset and the county of Hampshire, while the other two locations are three miles further west.

Christchurch Bay is an embayment that curves gently for ten miles from Hurst Spit in the east to Hengistbury Head in the west. It is bordered on the south by the Solent and landward to the north mostly by cliffs that are either actively eroding or have stabilised naturally or through human intervention. The beaches along the bay consist of gravel mixed with sand, clay, and silt. These beach materials are all products of cliff erosion and littoral transport. Cliff erosion occurs due to wave action at the cliff base and slumping caused by shearing and liquefying the stratified material of which the cliffs are composed. Littoral transport is caused by the accretion of sediments brought by the Solent from the

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offshore seabed and from other sediment sources in the Christchurch Bay sub-cell of Coastal Cell Five.

While the field trip covered just three miles of the ten-mile-long stretch of Christchurch Bay, much of the description can be generalised to the parts not visited.

III. HIGHCLIFFE AND BARTON-ON-SEA

The coast at Highcliffe, as its name suggests, is characterised by cliffs about 20 m high facing the Solent to the south. An exposed part of the cliffs showed a light grey sediment lying underneath a sand formation. Because of a slight east-north-east tilt – ¾ º according to one of the field leaders – of the underlying syncline and the presence of groundwater, these cliffs were previously slipping and falling but have since been artificially stabilised using drainage of the cliff strata and regrading of the base.

At the foot of the cliffs, the beach that had developed from the eroded cliff material was exposed to the tidal and wave activity of the Solent and the prevailing southwest winds, exacerbated by the lack of sediment nourishment caused by the long groyne at Hengistbury Head. Without protection, this would have led to erosion of the beaches and further cliff erosion. So, a sequence of rock armour groynes was built to defend the beach from the west to east longshore transport of sediments caused by the wind-driven waves. The longer groynes protect against upper littoral drift, while the shorter groynes protect against lower littoral drift (Plates 1 and 2).

Plate 1. **Groynes at Highcliffe** (Photo: M. Hackett, 2008)

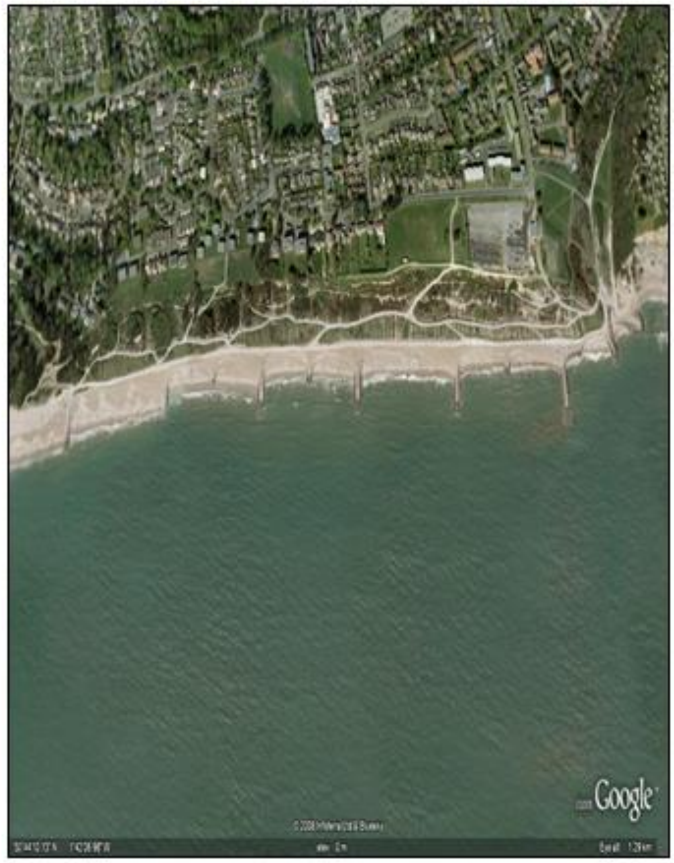

Plate 2. Sequence of groynes at Highcliffe (Satellite image: Google Earth, 2008)

Separating Highcliffe on the west from Barton-on-Sea on the east is a collapsed valley named Chewton Bunny, which is now a nature conservation protected area. Formerly, Chewton Bunny was a narrow valley with a little stream running freely to the sea. Due to the slight ENE tilt of the underlying strata and to seepage of water into the strata, landslides occurred in the late 1960s and early 1970s. The local council decided to stabilize the collapsed valley by placing rock armour groynes at the base of the landslide with a culvert for the egress of the Chewton Bunny stream. One groyne was placed shore parallel to prevent the so-called "terminal groyne syndrome" at the slightly shore perpendicular groyne. (Terminal groyne syndrome is the loss of beach material on the downdrift side of a shore perpendicular groyne.) (Plate 3). Gravel was imported and placed at the foot of Chewton Bunny to help stabilize it at the shore.

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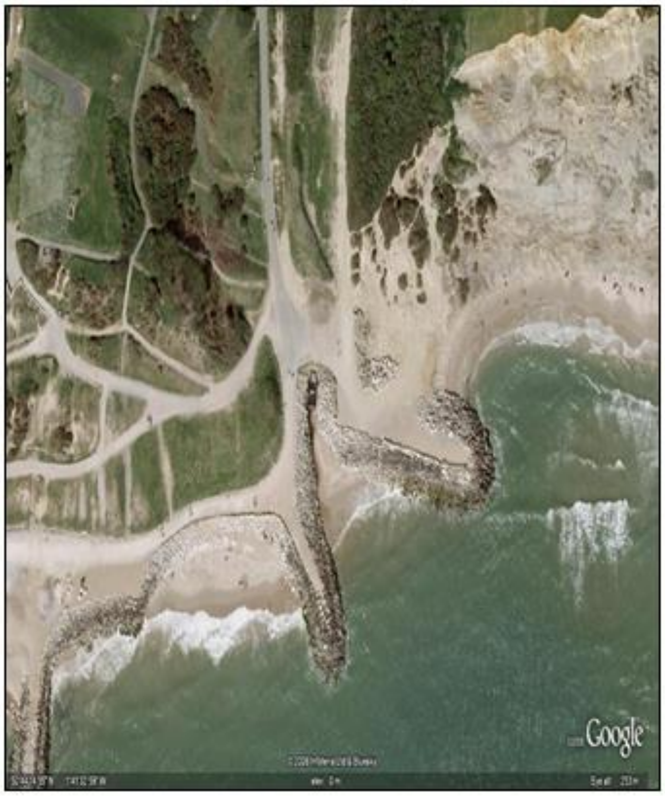

Plate 3. Culvert between Groynes at outlet of Chewton Bunny
(Satellite image: Google Earth, 2008)

While stabilising the beaches and cliffs at Highcliffe, the sequence of groynes, however, prevents sufficient sediment from the west to east littoral drift from reaching the beaches east of Chewton Bunny at Barton-on-Sea, causing the beach there to be denuded of material and contributing to the erosion of the cliffs under Barton-on-Sea. This is an excellent example of a coastal engineering solution in one area causing a problem in an adjacent area and shows that some beach recession could be due to sediment starvation caused by groynes.

At Barton-on-Sea (which is almost literally on the sea), the beach and cliffs have been left unprotected for nature to take its course because the area has been declared a Site of Special Scientific Interest for observation and research. The Naish Farm Estate is located on the plateau above the cliff, east of Chewton Bunny. As the cliff slumps and recedes, the houses at Naish must be moved further inland. In fact, from observation, houses close to the edge of the cliff top will have to be moved sooner rather than later. (See Plates 4 and 5)

Plate 4. Slumping cliffs at Barton-On-Sea (Photo: M. Hackett, 2008)

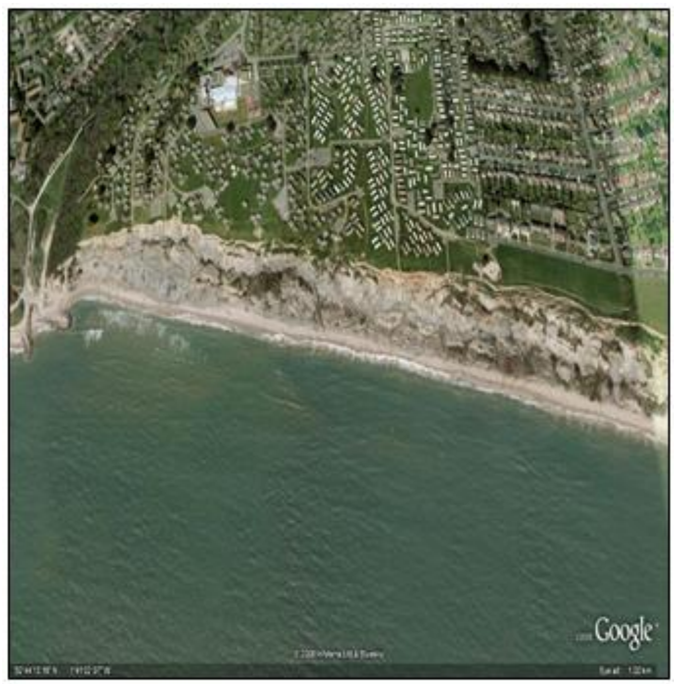

Plate 5. Cliffs and Naish Farm Estate at Barton-On-Sea
(Satellite image: Google Earth, 2008)

The plateau on top of the cliff consists of gravel, clay, and silt – good beach material – and most of the rest is fine to medium sand. But the sand, unlike the gravel, is too fine to accrete on the beach to help consolidate it and is removed by offshore and longshore transport. This accounts for the narrowness of the 0.8-mile stretch of beach at Barton-on-sea. At the base of the cliff are found copious amounts of mud, a

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result of the mixing of the clay and silt with the groundwater flowing between the cliff strata. Barton-on-Sea and its undercliffs are left for nature to manage.

IV. HENGISTBURY HEAD AND CHRISTCHURCH HARBOUR

Hengistbury Head, unlike the cliffs at Highcliffe and Barton-on-Sea, is a stable geomorphological feature. It is composed mainly of the Hengistbury Beds that were deposited in the Tertiary, as well as later Pleistocene river deposits. The Hengistbury Beds, called ironstones doggers, are highly resistant to erosion, and it was this factor that had prevented the most prominent Hengistbury feature, Warren Hill, from being eroded by wind, wave, and tide over geological time (Pepin p. 13).

From 1848-1856, mining and dredging of the ironstone doggers was carried out along the shore and in the sea off the Head. The removal of the doggers, which had acted as natural breakwaters, resulted in an erosion rate of about 9 m/yr. The beach continued to erode until 1938 when the long groyne was built and subsequently, the beach recovered as sediment accreted west of the groyne and plants were re-established (Ibid. p. 14)

An unexpected effect of the long groyne at Hengistbury was that it trapped such significant quantities of beach material that it cut off the supply of sediment to the Highcliffe beaches, resulting in them being starved of beach sediment and experiencing erosion. Consequently, a sequence of groynes had to be built to preserve the Highcliffe beach. Again, this is another example of humans' attempt to control the coastal zone, causing problems in a down drift area (Komar, p. 203).

It has since been recognised that beaches act as buffers between sea and land, especially along coasts of high wind and wave energy, as found along the south coast of England. So, to preserve the beaches along the south coast, shore perpendicular groynes were constructed to stop the longshore drift of beach sediments.

In one attempt at beach replenishment, Poole Harbour was dredged, and the material was brought to Bournemouth to nourish the beach, but the sediment migrated back to Poole after some time. This happened because the sediment went back to sea as bedload and was brought round back to Poole driven all the way by bottom currents. In effect, this means that the depth of closure can go down to 20 – 25 m, as in this case. Since the depth of closure is theoretically defined as the depth beyond which sediment transport is insignificant or negligible (Nielsen, p. 109), it is either that the depth of closure is 'leaky' or that the concept of the depth of closure may not fully valid and may need modification.

Enclosed by Hengistbury Head and the Mudeford Beach sand spit is Christchurch Harbour, a tide-dominated mud lagoon containing salt marshes, having a narrow inlet from the sea at Mudeford Harbour. This is a good example of the juxtaposition of two coastal environments: (1) a wave-dominated beach on one side and (2) a tidal dominated lagoon on the other side. (Plates 6 and 7)

Plate 6. Christchurch Harbour and Mudeford Beach
(Photo: M. Hackett, 2008)

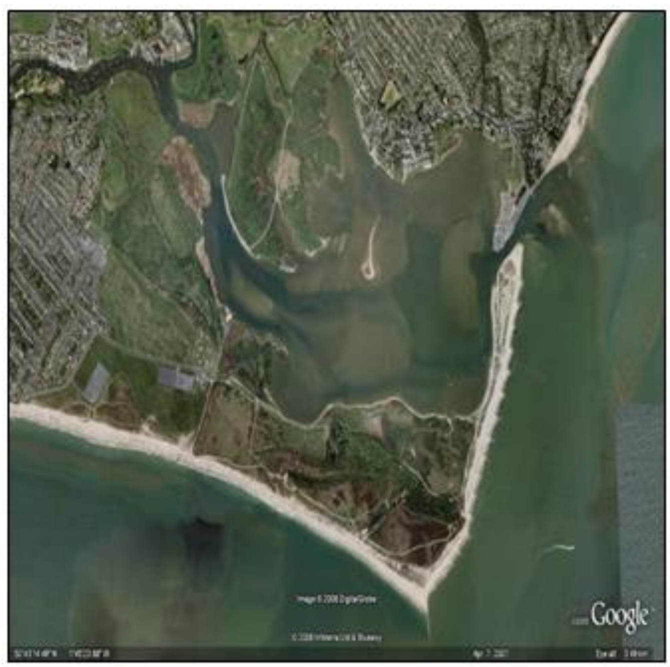

Plate 7. Hengistbury Head and Christchurch Harbour
(Satellite image: Google Earth, 2008)

The sand beach at Mudeford is protected against longshore drift by a series of groynes built slightly oblique to the shoreline. These also help to prevent sediment from filling the Christchurch Harbour inlet. Unlike the Head, the Hengistbury spit, because of its sand composition, is a very ephemeral coastal feature, and in the not-too-distant future, the sea will one day be lapping at the doorsteps of the cottages.

V. CONCLUSION

In this brief review, covering all or even most of the sediment dynamic-coastal defence interactions has not been possible. But even such a brief report has been succinct enough to demonstrate some of the essential ways sediment dynamics and coastal defence structures inter-relate. Human exploitation and removal of natural beach materials such as sand, gravel, and boulders evidently have unpredictable negative impacts on the coastline. In the past, this has led to significant erosion and loss of land. Even today, with improved knowledge of coastal dynamics and structures, human attempts to alleviate anthropogenic coastal problems while solving the problems have frequently caused troubles elsewhere along the coast, which require further solutions, which generate more problems, and so the domino effects continue.

Clearly, much more work needs to be done in the field of coastal engineering, both in theoretical work and in fieldwork, to better understand the complexity of the forces and materials that mould the coastline. Otherwise, we would have evolved from the sea millions of years ago, only to be inundated by the sea millions of years later.

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