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The development of artificially created breaches in an embankment as part of a managed realignment, Freiston Shore, UK.

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ABSTRACT

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Recently there has been an increase in managed realignment, despite the lack of a complete understanding of the possible impacts it may cause. Therefore, it is essential to highlight impacts from past schemes and use this experience to help select and design future sites. The channels within the breaches created for a managed realignment at Freiston Shore were subject to enhanced erosion. Hydrodynamic data were recorded within a channel in a breach and inside the managed realignment site. In addition, RTK-GPS and aerial photography were used to calculate the change in plan view area of the channels in the breaches. In the first 1 to 2 months following the breaching of the embankment the channels eroded rapidly, increasing their plan view areas by 5 to 10 times. Initially, after becoming inundated during a high water, the site continued draining until the subsequent high water; however, owing to the erosion of the channels in the breaches, the flooding and draining of the site became more rapid. After 14 months, the tidal curve inside the site was similar to that over the saltmarsh. The erosion of the channels in the breaches was a result of the saltmarsh being at a higher elevation than the managed realignment site. The findings from this study demonstrate the importance of the site elevation relative to the adjacent intertidal zone.

ADDITIONAL INDEX WORDS: *Intertidal, hydrodynamics, erosion, coastal management.*

INTRODUCTION

Intertidal flats and saltmarshes occur commonly around the world, fringing large areas of the coastline. These areas are important for coastal defences, as well as being valuable habitats for wildlife. The wide intertidal flats and vegetated saltmarsh offer protection from the sea for surrounding low-lying land; these areas are becoming ever more important, owing to increased concerns of sea-level rise, combined with an increase in storminess. Areas with coastal defence structures in place may exacerbate the problems; the defences prevent the natural response of the intertidal zone to a rise in sea level, i.e. a landward migration to maintain the same elevation relative to the tidal frame. Hence, it is anticipated that non-intrusive, sustainable forms of coastal protection will be used increasingly in these areas in future years. One particular type of coastal defence, which has become popular recently and is being suggested for many sites, is that of managed realignment (ALLEN, 2000a; BLACKWELL *et al.*, 2004). This involves the breaching or removal of the most seaward embankment, allowing the site to be inundated by the tide, which, in time, leads to the creation of mudflat and saltmarsh environments. In addition to acting as a sustainable part of the flood defence system, managed realignments also help to create ecological conservation areas (MACLEOD *et al.*, 1999). To date, this approach has not been extensive in the UK, but is currently being proposed for a number of coastal management schemes despite a lack of understanding of all the potential impacts. Consequently, it is essential to highlight the effects of previous managed realignments and gain experience from them to help identify potential impacts at proposed sites.

The area under investigation is a 78 hectare managed realignment, within a tidal embayment on the east coast of England at Freiston Shore in The Wash (Figure 1) (SYMONDS and COLLINS, 2005). Artificial embankments, rising some 3 to 4 m above the upper parts of the intertidal zone, bound much of The Wash. The most recent embankment was completed at Freiston Shore in 1982. The embankments currently act as a front line of defence for 80,000 ha of low-lying Fenland, including urban areas and prime agricultural land. In total, 1,245 km^2 have been reclaimed, with this area now being used primarily for agricultural purposes (COLLINS *et al.*, 1981).

In contrast to the remainder of The Wash, the saltmarshes around Freiston Shore retreated by up to 15 m per year following land reclamation in 1982 (BREW and WILLIAMS, 2002). This effect was attributed to an insufficient intertidal mudflat elevation at the time the embankment was constructed, preventing vegetation from colonising (PYE, 1995). The embankment experienced erosion during high wave energy events associated with winter storms; this was the main reason the site was selected for managed realignment. The scheme involved strengthening of the old bank, the creation of an artificial creek system, which joined with existing creeks on the saltmarsh and the breaching of the embankment at 3 locations. An attempt was made to simulate the natural creeks, in terms of their general characteristics, i.e. size, length, and sinuosity. A breach width of 50 m was chosen

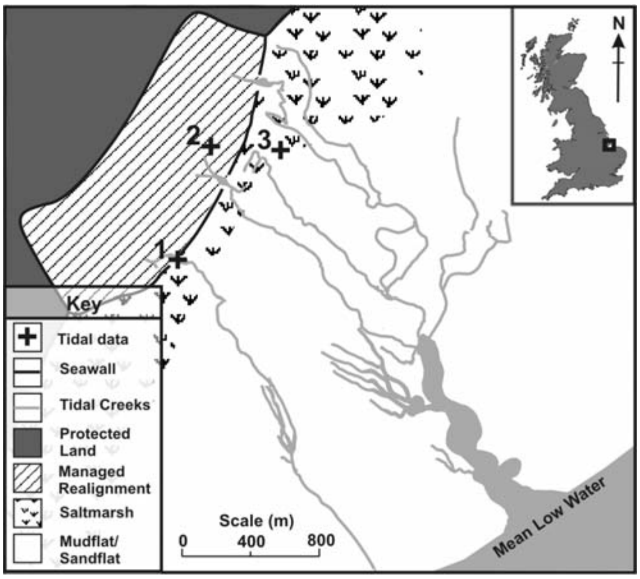

Figure 1. Map showing the managed realignment site at Freiston Shore.

for all three breaches on the basis of numerical modelling (HALCROW, 1999). The size of the breaches was designed to allow the managed realignment site to flood and ebb simultaneously with the adjacent saltmarsh. The embankment was breached at the end of August, 2002 immediately prior to the highest spring tides of the year.

METHODOLOGY

A number of methods have been utilised to investigate the development of artificially created channels within breaches in the embankment. A self-logging Autonomous Benthic Recorder (ABR) (manufactured by Valeport, UK) was deployed within the artificial channel in the most southerly breach (Breach 1) to record the first set of spring tides to flood the site (tidal data 1 in Figure 1). The ABR measures water level and current flow at 0.25m above the channel bed. Breach 1 was chosen as it was the most easily accessible of the three breaches, and was thought to be representative of the other two. Unfortunately, due to higher current speeds than predicted (1m/s from the numerical modelling), rapid erosion was experienced in the channel; this resulted in the ABR being displaced due to scour some four days after it was deployed. When originally deployed, the instrument was attached to a steel scaffold pole, which was driven into the channel bed to a depth of 1.5 m. As such, the bed must have been eroded by at least 0.5 to 1 m over three days to remove the scaffold pole, which is greater than the scour expected around such a structure with the flows recorded. In addition to the ABR, data from a tide recorder within the managed realignment (tidal data 2 on Figure 1) and one on the adjacent saltmarsh (tidal data 3), deployed by Gardline Surveys (UK) on behalf of the Environment Agency (EA), were made available. The pressure sensors were established level with the surrounding terrain and the instruments were deployed continuously following the initiation of the managed realignment.

To accurately measure the change in area of the channels within the breaches, a Real Time Kinematic Global Positioning System (RTK-GPS) package was used to record the position of the bank of the channel in Breach 1. Aerial photography of the intertidal zone has also been collected, on behalf of the EA, every 6 months since 1991; these were at a scale of 1:5000, covering the whole of the intertidal zone. A number of these photographs have been geo-referenced and used to calculate the area of the channels within the breaches (taken to be the area inside the steep channel banks).

RESULTS

Hydrodynamics

Over a tidal cycle in the initial set of spring tides to flood the site, the ebb flow lasted for 2.5 times the length of the flood. However, the peak current speed during the flood (2.6 m/s) was up to 5 times greater than the ebb (0.5 m/s) (Figure 2). This caused the managed realignment site to become submerged during the short flood period, draining at a relatively low steady rate, throughout much of the following low water (LW), before it flooded again, on the next high water (HW). Such flows were in response to the high water level of the tide, combined with a gravity flow caused by the outer saltmarsh being 0.5 to 1 m higher that the adjacent area of the managed realignment (SYMONDS, 2006).

During the initial set of spring tides, the site continued to drain throughout the ebb tide period, before being flooded again (Figure 3a). During the tides on 9th September, 2002 and 10th September, 2002 water was still draining when the following HW started to reflood the site. As a result of the first set of spring tides (6th September, 2002 to 13th September, 2002) the channels within the breaches were eroded and thus the drainage of the site became more rapid; the site remained submerged for 6 hours after HW in the following spring tidal cycle, compared to 12 hours in the initial tidal cycle (Figure 4). Some two months after breaching, the tidal curve inside the managed realignment was similar to that over the saltmarsh during the flood stage of the tide, but during the ebb stage of the tide the site still remained submerged for longer than the saltmarsh by 3 to 4.5 hours (Figure 3b). On the basis of the length of time the site remained submerged, after eight months of flooding the drainage of the site appeared to reach a relatively stable rate, with the site consistently draining in 3.5 to 4 hours, while the adjacent saltmarsh drained in 3 hours. Even 14 months after the breaching of the embankment the tidal curve inside the managed realignment site still did not ebb simultaneously with that over the saltmarsh (Figure 3c), as it was initially designed to do.

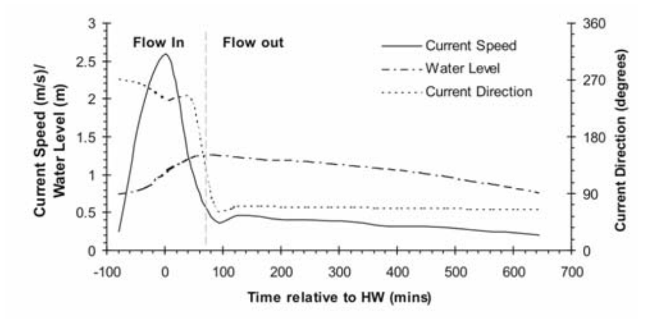

Figure 2. Hydrodynamic conditions in the channel within Breach 1 over a tidal cycle (06/09/2002 am).

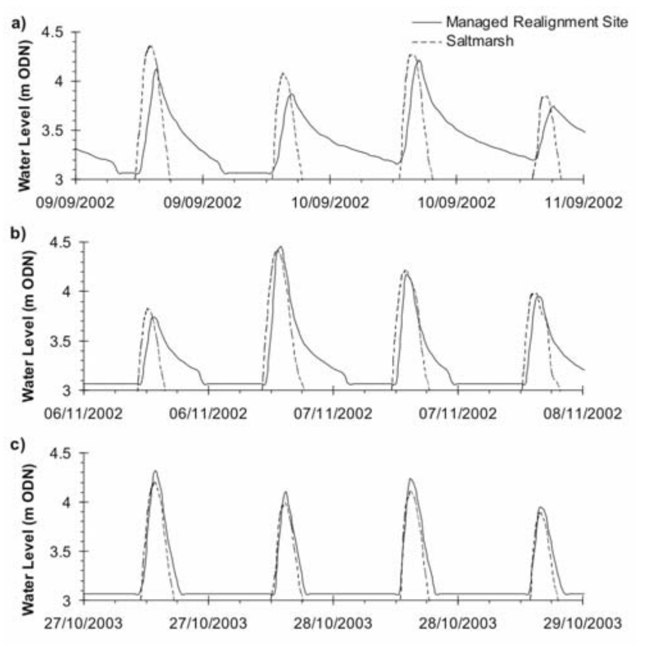

Figure 3. Measured water level inside the managed realignment site and on the saltmarsh, a) 1 week after breaching, b) 2 months after breaching and c) 14 months after breaching.

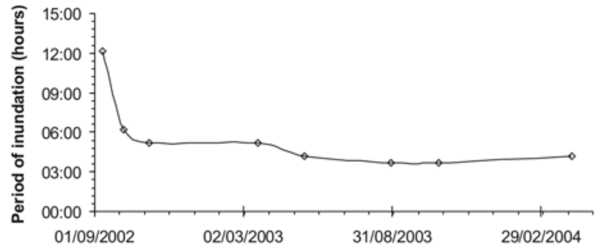

Figure 4. Average length of time the managed realignment site remained submerged following high spring tides over an 18-month period.

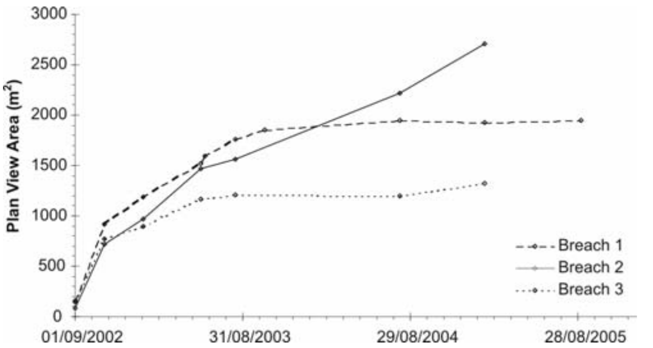

Figure 5. Change in plan view area of the channels within the 3 breaches.

Channel Development

The development of the channels within the breaches was studied by examining the change in their plan view area. These data were derived on the basis of geo-referenced vertical aerial photography, combined with RTK-GPS measurements. The three channels within the breaches underwent a rapid phase of erosion, during the first one to two months following the initiation of the managed realignment scheme (Figure 5). This rapid erosion of the channels in the breaches resulted in the initial channel dimensions of 2 m wide by 1 m deep (Figure 6) increasing to become roughly 20 m wide and 4 m deep (Figure 7). Subsequently, the 3 channels continued to erode at a near linear rate for roughly 12 months. Over the following 18 months the channels within Breaches 1 and 3 have remained relatively stable, increasing by a maximum of 100 m^2. In contrast, the channel within Breach 2 continued to erode at a slightly reduced rate to that of the initial rapid erosion, with the channel enlarging by 1200 m^2 over the final 18 months of measurements. In addition to the higher rates of erosion within Breach 2 when compared to the other breaches, the natural creek to which it is connected has undergone erosion, increasing in width from 5 m at the time of breaching to 25 m some 30 months later. This change increased the potential discharge entering and leaving the channel. The natural creeks connected to the channels, within Breaches 1 and 3, have experienced erosion, but to a lesser extent and have widened and deepened to double their size in the 30 months since breaching, from a width of 3 to 6 m and a depth of 2 to 4 m approximately.

DISCUSSION

The breached site was only reclaimed several centuries before the managed realignment, and was lower than the saltmarsh, owing to compaction and dewatering of the site and accretion on the adjacent saltmarsh. This, combined with the tight confines of the original artificial channels within the breaches, prevented the site from flooding and ebbing as intended, leading to strong currents on the flood tide. This led to a rapid initial rate of erosion in the artificial channels in the breaches.

Over the first month following the breaching of the embankment, there was a marked reduction in the length of time the site remained submerged. At this time, the flood phase started to mimic closely the tidal curve over the adjacent saltmarsh. After some 20 months, the ebb phase became similar to that on the saltmarsh. The reason for this change in the drainage was that the initial dimensions (1 m deep, 2 m wide) of the artificial channels within the breaches were insufficient to accommodate the volume of water entering and leaving the managed realignment site. As a consequence, some 2 months after the breaching of the embankment the channels in the breaches had eroded to 10-15 times their original size (SYMONDS, 2006). Since this initial period of rapid erosion, the rate of change diminished; this is consistent with the findings of a laboratory experiment undertaken by SHIMIZU (1991), where it was stated that a channel will undergo a period of rapid erosion, followed by a much longer period of smaller changes. Similar erosion patterns have been experienced at other schemes. For example, at Tollesbury, Essex, UK, a 1 m wide breach eroded, over a few days, to a pre-determined (modelled) width of 60 m (ALSOP *et al.*, 2004) whilst in the Westerschelde, Holland, within 85 years of the re-flooding of a series of enclosures, a creek network developed that reached back some 12 km from a main channel which had grown at its mouth to a width of approximately 750 m (ALLEN, 2000b).

In addition to the erosion of the channels within the breaches and the natural creeks they connect to, the enhanced development of a creek system over the mudflats on the mid-intertidal zone was

Figure 6. A seaward view of the channel within Breach 1, shortly after it was created (22/08/2002).

Figure 7. A seaward view of the channel within Breach 1, two months after the initiation of the managed realignment scheme.

witnessed (SYMONDS and COLLINS, in press). This creek development was the result of water from the managed realignment draining across the intertidal zone rather than just inside the natural creeks. This development ceased 2 years after the initiation of the scheme as the channels in the breaches and the natural creeks they connect to eroded to a sufficient size to contain all of the flow draining the site.

The erosion of the three channels within the breaches was greatly reduced some 27 months after the breaching, with the possibility of the channels starting to reach a dynamic stability. Breach 2 became the dominant drainage route, and, as such, it focused the majority of flow during the drainage of the site and thus it suffered more erosion than the other channels. This pattern could be owing to: (a) the topography of the site focussing the flow into this particular breach; or (b) the channel being connected with the most efficient natural drainage creek, allowing a greater volume of water to flow into and out of the managed realignment than Breaches 1 and 3. Such dominance of one of the breaches is difficult to predict, although with modern high resolution numerical models it is possible to identify areas prone to erosion and accretion.

CONCLUSIONS

Owing to the saltmarsh being at a higher elevation than the adjacent managed realignment site, the initial design of the channels within the breaches of the site was such that they were unable to allow the necessary volume of water into and out of the managed realignment site without adjustment. The channels were rapidly eroded in the first few months following the breaching, after this, a more constant rate of erosion was experienced, with the most recent measurements showing the channels to be up to 20 times wider than they were originally designed. The development of the channels in the breaches meant that after some 14 months the flooding and ebbing of the tide inside the site was nearly synchronous with that over the adjacent saltmarsh.

In cases where multiple breaches are made in an embankment, it must be remembered that the breaches are prone to develop at variable rates. At Freiston Shore all three breaches developed differently, with the central breach eroding to nearly twice the width of the other two. Even if an accurate prediction of breach width is achieved for the site, high resolution numerical modelling is necessary to identify breaches which may be prone to erosion, owing to variations in the local topography and drainage patterns.

From the rapid development of the channels within breaches in an embankment, it is clear that the elevation of the site relative to the adjacent intertidal zone (saltmarsh in this case) is important for the design of managed realignment sites. In addition, this case provides a valuable example of how breaches of insufficient depth may develop when the managed realignment site is lower than the adjacent saltmarsh, as may be the case in many potential sites. The erosion and development of breaches in an embankment may not be a problem at some potential managed realignment sites, while at others it maybe unacceptable; hence, care must be taken to identify impacts such as this prior to the initiation of any schemes.

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