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Mesoscale Morphological Changes on Linear, Nearshore Sandbanks, Co.Wexford, SE Ireland.

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ABSTRACT

The nearshore zone of County Wexford, south-east Ireland, is characterised by a series of coast-parallel north-south trending linear sandbanks with intervening channels. These sandbanks are up to 30metres in elevation, and individual banks are up to 15km long and 3km wide. They appear to be temporally persistent and were noted on medieval charts. Several theories exist regarding the processes responsible for the formation and maintenance of these sandbanks. This study documents historical patterns and rates of bathymetric and morphological change on the sandbanks at a meso-timescale (decades to centuries), identifying possible sources, sinks and transport corridors for sediment from 1840 onwards. The results indicate progressive northward extension and steepening of the landward margin of the sandbanks over a 135 year period.

ADDITIONALINDEXWORDS: *coastal morphodynamics, tidal currents, sediment budget*

INTRODUCTION

Sandbanks are elongated sedimentary bodies which can extend many kilometres in length, a few kilometres in width and several tens of metres in height. In order for a sandbank to be present, there are two fundamental requirements: an adequate source of sand, and a hydrodynamic regime capable of moving sediment (PATTIARATCHI and COLLINS, 1987). Many different types of sandbanks exist, and there are numerous theories for their origin and maintenance. While some have been attributed to tidal origins, such as those in the North Sea (HOUBOLT, 1968; CASTON, 1972), others have been ascribed to storm-related phenomena, the post-glacial rise in sea level and the hydraulic regime (Swift, 1975).

There are two main types of sandbanks; those which are actively maintained, and those which are moribund (inactive) (KENYON *et al.*, 1981). Moribund sandbanks tend to be present in deeper waters, where the tidal current regime is too weak (less than 50cm/s) to cause active sediment movement, or else in low energy shallow water areas (COLLINS *et al*., 1995; BELDERSON *et al*., 1986). In areas where sandbanks are active, tidal currents need to be strong, exceeding 90cm/s, bedforms will be present and their morphology will be asymmetrical in profile (BELDERSON *et al.*, 1986). DAVIES and BALSON (1992) suggest sandbanks transform from being actively maintained to moribund due to sea level rise during which bottom tidal currents are reduced and the ridges are drowned in situ. Features which undergo this process, can become relict and may eventually be buried by other sediments.

Theories abound regarding sandbank genesis, development and maintenance. MARSSET *et al.* (1999) suggest that sandbanks on continental shelves result from complex interactions between relative sea level change and hydrodynamic processes. Changes in sea level will influence the long-term state and preservation of the banks, while hydrodynamic processes shape the banks on a smaller scale both in space and time (MARSSET *et a*l., 1999). The best documented sandbanks are located in tide-dominated areas. These were first examined by OFF (1963) who noted their common occurrence in shallow tidal seas where currents exceed 0.5m/s and where sufficient sand is available. Tidal sandbanks are aligned to the tidal current regime of the area and their size depends on current strength. They tend to be asymmetrical in cross-section and gradually move in the direction of their steeper slope (JOHNSTON *et al*., 1982).

THE STUDYAREA

Prominent bathymetric features exist along the south-eastern seaboard of Ireland in the Western Irish Sea as a series of north-south trending sandbanks and intervening channels, aligned sub-parallel to the coast. These features are marked on medieval maps and charts because of the threat they posed to shipping and appear to have been persistent features of the coastline for at least the last half millennium. They are well developed off County Wexford between 2km and 10km offshore (JOHNSTON, 1984), and stand in 20-30meters of water, rising to within a few meters of the water surface (WHEELER *et al*., 2000). The crests are occasionally exposed intertidally. The inner banks within the study area are named Holdens Bed, Long Bank, Dogger Bank and Rusk Bank while the outer banks are Moneyweights Bank , Blackwater Bank, Lucifer Bank and New Ground. According to Dobson *et al*. (1971), these banks rest on a mantle of Quaternary till and comprise bundles of cross-bedded medium to coarse sand and have associated with them lower order bedforms.

Various schools of thought exist regarding the formation of the sandbanks at Co. Wexford and their present dynamics, however, no detailed study has been undertaken. DOBSON *et al*. (1971) and DOBSON (1977) attributed their development to fluviatile erosion and deposition during low sea levels in the late glacial period, followed by coastal erosion during temporary still-stands of the postglacial transgression, and modification by contemporary tidal currents. CARTER (1983) and JOHNSTON (1984) suggested the banks may have originated as transgressive gravel barriers formed by rapid shoreface erosion, that were overstepped during the early Holocene sea level rise. OFF (1963) described them as tidal sandbanks, as they are parallel to peak tidal currents and have asymmetrical cross-sectional profiles.

Sea level change during the Holocene is poorly documented in south-east Ireland, however, the general pattern is one of rapid early Holocene sea level rise followed by a reduction in sea level rise over the past 6000 years. Tidal range in the area is less than 1.0 m on spring tides, rendering the area microtidal and dominant wave approach is from the south and southeast. Atlantic swell does filter into the southern Irish Sea but the dominant waves are those derived from local south and south-east winds.

The origin of these sandbanks is the subject of ongoing study; the aim in this paper is to document and interpret contemporary dynamics of the sandbanks as revealed in bathymetric surveys over a 135 year period.

METHODOLOGY

To assess historic changes in the Wexford sandbank bathymetry and to quantify sediment volumetric changes, original soundings for eleven bathymetric charts were obtained from the British Admiralty. These dated from 1844 to 1979 although not all the charts extended over the entire survey area. The area under comparison extended offshore to the 50m contour line from Cahore Point in the north, to Greenore Point in the south. Bathymetric data covering all of this area was primarily limited to 19th Century surveys, as coverage since the start of the 20th Century has been much less.

Depth and positional data from each bathymetric chart was converted into digital format for interpretation, with Irish Grid selected as the co-ordinate system. All levels were corrected to Ordnance Datum (O.D.) Poolbeg , sometimes called O.D. Dublin. To interpret the digitized XY and Z data, the grid-based graphics computer program SURFER 6.01 (Golden Software) was used. SURFER interpolates irregularly spaced XYZ data onto a regularly spaced grid. Once gridded the XYZ data had a resolution of approximately one point each fifty metres. Contour maps and surface plots were created to display the changing bathymetry over the time-scale provided, and temporal volumetric changes between two bathymetric surveys were calculated.

RESULTS

The bathymetry of the research area is quite irregular. While inshore areas (landward of the 6m contour) are relatively planar, nearshore areas (seaward of the 6m contour) are undulating, and consist of alternating channels and sandbanks. The sandbanks are aligned coast-parallel and are north-south trending, forming a punctuated line along the coast. In most cases the western flank of the sandbanks is higher than the eastern, resulting in a marked asymmetry in the cross-section. Sandbank asymmetry is considered to be indicative, in general, of the dominance of the currents on one side of the bank over those on the other (CASTON, 1972; KENYON *et al*., 1981). Bathymetric analysis from 1844-1979 demonstrated that the sandbanks have been relatively stable in their overall position over the 135 year period, suggesting they are in equilibrium with the hydrodynamic regime of the area. The study area was divided into 3 main areas for detailed analysis of bathymetric change.

Zone 1

Two bathymetric surveys (1844 and 1873) were available for zone 1, which covered the area between Raven Point and Cahore Point (Figure 1). Figures 2 and 3 display interpolated 2-dimensional and 3-dimensional

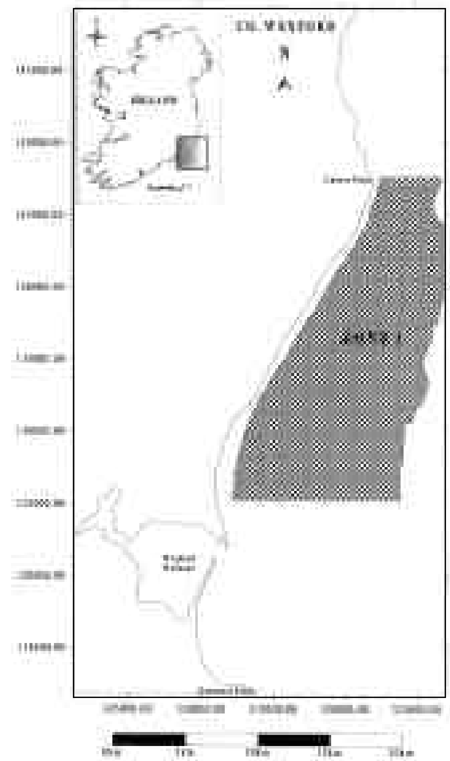

Figure 1. Location of Zone 1 in Co. Wexford.

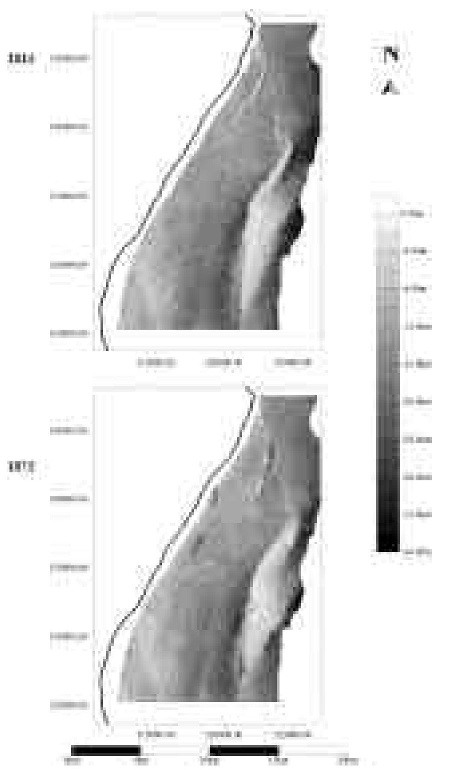

Figure 2. Contour plots of bathymetries analysed in Zone 1 (1844-1873), Co. Wexford.

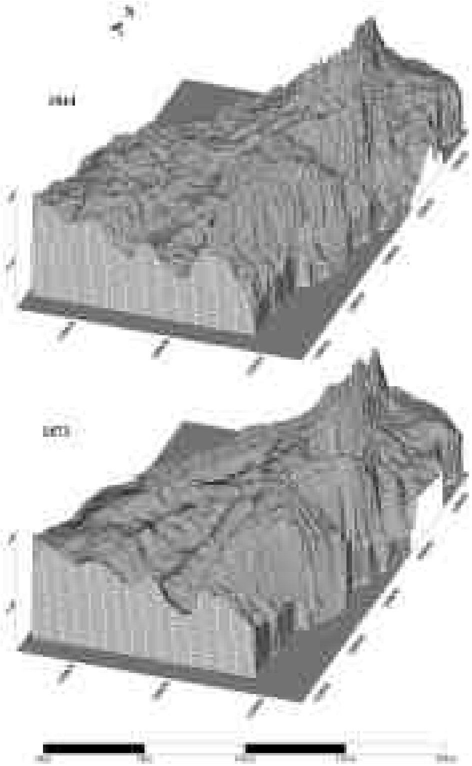

Figure 3. 3D representation of bathymetries analysed in Zone 1 (1844-1873), Co. Wexford.

representations of each bathymetry. Initial examination of this area reveals that the overall shape of the seabed has not changed significantly between 1844 and 1873. The most obvious changes are in the orientation of Rusk Bank and the position of Moneyweights Bank. The gross morphology of Blackwater Bank remained relatively unchanged, however, sediment accumulation appeared to have taken place along the eastern flank of the bank.

This zone covered an area of c. $195 x 10^6 m^3$. Between 1844 and 1873 there was a net sediment volume gain of c. $85 x 10^6 m^3$ in this zone. Accretion was significantly more widespread than erosion, with a positive volume change of c. $140 x 10^6 m^3$ against a negative volume change of c. $55 x 10^6 m^3$. This suggested a mean accretion rate of c.3 million cubic meters per year between 1844 and 1873. The spatial distribution of change between 1844 and 1873 in zone 1 is illustrated in Figure 4. Consistent with other contour plots showing the spatial distribution of volumetric change, the shaded area represents accretion, while non-shaded areas indicate erosion. Erosion is particularly apparent in the channel which runs parallel to Blackwater Bank on its western (landward) side while accretion has characterised the eastern side of Blackwater Bank (Figure 5). This suggests sediment input from a southeast direction and/or erosion along the landward margin of the banks and parallel channels, with the eroded sediment accumulating

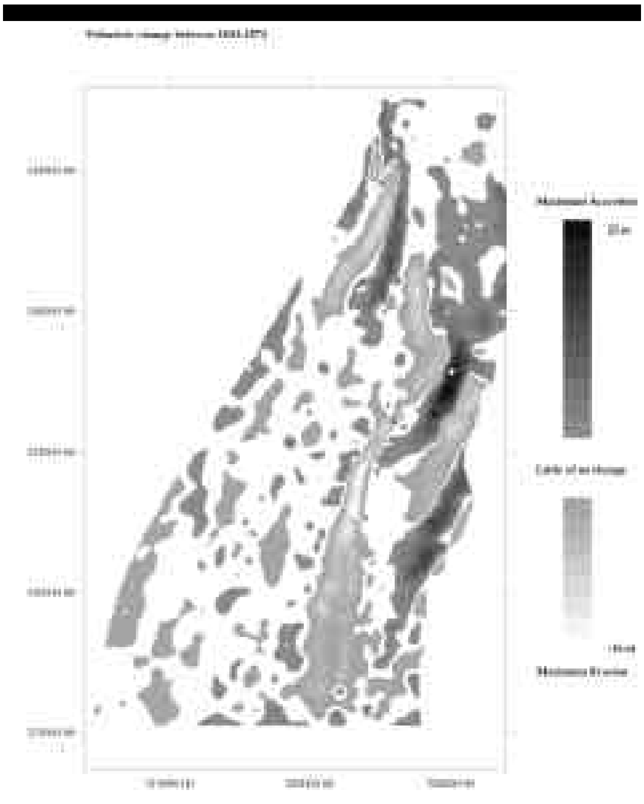

Figure 4. 2D representation of volumetric changes in Zone 1 (1844-1873), Co. Wexford.

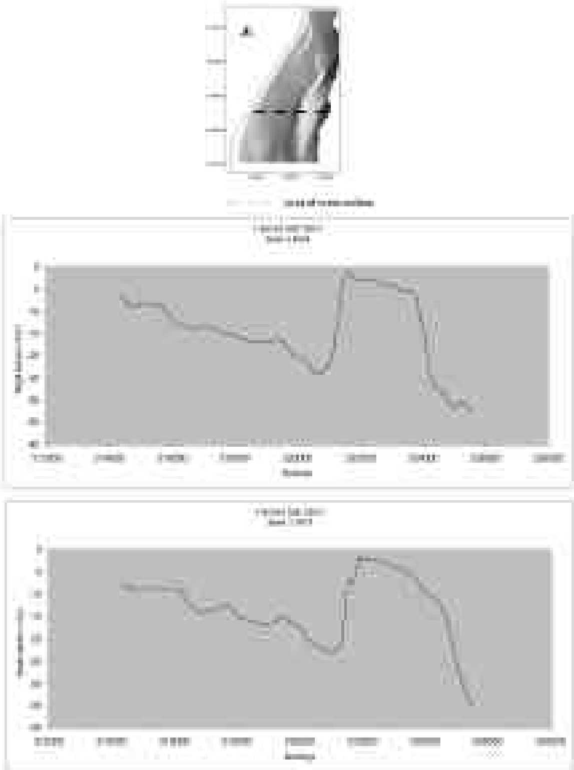

Figure 5. Cross-section profiles from Zone 1 (1844-1873), Co. Wexford.

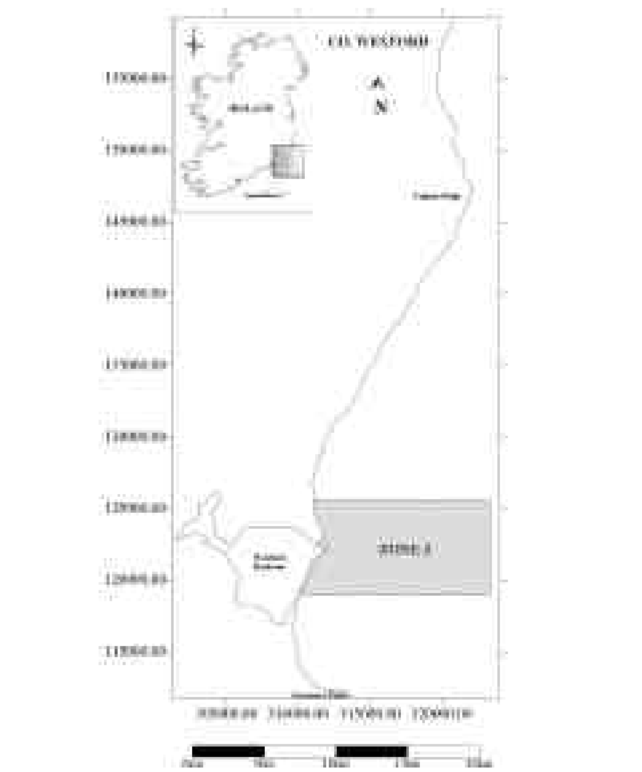

Figure 6. Location of Zone 2 in Co. Wexford.

on the seaward margin of the bank. This area is offshore of the rapidly eroding sandy coast at Blackwater Head which provides a potential sediment source. It is interesting to note that accretion is more widespread in northern areas of the zone, suggesting northerly sediment transport.

Zone 2

Zone 2 covers the approaches to Wexford Harbour, and covers an area of c. $77x10^6m^3$ (Figure 6). Three bathymetric surveys (1845, 1873 and 1908) cover this area. Contour maps and surface plots in Figures 7 and 8 show seabed changes between 1845 and 1908. The abrupt change in the direction of the channel at the entrance to Wexford Harbour is particularly noticeable. Change is also noted in the positions and morphologies of the banks and channels. Lucifer Shoal became wider, and decreased in height. The channel between Long Bank and Lucifer Shoals also became broader, while the channel parallel to Wexford Harbour became broader but more gently sloping. Cross-sections in Figure 9 consistently portray the sandbanks as being steeper on the landward slopes and more gently sloping on the seaward margin, causing a marked asymmetry.

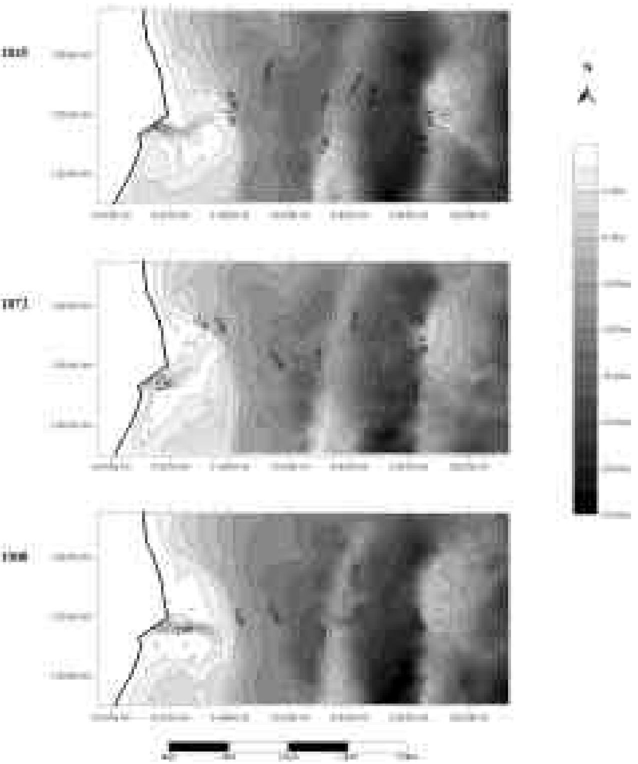

Figure 7. Contour plots of bathymetries analysed in Zone 2 (1845-1908), Co. Wexford.

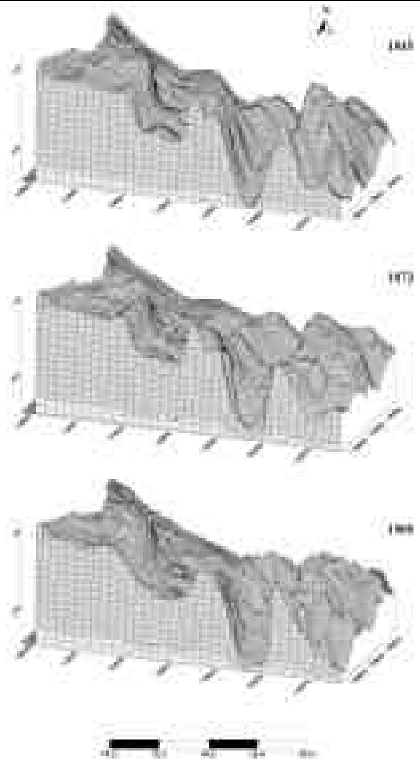

Figure 8. 3D representation of bathymetries analysed in Zone 2 (1845-1908), Co. Wexford.

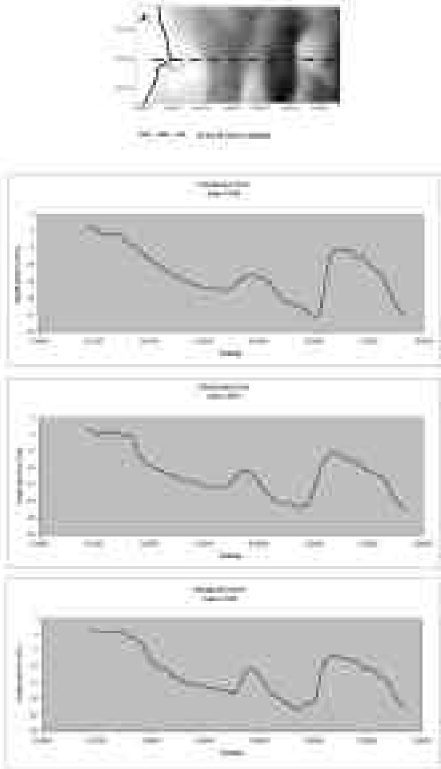

Figure 9. Cross-section profiles from Zone 2 (1845-1908), Co. Wexford.

Between 1845 and 1873 there was an overall positive volume change of c.21.5x10^{6}m^3 of sediment. Between 1873 and 1908 volumetric calculations indicated a net loss of c. 15x10^{6}m^3 of sediment within this same area. The spatial distribution of the volumetric changes in zone 2 is displayed in Figure 10. Between 1845 and 1873 erosion took place in the area surrounding the entrance to Wexford Harbour. Some erosion also took place at the northern end of Long Bank. In the region surrounding Lucifer Shoals accretion occurred at the northern and landward margins, extending the bank northwards, while erosion dominated the southern margin. Between 1873 and 1908 erosion was the dominant process within this zone, with only isolated areas of accretion. Erosion was very evident in the channels between Wexford Harbour and Long Bank and between Long Bank and Lucifer Shoals, particularly along their landward flanks.

Zone 3

Zone 3 extends from Rosslare Strand to Greenore Point and covers an area of c. 93x10^{6}m^3 (Figure 11). Bathymetric surveys were undertaken in 1845, 1873, 1908 and 1979.

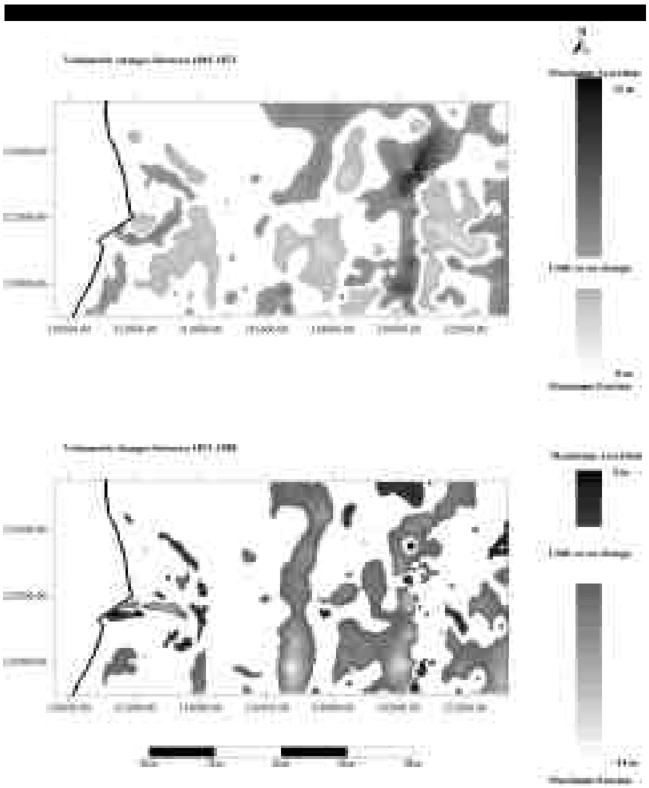

Figure 10. 2D representation of volumetric changes in Zone 2 (1845-1908), Co. Wexford.

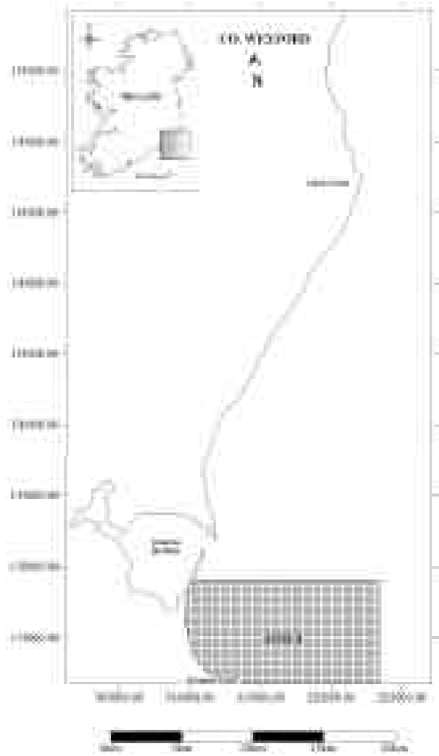

Figure 11. Location of Zone 3 in Co. Wexford.

Contour maps and surface plots portray how the bathymetry in this area has changed in Figures 12 and 13. In the 1845 representation of the bathymetry there were a series of ridges and parallel channels. By 1979 these ridges appear to have developed into distinctive sandbanks: New Ground, Long Bank and Holdens Bed. They appear to have increased in area, though not necessarily in height. As the banks have become more defined, so too have the channels between. In contrast, the bathymetry of the inshore areas in South Bay has remained relatively planar and consistent over the years, with much less change in comparison to deep-water areas. Cross-sections (Figure 14) depict these changes quite clearly.

Within this zone there was a positive net volumetric change of c. 25.5x10^{6}m^3 between 1845 and 1873. Between 1873 and 1908 this trend reversed and there was a net loss of c. 15x10^{6}m^3 of sediment within this same zone, and between 1908 and 1979 this loss increased resulting in a net loss of c. 28x10^{6}m^3 of sediment. Between 1873 and 1979, the annual rate of sediment loss from this zone therefore remained relatively consistent. Areas of volumetric change between 1845 and 1979 for zone 3 are displayed in Figure 15. Most bathymetric change took place in deep-water areas. Between 1845 and 1873 erosion took place on the seaward side of New Ground, while accretion dominated the landward side. A large area of erosion was also noted within the channel between New Ground and Long Bank. Around the northern extremities of New Ground sediment accumulated. Between 1873 and 1908 erosion was more widespread, particularly in the channel parallel to the westward side of Long Bank, and also in the channel either side of New Ground. Accretion also took place along New Ground. Erosion was the dominant process between 1980 and 1979 especially in the channel between New Ground and Long Bank, generally over New Ground and at Holdens Bed. Accretion took place only on certain areas of New Ground and at the northern end of Long Bank. Thus, despite accumulation between 1845 and 1873, most areas experienced subsequent erosion and sediment depletion.

DISCUSSION

Over the study period the general orientation and morphology of the sandbanks remained consistent. However some distinctive changes were observed. Blackwater Bank, although retaining its general position, experienced sediment accumulation on its eastern flank, particularly at its northern extremity, while western edges of the sandbank eroded. Two smaller banks, Rusk Bank and

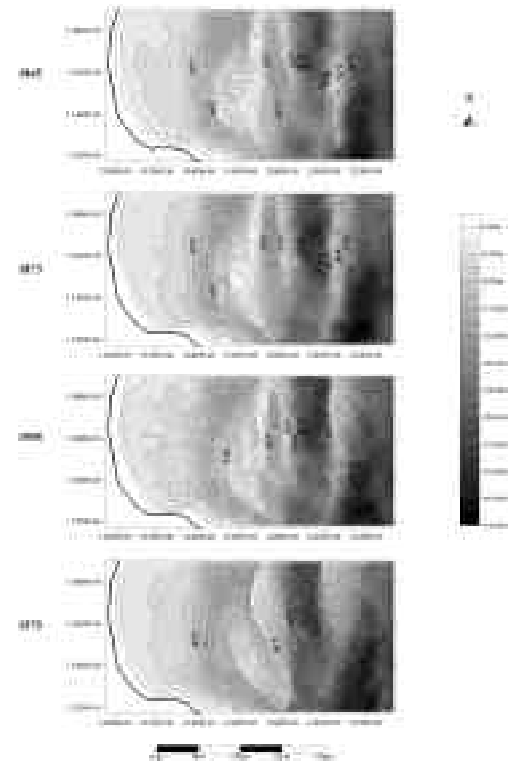

Figure 12. Contour plots of bathymetries analysed in Zone 3 (1845-1979), Co. Wexford.

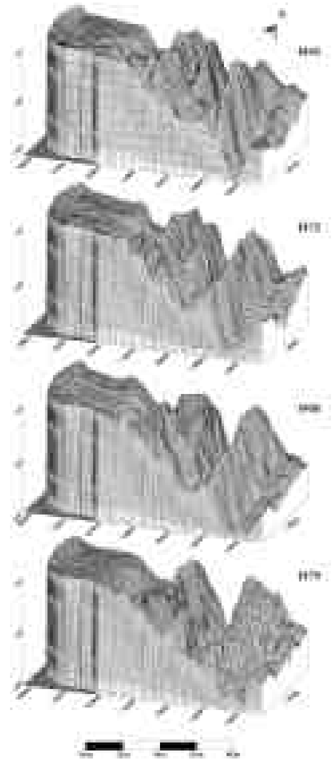

Figure 13. 3D representation of bathymetries analysed in Zone 3 (1845-1979), Co. Wexford.

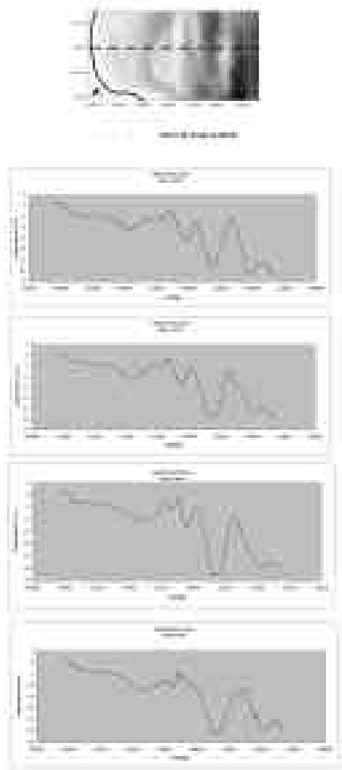

Figure 14. Cross-section profiles from Zone 3 (1845-1979), Co. Wexford.

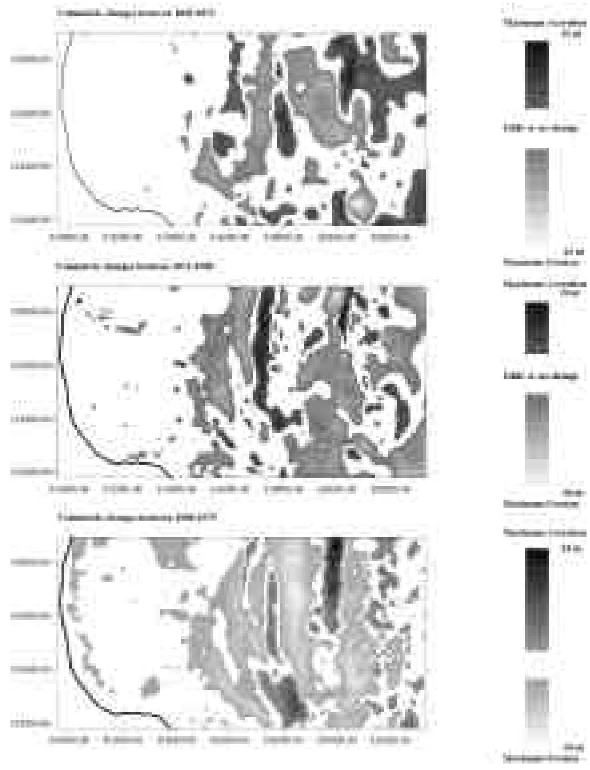

Figure 15. 2D representation of volumetric changes in Zone 3 (1845-1979), Co. Wexford.

Moneyweights Bank, appear more mobile than the others. They did not change significantly in size, but they moved in an eastward direction. Lucifer Shoals portrays a marked asymmetry in cross-section. This bank experienced a northerly accumulation of sediment up until 1873 as sediment appeared to be removed from southern localities; post 1873 this sandbank remained relatively unchanged. Up until 1873 sediment accumulated at the northern regions of New Ground, while erosion was more apparent further south. Post 1873 erosion is the predominant process particularly along the western flank of the bank. During this latter period accretion does take place at the north-western end, and to a lesser extent on the eastern flank. Long Bank experienced erosion along its western flank throughout the study period. Post 1873 there is a marked area of accretion along the central and eastern side, however erosion is evident elsewhere on the sandbank. At Holdens Bed accretion takes place until 1873 at the northern end while post 1873 erosion is widespread over most of this bank, excluding central areas.

Channelisation appears to be an important process within the study area. Over the study period coast-parallel channels appear to have increased in both width and depth. This process may have resulted in higher flow velocities and erosional energy, resulting in downcutting of the channels (WHITE, 1996). An increase in channel size is particularly apparent in the channel between Long Bank and Lucifer Shoals and Long Bank and New Ground. As the channels expanded, they often eroded the landward margin of sandbanks particularly at Blackwater and Long Bank.

The linear nearshore sandbanks have marked asymmetrical cross-sectional profiles that comprise steep landward flanks and gentler seaward margins. Lateral movement possibly results from the removal of sediment from the western side (steeper side) of the banks, with some deposition on the eastern side. The banks do not, however, appear to have migrated onshore as discrete entities or to have caused deposition on their landward margins. Instead, erosion on the landward margin is accompanied by sediment deposition on the seaward margin which suggests recycling of surficial sediments within the banks and adjacent channels. The pattern of erosion and deposition suggest that channel and landward flank erosion is caused by tidal currents while accretion of sediment on the seaward margin is driven by wave action.

The growth of sandbanks laterally is considered by CASTON (1972), to be the result of two processes: (1) oblique movement of sand upslope under the influence of the near-bed tidal currents (2) periodic downslope dispersion of sand by wave action. Much more apparent in the study area is the elongation of the sandbanks in a northerly direction. This may indicate the dominance of a northerly moving sand stream, suggesting preferred growth in this direction. Northward accumulation of sediment on several banks is indicative of wave-induced sediment transport along the crests and seaward margin of the banks. Wave breaking occurs frequently along the bank crests and wave energy dissipation is high; this promotes sediment entrainment and transport on the bank crest and seaward flank.

In a temporal sense, a period of net sediment accumulation between the 1840s and 1870s was followed by sediment losses since. The sediment accumulation during the early period may have been associated with reduction in tidal prism in Wexford Harbour and consequent reworking of the ebb-tidal delta as suggested by ORFORD (1988). A subsequent reduction in sediment supply to the area has led to net sediment losses. The patterns of morphological and volumetric change reported here, suggest that the large volumes of sediment being introduced by coastline erosion along the Wexford coast do not contribute to the morphodynamics of the nearshore banks. It is, however, likely that changes in bank morphology exert a control on incoming wave energy dispersal patterns and may influence coastal erosion patterns.

CONCLUSIONS

Analysis of bathymetric changes indicates that the sandbanks of eastern Co. Wexford are active, as opposed to moribund. Contemporary modification is ascribed to tidal and wave-induced currents and has resulted in maintenance of overall form but with distinctive morphological modification. The results suggest that:

- The nearshore zone experienced an influx of sediment between the 1840s and 1870s that was followed by a period of accentuation of nearshore bar features.
- The nearshore zone has experienced net erosion post 1870 probably as a result of northward sediment dispersal along the sandbanks.
- Bank modification is characterised by landward erosion and steepening and seaward and northward accumulation.
- The major driving forces of morphological change are (a) tidal currents which enhance channelisation landward of the banks, and (b) wave-induced currents which produce landward and northward sediment transport along the seaward margin of the banks.
- Sediment cycling takes place within the banks of a finite sediment volume. Leakages northward probably reduce the sediment volume in the medium term.

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