Coastal erosion in the eastern half of Christchurch Bay

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Abstract

Christchurch Bay has a long history of shoreline recession and this has given rise to some major coastal engineering problems. An area of particular concern is Hurst Beach at its eastern end, where the maximum rate of recession has increased from 1.5ma-1 (1867 to 1968) to 3.5ma-1 (1968 to 1982). Hurst Castle itself is now subject to wave attack on part of its frontage. The littoral sediment movement was assumed to be essentially continuous around Christchurch Bay, but, in fact, a littoral drift sub cell boundary (ie a partial barrier to littoral drift) is present in the vicinity of Hordle Cliff. Therefore, the increased recession of Hurst Beach is a local problem. Milford on Sea is situated on a thick sequence of Pleistocene Gravels, whose erosion contributed substantially to the maintenance of Hurst Castle Spit as a major physiographic feature. However, a series of coast protection works were constructed to protect Milford on Sea between 1936 and 1968, removing this important source of sediment.

In the long term, without any further human interference, recession rates of up to 6ma-1 will probably occur along Hurst Beach. A breach of Hurst Beach is a major concern, as it would create an island at Hurst Castle and expose the vulnerable, low lying, northern coast of the West Solent, including the village of Keyhaven, to increased wave attack and tidal scour. Ecologically important saltmarshes would also be destroyed.

Shingle renourishment is the only environmentally acceptable engineering solution. Limited renourishment has already commenced. Any cost benefit decisions must consider the wider implications of a breach in Hurst Beach, including environmental and ecological considerations.

This case study demonstrates the importance of a detailed understanding of both the littoral and offshore sediment movement for the planning of coast protection.

Introduction

Hurst Castle Spit, situated at the eastern end of Christchurch Bay, is a well known example of a spit (Figures 1&2). Visually, it is dominated by Hurst Castle, built between 1541 and 1544 and considerably extended between 1861 and 1873, and Hurst Lighthouse. It can be divided into two distinct segments, following Lewis (1938):

(i) Hurst Beach, a solitary transgressive storm beach oriented towards the dominant waves in Christchurch Bay. The Isle of Wight and the shallow offshore shoal, the Shingles Bank, have a major effect on the energy and direction of the waves impinging on its shoreline. It formerly commenced near Sturt Pond, where the beach crest elevation exceeded the ground elevation. However, the first 600m of Hurst Beach was armoured to form a revetment in 1967/68, and it now commences at Saltgrass Lane.

(ii) An active recurve, oriented towards the dominant waves in the West Solent. Three "fossil" recurves are present in the saltmarsh which has formed in the lee of the spit.

Hurst Castle Spit is mainly composed of sub angular to sub rounded flint pebbles (henceforth called shingle) derived mainly from the coastal erosion of Pleistocene fluvial gravels; the so called "Plateau Gravel" described by Keen (1980). The net littoral drift is eastwards. However, Hurst Castle Spit is not the sediment sink to the system, as the offshore movement of shingle to Christchurch Bay and the West Solent occurs at Hurst Point, due to the high tidal energy of the area (Dyer 1972; Nicholls 1985). Much of this material probably contributes to the Shingles Bank.

Hurst Beach, like the rest of Christchurch Bay, has a history of shoreline recession. In the period 1867 – 1968, the maximum recession rate, including the Milford on Sea frontage, occurred in the vicinity of Sturt Pond and averaged 1.5m a-1. At Milford on Sea, prior to coast protection, this recession resulted in cliff erosion, while on Hurst Beach, overwashing of the crest during storms moved the beach north eastwards across the saltmarsh or recurve deposits.

The coast erosion at Milford on Sea necessitated the construction of coast protection measures, the first groyne being built between 1867 and 1898. Major works commenced in 1936 and are described by Stopher & Wise (1966). Additional defences were required both to the east and to the west of the original 1936 works. A system of groynes was constructed along the proximal 600m of Hurst Beach in the period 1955 – 1959, but failed to trap sufficient shingle or prevent accelerating recession. Therefore, the shingle bank was armoured to form a rubble revetment in 1967/68. At present, the Milford on Sea defences extend from Paddy's Gap to Saltgrass Lane (Fig 2) and total about 1.9km in length.

Coast defences were also required at Hurst Castle in the period 1964 – 1966. However, they are not the first defences at this site, as a revetment with groynes, "The New Wharfe", was constructed as early as 1717 (Heygate 1920).

The recession of Hurst Beach increased significantly after 1968, attaining a maximum rate of 3.5m a-1 in the period 1968-1982 (Figure 3). These rapid changes have continued to the present. Overwashing is most frequent at the end of the Milford on Sea defences, occurring on several occasions each winter. The fact that terminal scour is not particularly evident today is partly because the crest has been repeatedly reformed by mechanical plant after storms, and more effectively, because of the shingle renourishment commenced in 1981/82.

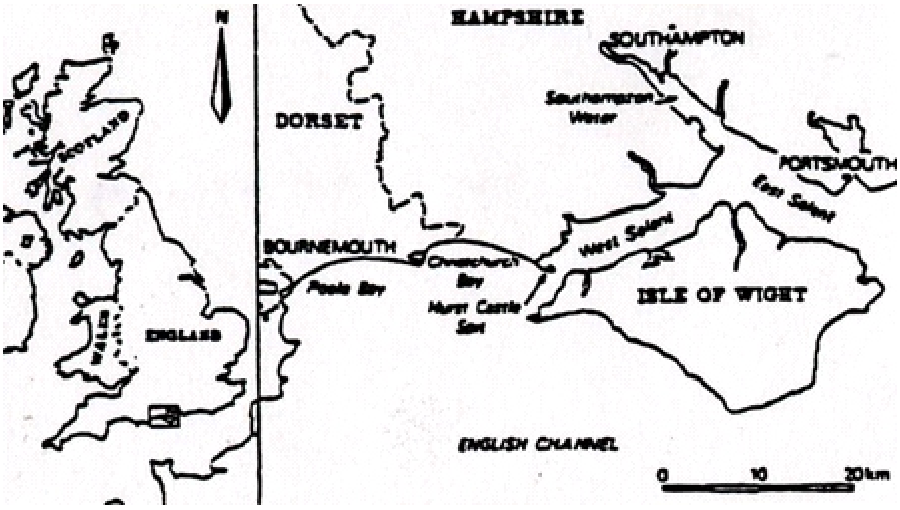

Figure 1 The location of Christchurch Bay

There are two main hypotheses which may explain the increased recession along Hurst Beach since 1968:

(i) Increased water depths over the Shingles Bank, allowing larger waves to reach Hurst Beach. Shingle extraction west of the Needles has been advocated as a cause of erosion along Hurst Beach (May 1966), although this seems too remote to be credible.

(ii) A decrease in beach volume caused by a decreased littoral drift. In addition to the coast protection measures at Milford on Sea, major projects have been carried out in the western part of Christchurch Bay, notably at Hengistbury Head, Highcliffe and Barton on Sea (Stopher & Wise 1966; Summers & Maddrell 1978; Mockridge 1983). They have all influenced the availability of beach sediment and its littoral transport within Christchurch Bay.

Evolution of the Shingles Bank

The recent historical evolution of the Shingles Bank was examined by comparing Admiralty surveys of 1880 and 1968 (Nicholls 1985). Such results must be treated with caution (Carr 1980), but the shoal areas appear to have moved eastwards and increased in size. This is somewhat contrary to the recollections of older inhabitants of Milford on Se who remember larger drying areas on the Shingles Bank at low water of spring tides than occur at present. However, a decline in the drying area is not necessarily inconsistent with the chart study as the latter also considers changes beneath low water. Some confirmation of the chart study is provided by the evolution of Hurst Beach (Nicholls 1985). Thus, changes have occurred on the Shingles Bank and these must be considered when analysing the evolution of Hurst Beach. However, on balance, they would favour increased stability, rather than increased erosion and cannot explain the sudden recent increase in recession rates.

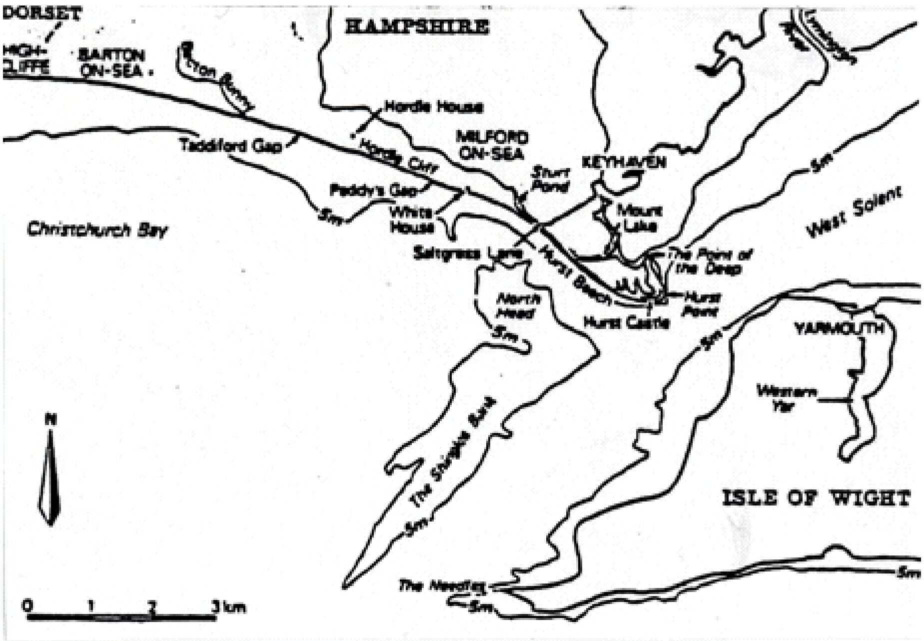

Figure 2 The eastern half of Christchurch Bay

Coastal evolution

The coastal changes to the east of Becton Bunny since 1867 were measured quantitatively by comparing the position of mean high water on five series of the Ordnance Survey 1:25000 maps, plus 1982 data from the authors. The 1939 series excluded Hurst Castle and Hurst Point. Such data must be treated with caution (Carr 1980), but in this case it indicates significant and consistent coastal changes (Figure 4).

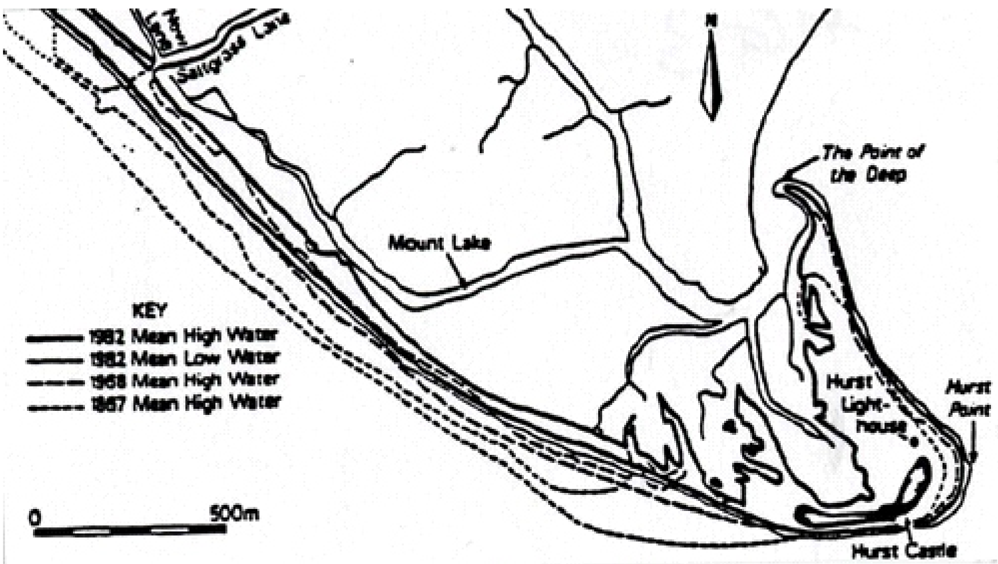

Figure 3 Coastal evolution of Hurst Castle Spit 1867 – 1982.

There is a distinct, twice repeated pattern of net erosion (Becton Bunny to Taddiford Gap / Hordle House and Paddy's Gap / White House to Hurst Castle (Keep)), followed by net accretion (Taddiford Gap / Hordle House to Paddy's Gap / White House and Hurst Castle (Keep) to the Point of the Deep). Rapid recession also occurred to the west of Becton Bunny at Barton on Sea prior to the construction of coast defences (May 1966). These results are confirmed by field evidence. The beaches where net accretion is predicted are wide, display "fossil" shingle crests, and at Hordle Cliff, the cliff is overgrown and degraded. This pattern of coastal change suggests that a partial or total barrier to littoral drift occurs in the vicinity of Hordle House. Visual wave observations and longshore sediment sorting patterns provide supportive evidence for such a barrier (Nicholls 1985).

Recent coastal evolution has been increasingly influenced by coast protection measures, particularly since 1968. For example, changes between Paddy's Gap and Sturt Pond virtually ceased because of the construction of a seawall, while erosion between Becton Bunny and Taddiford Gap increased due to the terminal scour caused by the coast defences at Barton on Sea.

Littoral sediment movement

The best method to predict littoral drift rates at an unknown site is to compute them from the historical change in the topography of the beach and offshore zone (Vitale 1980). The minimum net littoral drift that was necessary to cause the measured change is hindcast. The volume of coastal feed (Qr) is given by:

$$Qr = AHeKe\,b \qquad (1)$$

where Qr = volume of coastal feed (m3 a-1)

A = rate of recession (ma-1)

He = height of the eroding coastline (m)

Ke = proportion of the eroded material which remains on the beach

b = length of coastline (m)

Harlow (1979, 1982) reduced *b* to a small, regular increment along the coastline (100m). If the loss to an offshore sink is zero, then the total volume of feed can be integrated to produce the rate of littoral drift. This approach is quite accurate in Christchurch Bay because a good quality cartographic database is available and most of the beach sediment is derived from cliff erosion. Only the single fraction of the beach sediments was considered, as sand is moved offshore from the beaches in the eastern half of Christchurch Bay (Nicholls 1985). This is of little significance as the sand fraction does not contribute substantially to beach stability.

The volume of shingle feed (Qsh) is given by:

$$Qsh = AHeKr\,b \qquad (2)$$

Where Kr = proportion of the eroded material which is shingle (ie coarser than 4mm).

In addition to the obvious sources of shingle from the Plateau Gravel in the cliffs of Christchurch Bay, three significant sources of shingle in the vicinity of Hurst Beach were identified with the aid of borehole information:

(i) The low lying Pleistocene terraces of so called “Plateau Gravel” at Milford on Sea which reach 5m in thickness. The gravel terraces descend below mean sea level to the southeast and continue beneath Hurst Beach, where they are overlain by fine grained saltmarsh deposits.

(ii) A previously unrecorded Pleistocene gravel filled channel beneath the Plateau Gravel in the vicinity of Sturt Pond, of approximate cross sectional dimensions 700x3.5m.

(iii) The “fossil” recurves.

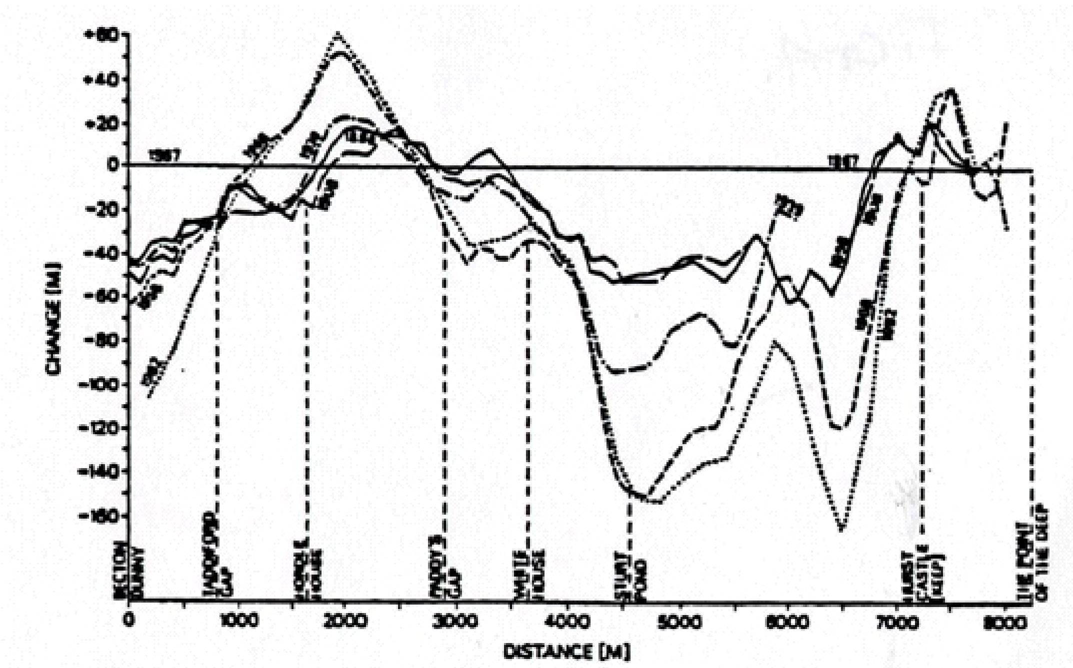

Figure 4 Movement of mean high water, 1867-1982, relative to mean high water in 1867. Positive changes indicate accretion; negative changes indicate erosion.

There is some uncertainty about the geometry of these sources, and hence, the exact quantities of shingle which have been produced by erosion. However, it is significant that the recession of Hurst Beach produces shingle. In addition to the sources of shingle within Christchurch Bay, there was an unknown contribution of shingle from Poole Bay, which was quite significant in the period 1848-1938 (Nicholls 1984). To express these uncertainties, a likely maximum and minimum value of littoral drift was determined. Any excess feed from Poole Bay was probably small and would raise the littoral drift equally at all points in Christchurch Bay. Therefore, it would not fundamentally alter the interpretation presented below.

The values of littoral drift vary considerably, depending on the period considered. Within these limits, the pre-1968 budgets demonstrated that the littoral drift of shingle between Becton Bunny and Hordle Cliff reached a minimum of 0 to 4900 m3a-1 in the vicinity of Hordle Cliff. East of Hordle Cliff, the littoral drift increased, due to local sources, reaching a maximum of 7500 to 18300m3a-1 at Hurst Castle. The bulk of this material (3700 to 15400m3a-1) was moved offshore to Christchurch Bay or the West Solent at Hurst Point. Thus, there are two littoral drift sub cells (Tanner 1973) in the eastern half of Christchurch Bay separated by a partial boundary to littoral drift in the vicinity of Hordle Cliff. The "local" sources of shingle at Milford on Sea and Hurst Beach contributed substantially to the maintenance of Hurst Castle Spit as a major physiographic feature.

The construction of coast defences at Milford on Sea has significantly reduced the availability of shingle in the eastern sub cell since 1968. It is difficult to accurately quantify this change, because of the limited geological knowledge of the Quaternary sediments beneath Hurst Beach, but by 1982 it appears that the volume of shingle produced by coast erosion had declined by 5800 to 6900m3a-1 compared with the period 1939-1968. Four sets of beach profiles measured on Hurst Beach between September 1980 and May 1982 demonstrated a decline in beach volume of 7300m3a-1 (Nicholls 1985), which is comparable to the deficit predicted by the sediment budget.

Recession of Hurst Beach

The coastal changes in the eastern half of Christchurch Bay cannot be understood without an appreciation of the sub cellular nature of the littoral drift. The coastal recession at Milford on Sea and Hurst Beach was largely in response to the increase in the littoral drift of shingle east of Hordle Cliff. The construction of coast defences at Milford on Sea has put the sediment budget in this sub cell into deficit. The resultant decline in the volume of Hurst Beach has caused the increase in recession rates. Thus, the coast protection schemes at Barton on Sea and Highcliffe have had little detrimental effect on the shoreline at Milford on Sea and Hurst Beach to date.

Without further human interference, the beach volume of Hurst Beach will continue to decline. At 1980-82 rates of depletion, all the shingle will be removed in only 27 years ! Of course, this is an unrealistic projection, as a reduced beach volume will allow increased recession, which in turn will generate more shingle from the local sources available. Thus, the beach volume will decrease, while the recession rate will increase to an upper limit estimated, using the sediment budget, to be about 6ma-1. The most immediate coast protection problem is Hurst Castle, where the western bastion is becoming a local headland. Despite a system of groynes, the beach in front of Hurst Castle continues to decline in volume. Only a solution of the root cause of the problem, which is the continuing recession of Hurst Beach, will stop further deterioration of the beach at Hurst Castle.

In the longer term, Hurst Beach may be breached. The formation of a breach is an uncommon event which normally involves landward hydraulic pressure (Carter1982). However, at Hurst Beach, the rapid decline in beach volume suggests a breach will ultimately form, possibly triggered by the movement of Hurst Beach across one of the existing channels within the saltmarsh. This would create an island at Hurst Castle and expose the low lying northern shoreline of the West Solent, including the village of Keyhaven, to increased wave attack and tidal scour. The ecologically important saltmarshes in the lee of Hurst Beach would probably be completely destroyed. A breach is unlikely to be self healing because of the swift tidal currents (up to 2.3ms-1 on mean spring tides) in the vicinity of Hurst Castle Spit. Thus, a breach in Hurst Beach would have serious widespread consequences.

Future planning options

There appear to be three major long term planning options at Hurst Beach:

(i) No action;
(ii) Extend the existing revetment to Hurst Castle;
(iii) Shingle renourishment

It has already been demonstrated that the first option will result in rapid and unacceptable changes to Hurst Castle Spit and its environs. The remaining two options would stop the recession of Hurst Beach. Of these, there is considerable merit in shingle renourishment both from a practical and environmental viewpoint.

Limited shingle renourishment commenced at Saltgrass Lane in 1981/82, with a more major, but still short term scheme, in winter 1985/86. However, these schemes can only stabilise the beach at Saltgrass Lane. Downdrift recession will continue because of the easterly increase in littoral drift along Hurst Beach. Renourishment of the entire length of Hurst Beach is required to stabilise its present configuration. To succeed, a renourishment scheme must stop the overwashing of Hurst Beach during storms and allow for depletion of about 15000 m3a-1. Within these limits, a range of schemes are possible. For example, (i) bulk renourishment of about 850000m3 which would have a life of about 50 years, or (ii) a bulk renourishment of about 100000m3 followed by renourishment of about 15000 m3a-1, which would have an indefinite life. (The bulk renourishment quantities are only approximate). A land based recycling operation, as described by Muir-Wood (1970) and Foxley & Shave (1983), has limited application at Hurst Beach because of the large offshore losses of shingle at Hurst Point. Suitable local sources of shingle for renourishment are:

(i) The active recurve. It contains about 200000m3 of shingle above -1.0m OD and there is probably more shingle at greater depth.
(ii) The Shingles Bank. This should not be dredged for commercial aggregate, as it dissipates a large amount of wave energy. However, it is permissible to remove some material for renourishment of Hurst Beach, particularly as much of the loss will ultimately be carried back to the Shingles Bank. The removal of 10^{5} m3 of material would only cause an average lowering of the Shingles Bank of about 0.1m.

Any cost benefit of engineering schemes designed to stabilise Hurst Beach must take account of the wider implications of a breach. It is considered that a major renourishment exercise for Hurst Beach can be justified and financial cost benefit should not be the sole criterion, because there are incalculable ecological issues at stake.

Discussion

Effective coast protection, or any similar intervention in the coastal zone, requires a detailed understanding of the littoral sediment movement. Where appropriate, offshore changes must also be considered. The case study from the eastern half of Christchurch Bay demonstrates the serious consequences of such intervention without such prescience. In hindsight, it is very evident that development should not have been allowed in rapidly changing coastal zones so that these could have evolved naturally, avoiding the need for costly coastal engineering works. At a site such as Milford on Sea, the coast protection schemes *were* necessary, because of property development, but their detrimental effects on Hurst Castle Spit could have been anticipated, which would have allowed effective long term measures to have been taken.

Cellular or sub cellular patterns of littoral drift are probably very common on "soft" coastlines (Stapor 1971; May & Tanner 1973; Stapor & May 1983). Christchurch Bay approximates a crenulated shaped bay which suggests a simple pattern of littoral drift. Despite several significant coastal engineering problems, the littoral drift sub cell boundary at Hordle Cliff was not recognised until this study. Therefore, for any coast erosion problem, it is very important to examine the pattern of coastal evolution and determine a sediment budget. The presence or absence of cells or sub cells is of particular significance as they delimit natural boundaries for coastal planning.

The case study utilised a low cost method for such investigations, which will be applicable in many other areas where the sediment supply is derived from local erosion, combining cartographic change with easily measurable geological parameters (see also Harlow1979). A series of maps is obviously a preferable basis for such an analysis. These are generally available as a result of the successive Ordnance Survey editions. A good knowledge of the local geology is also required so that every sediment source can be identified. Low lying areas are of importance, as they often contain poorly exposed successions of Quaternary sediments which may show significant vertical variations in grain size. Therefore, boreholes may be necessary.

A sediment budget allows the assessment of several coast protection strategies, including the outcome of no action. At Hurst Beach, this last option has been shown to have serious long term consequences. Renourishment is increasingly favoured as a coast protection technique and the authors feel it appropriate for Hurst Beach, particularly when environmental factors are taken into account.

In conclusion, it is hoped that this case study illustrates the relationship between planning and process in the coastal zone. The identification of littoral drift cells and sub cells is of particular significance, as they delimit natural coastal units for the coastal planner.

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