Possible Causes of Saltmarsh Erosion

With reference to the Deben Estuary

Prepared for the River Deben Association and the Deben Estuary Partnership

Carol Reid

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Carol Reid BSC (Hons) Life Sciences, is an independent ecologist and former conservation adviser with Natural England/English Nature. She has specialist knowledge of coastal and marine habitats, including: survey, designation and management of protected sites; saltmarsh habitat creation; and sediment recharge.

Report specification

To prepare a short report to describe possible factors causing saltmarsh erosion. Factors to be considered will be: human activities, physical processes and biological processes. Reference will be made to the findings of wider, regional studies and observations, with specific reference to the Deben Estuary to illustrate current understanding, where possible. Human activities will cover historical land claim and embankment of saltmarshes; pollution; and water-based activities. Physical processes will consider wind and wave energy, sedimentation and sea-level rise. Biological processes will look at findings of studies on the activity of invertebrates in the saltmarsh and mudflats. The latter to include a literature search for any work carried out on crabs burrowing into saltmarsh and any further studies on ragworm bioturbation post the 2006 studies by Professor Hughes. Recommendations for future work will be made.

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Introduction

Factors which may impact on saltmarsh erosion are discussed in this report with reference to the Deben estuary, where specific information is available. Physical processes such as sea level rise, the tidal energy regime, wind and wave climate and sediment supply are considered in the context of historical land claim which has reshaped the Deben valley since the 11th century. Possible pollution impacts and biological processes are also reviewed.

Saltmarsh losses in the Deben Estuary Site of Special Scientific Interest

Studies of saltmarsh change in the Deben covering the periods 1971 to 1998 reported a reduction in area from 311.7 hectares to 240.7 hectares, representing a net loss of 22.8 per cent loss (Cooper & Cooper, 2000).

A recent report on management units within the Deben Estuary SSSI has indicated that between 2000 and 2007 the saltmarsh had incurred further net losses (Boyes & Thomson, 2010). Due to advances in mapping techniques and differences in habitat coverage it is difficult and unreliable to make a direct comparison with the current work and earlier reports, however rates of saltmarsh change have been compared. Though still indicating a negative trend, the current survey indicates a slight reduction in annual rates of loss. This slowing of rates of net loss was also reported in a survey of saltmarsh change in Essex SSSIs (Thomson *et al*, 2011).

The Environment Agency (2011) has attempted to compare the results of their recent national study with historical data. Applying a correction factor, the EA work does suggest that the rate of loss nationally may have reduced. However, they acknowledge that this exercise may be highlighting differences in mapping methodologies rather than actual changes on the ground. Furthermore, rates of change are unlikely to stay the same in the face of accelerated sea level rise. The main driver for the EA national overview was to create a consistent baseline from which future studies in saltmarsh extent can be reliably compared and inconsistencies between data eliminated. Natural England and the EA are currently comparing the recent Deben Estuary SSSI study with the EA baseline data to ensure that the final area calculations for saltmarsh are consistent. The results of this investigation will be reported in 2013.

The pattern of erosion illustrated in the 2010 Boyes and Thomson study and the earlier reports, involves the marsh frontage and creek banks and is characteristic of coastal squeeze. This develops where sea defences are preventing saltmarsh from moving landward in response to factors such as changes in the hydrological regime of the estuary following land claim, and sea level rise.

Land claim

Periodic land claim and enwalling of the Deben estuary occurred mostly between the 11th and 17th centuries, with extensive areas of saltmarsh undergoing reclamation in the lower reaches at Falkenham, Bawdsey and Felixstowe. The enclosed high marshes were subsequently converted to agricultural use. Further embanking was carried out in the middle and upper reaches in the 19th century: clay banks were constructed at Waldringfield, Martlesham Creek and Woodbridge at this time. Following the 1953 floods, sea walls have been raised and revetted to increase flood protection of low lying land in the upper estuary. Overall, land claim has reduced the original extent of the Deben valley by 76 per cent (Royal Haskoning, 2008), removing a total of 22.4 square kilometres of the intertidal area (Beardall *et al*. 1991).

Enwalling areas of the estuary flood plain effectively displaces water during a natural tidal cycle. With less of the intertidal area available for flooding by the incoming tide, water depth can increase submerging the remaining mud flats and marshes for longer periods, and the tidal range may increase upstream (French, 1997). In addition, frictional drag may be reduced leading to excess tidal energy and an increase in current velocities altering the erosion and accretion pattern of the estuary. Erosion may be initiated along the front edge of the remaining marsh and can penetrate the marsh interior cutting new creeks and extending them headwards, as well as scouring the creek beds and banks (van der Wal & Pye, 2004). Where the heads of creeks are truncated by a sea wall they extend along the line of the sea defence; this type of creek formation appears to have developed within the saltmarsh opposite Waldringfield and in the marshes upstream of Kyson Point. Eroded sediments may be redeposited in the main channel and some may be transported out of the estuary on the ebb tide.

Where previously embanked land has been reflooded this can also affect the hydrodynamic regime of the estuary. Unplanned breaches at Methersgate, Hemley, Waldringfield and Sutton Hoo may have altered flow velocity.

In places where embankments protrude into the estuary local impacts on flow conditions can be readily observed. Restricted tidal flow around the Tide Mill Yacht Harbour has increased current velocities leading to erosion of the Ferry cliff. Back eddies have formed promoting siltation inside the Ferry quay.

Sea level rise and coastal squeeze

Accounting for global sea level rise and post-glacial land adjustments, sea levels on the south-east coast of England are increasing by between 1.5 and 2mm per year. These changes are moving the low water mark landward but coastal defences are preventing a compensatory landward migration of the high water mark. Consequently intertidal habitats are being squeezed between rising sea levels and artificial defences, or steeply rising ground. Under this scenario, the typical outline of stable and accreting marsh, fronted by a gently sloping bank, changes to a cliffed or mud-mound profile as erosive processes attack the lateral edge. Erosive forces may also penetrate the creek network causing creeks to widen and extend headwards. The elevation of saltmarsh in the tidal frame is a critical factor in determining the number of tidal inundations it undergoes. Depending on sediment availability, saltmarshes may be able to keep step with sea level rise by building vertically. However, if vertical accretion rates are outpaced by rising sea levels the frequency of tidal flooding will increase, inhibiting plant growth. This will lead to changes in the vegetation composition of the marsh as high and mid-marsh communities, unable to tolerate the changing conditions, revert to low marsh, with common cord-grass (*Spartina anglica*) often representing the final stage of this regression. This process is evident in the upper reaches of the Deben where the saltmarsh is dominated by the tall stems of cord grass. Eventually, saltmarsh communities 'drown' and are replaced by bare mudflat.

These changes in saltmarsh morphology and vegetation composition follow the same processes as those discussed under land claim.

Wind and wave climate

Wave climate on the East Anglian coast is dominated by the storm wave environment of the southern North Sea. Van der Wal and Pye, (2004) have linked a higher incidence of strong winds and an increase in mean wave heights in the North Sea with accelerated saltmarsh erosion on exposed estuaries on the Essex coast in the 1970s. These sites would have been particularly susceptible to easterlies and south-easterlies. Meteorological records and independent evidence also suggests that southerly and south-westerly winds also increased in intensity and frequency during this time.

The predominant wind influence on the Deben is from the north-east (50%) with south-westerlies prevailing 32% of the time (CEFAS West Gabbard Buoy: Jan-Dec 2003; Burningham & French, 2007). Wave action is dampened by the narrow mouth and the presence of the shifting, shingle banks of the Knolls. The off-shore banks also help to buffer the estuary during stormy conditions. However, a run of north-easterlies can lead to erosion and relocation of the Knolls leaving the mouth exposed allowing waves to propagate into the estuary.

There are signs of wave erosion at the southern end of the Bawdsey saltmarshes (personal observation), and this could be attributed to wind generated waves from the south-west.

However, it is not known if there is any evidence to suggest a correlation between increases in the frequency and strength of north-easterly and south-westerly winds over the last 30 years or so and increased rates of saltmarsh erosion during this time.

Storm surges

Storm surges may cause major morphological changes to saltmarshes, including front edge erosion, sediment deposition onto marsh surfaces, and breaching of sea walls, as evidenced at Hemley, Waldringfield and Methersgate marshes in 1953. There is no conclusive evidence that storm surge events have increased in recent decades (van der Wal & Pye, 2004).

Boat wash

Regular boat traffic, particularly in the narrower sections of the upper estuary, may contribute to saltmarsh erosion. Certain factors increase the susceptibility of the shoreline to erosion (UK marine special areas of conservation project):

- An exposed point of land in a narrow channel.
- A steep, near-shore gradient.
- Water level in proximity to vulnerable areas of the shoreline.
- High levels of boating activity concentrated near to the shore.

Sediment sources

It has been estimated that the supply of sediment to the Deben estuary from offshore is around 16 times greater than that supplied from freshwater inputs (Beardall *et al*., 1991). Eroding subtidal and intertidal clay outcrops off the Suffolk coast contribute sediment to the estuary, but the main source of supply to the Deben and other east coast estuaries is derived from the erosion of soft cliffs at Holderness, north-east Yorkshire, and the north-east section of the East Anglian coastline, at Covehithe and Eastern Bavents. However, there has been a general reduction in sediment supply to coastal systems over the past 200 years owing to coastal and river engineering works.

The dominance of the ebb current in the middle and lower reaches of the Deben promotes the transport of sediment out of the estuary; and the action of small, wind-induced waves in the middle reaches may facilitate this process by causing the resuspension of sediments in the water column (Royal Haskoning, 2008).

As sediment supply is likely to be a critical factor in response to sea level rise any losses of sediment from the estuary threaten the sustainability of saltmarshes.

Excavation of sediment

In addition to the saltmarsh losses due to land claim, mud digging has reduced the area of vegetated marsh outside the sea walls. In some places on the Deben, borrow dykes have been dug inside the saltmarsh to supply material to construct sea wall embankments, for example at Waldringfield, Methersgate and Hemley. Digging has also created grid lines in the saltmarsh at Methersgate and Hemley. These excavated channels do not act as sediment sinks but instead have become tidal reservoirs discharging large volumes of water on the ebb, eroding existing creeks and initiating internal creek dissection (French, 1997). Saltmarsh and mud have also been removed or displaced to create berths for boats and for oyster pits (opposite Falkenham Creek).

Dredging

Channel dredging is not carried out in the Deben Estuary. Small-scale plough dredging removes recently deposited silts to the channel and the sediments are redistributed by the tide. This has a temporary, localised impact as the sediments are resuspended and redeposited, but this would not influence the wider estuary geomorphology.

Pollution

The chemical and biological quality of the Deben was given a 'C' standard rating and described as 'fairly good' under the [1]Environment Agency's General Water Quality Assessment of 2007 (Environment Agency, 2010). During this assessment very high levels of nitrates and moderate levels of phosphates were recorded in the estuary. The main input of these chemicals is likely to derive from diffuse sources, including agricultural production, sewage treatment discharges – there are treatment works at Melton, Woodbridge and Felixstowe – and naturally occurring phosphates leaching from crag-based soils around the Deben estuary. The saltmarsh itself releases nitrogen and phosphorous as organic matter decomposes. If excess loadings of nitrogen and phosphates occur in the water this encourages the growth of algal mats in the summer which can smother the saltmarsh and mud surface and may affect the germination and growth of pioneer saltmarsh species (Boorman, unpublished data).

The major source of diffuse pollution into the Deben Estuary derives from agricultural land use. In addition to fertilisers entering the estuary and contributing to the production of algae, pesticides may have direct impacts on saltmarsh growth. Work has been undertaken on the effects of Mecoprop® on saltmarshes (Royal Haskoning, 2007). Drainage ditches are vulnerable to contamination if it rains soon after application of this herbicide. Pollutants can then drain into the saltmarsh creek system and may be persistent.

[1]The GWQA is being replaced by a more comprehensive monitoring programme required under the Water Framework Directive.

Mason *et al* (2003) have suggested that sublethal concentrations of herbicides have contributed to increased erosion of saltmarsh in eastern England over the last 40 years.

Their research indicated that concentrations of herbicides within the ranges found in the aquatic environment, and sublethal concentrations, decreased growth rates and photosynthesis in microscopic algae (diatoms) and reduced photosynthesis in higher plants. They also noticed that the stability of sediments had decreased due to a reduction in the biological 'glue' produced by diatoms. These toxic effects on plant production processes could threaten the overwinter survival of saltmarsh and the destabilisation of sediments could impact upon pioneer saltmarsh development.

Boorman (unpublished data) has suggested that Tributyltin (TBT) - used as an anti-foulant before it was banned in 1987 due to its toxic effects on molluscs - affects the growth of saltmarsh plants. Though it only has a half-life of days or weeks in the water column, below the mud surface it has a half-life of tens of years. However, significant amounts of TBT, herbicides and pesticides, may become adsorbed onto sediment particles on saltmarsh surfaces. The combined effects of adsorption and burial under accreting sediment essentially inactivates these pollutants and over time they become unavailable to plants and animals, reducing their potential to build to toxic levels in the food chain. Erosive processes may remobilise these contaminated sediments or they may be removed to sediment sinks, such as marine basins (Royal Haskoning, 2007).

Herbivory and bioturbation

Ragworms

Ragworms living above and below the mud surface disturb the sediment by their movements, feeding behaviour and burrowing, a process known as bioturbation. They are generalist feeders, and deploy several different feeding mechanisms. Through their 'engineering' activities they irrigate and oxygenate the sediment. In the laboratory it has been demonstrated that secretions made by ragworms (*Nereis diversicolor*) while constructing their burrows increase the shear strength of sediments, and high densities of burrows dissipate wave energy and reduce erosion (Murray, 2002).

Conversely, (Paramor & Hughes, 2004) claim that the feeding (herbivory) and burrowing activities of ragworm are a key factor in creek erosion and the loss of pioneer saltmarsh. Their laboratory experiments showed that ragworm consume and bury saltmarsh seeds and seedlings. However, field experiments using mats to exclude ragworm from a small area of creek network were inconclusive in demonstrating the establishment of *Salicornia* sp (glasswort) in the absence of burrowing. Sediment did build up on the mats placed in the creeks and this was attributed to the exclusion of ragworm and other mud invertebrates, but the experimental procedure failed to eliminate the influence of the mats in stabilising the sediment. Other researchers have opted to use insecticides to exlude ragworm. This treatment reduced the densities of ragworm, other worms and smaller marine animals while the aggregates of microscopic algae (diatoms), which form a biofilm adhesive on the mud surface, were unaffected. Over a four-day period, an increase in sediment stability was reported along with a decrease in the water content due to a reduction in bioturbation and grazing pressure (de Deckere *et al*, 2005). However, the influence of ragworm on sediment stability may be more complex. Bioturbation enhances the aeration of sediments which enables diatoms to settle deeper into the mud than they would if the ragworm were absent (Scaps, 2002). Also bioturbation facilitates the recycling of nutrients which stimulate the growth of diatoms. Paserelli *et al* (2012) demonstrated that even if ragworm consume significant amounts of diatoms, by inputting nutrients into the water column, they accelerated the growth of diatoms and their 'glue' secretions, as well consolidating sediments themselves by building burrows. In this way ragworm appear to have a dual effect on the adhesion of sediment particles.

Landscape-scale coastal habitat creation, where sea walls have been deliberately breached to allow flooding of former farmland, have demonstrated the successful establishment of pioneer saltmarsh. Abbott's Hall on the Blackwater Estuary (personal observation), Freiston Shore in Lincolnshire (Morris *et al*, 2004), and Trimley Marshes on the Orwell (Royal Haskoning, 2007) all developed extensive areas of glasswort during the first growing season after breaching. Bioturbation and herbivory does not appear to have inhibited glasswort colonisation on these sites. Elevation in relation to tide levels is generally regarded as the most important environmental factor affecting the establishment of saltmarsh species (Wolters *et al*, 2006).

The Tollesbury set-back site in Essex was breached in 1995 and glasswort was recorded during the first year of monitoring, in 1997. It became established as the dominant species over six hectares of the 21-hectare site by 2001 (Garbutt *et al*, 2003). Ragworm were present within the site during the development of pioneer saltmarsh. During 1999 to 2000, densities of ragworm on the mud flats within the site increased from 100 individuals per square metre in November 1999, to 850 the following summer (Brown, 2000). The work at Tollesbury demonstrated that the population varies throughout the reproductive cycle and can be heavily depleted by predators: ragworm numbers increased in the summer due to recruitment and recovery following predation by wading birds in winter. On the Stour and Orwell estuaries and in the Essex estuaries of the Colne, Blackwater, Crouch and Roach, the densities of redshank and curlew are closely linked to densities of ragworm (McLusky, 1981). The large number of wading birds visiting the south-east estuaries is a qualifying criterion for protection under UK legislation and for classification as important European and international wetlands. As well as ragworm numbers being controlled by bird feeding, ragworm populations are also influenced by competition with other species, and their distribution in estuaries is affected by salinity gradients, which tends to draw maximum numbers to the middle sections.

As mentioned above, ragworms employ a variety of feeding strategies depending on food availability and do not feed exclusively on saltmarsh plants. They can be carnivorous and actively search for soft-bodied invertebrates on the surface of the mud, or they can switch to deposit feeding capturing living and decaying plant and animal material and drawing it into their burrows. When concentrations of algae in the water column are sufficiently high this may be the prompt to change to filter feeding and in this way ragworm may play a significant role in controlling algae (Riisgård, 1991). Gribsholt and Kristensen (2002) have shown that ragworm, and other invertebrates, are important in limiting the spread of algal mats on the mud surface, which, if they develop unseasonally early, could inhibit the propagation of saltmarsh plants.

Bioturbation is a natural process in an estuary system as mud-dwelling species disturb the sediment as they move and feed. Thousands of marine snails feed on the mud surface, shrimp-like animals and shellfish burrow just below the surface while some marine worms excavate tubes deep in the sediment. The manifestations of bioturbation in the form of burrows, tubes or depressions can increase surface roughness and actually reduce erosion. The mucous 'glue' secreted into burrow walls bonds sediments and can fix them in place for some time. Through the process of ingesting and excreting food, ragworm cycle vital nutrients and chemicals in the estuary making them available for other marine life, including microscopic algae which help to bind the surface sediments. By drawing oxygenated water deep into the mud, they create ideal conditions for microorganisms to thrive. These bacteria play an important role in the fixation of nitrogen, which is fundamental to plant and animal life in the estuary (Scaps, 2002).

Shore crabs

There is a suggestion that shore crabs burrowing into mud banks are eroding the saltmarsh. Shore crabs employ a variety of survival strategies to avoid desiccation and predation at low tide, and during moulting. They seek shelter under algal mats, seaweed, the base of sea walls, any objects washed up on the shore, crevices in saltmarsh banks, or burrow just under the surface of soft muds or sand on the tidal flats. In the summer crabs spend their time in the upper estuary migrating to deeper waters in the winter, or generally being more widely distributed in the estuary during the colder months.

Evidence of shore crabs burrowing into saltmarsh banks has been described in a study on the coast of south-west Wales (Crothers, 1966). During the summer the burrows were found to be occupied mostly by small, first-year crabs. It was suggested that crab larvae initially settled on the shore and remained there as juveniles until the following spring, sheltering under seaweed or stones at low tide or seeking refuge in burrows located above the high water mark of neap tides. Studies of adult crabs found that they either sheltered on the intertidal flats during low tide or retreated below tide level on the ebb, while some remained below tide levels at all times.

It is possible that as mud cliffs are eroded by natural processes they may be more vulnerable to collapse if they are intensively burrowed. Burrowing activity is not well documented in the literature. The spatial and seasonal distribution of shore crabs in the estuary, their mobility with the tides, the evidence of burrowing being connected primarily with the early stages of their life cycle, and the likelihood that juvenile crabs are more heavily predated than adults, suggest that any possible impact on saltmarsh is likely to be incidental to erosive processes rather than a major cause of saltmarsh erosion.

Chinese mitten crabs

Chinese mitten crabs are native to East Asia but have established in estuaries on the east coast of England following introduction via ship ballast water. They are now common in the Thames, Medway, Humber and Dee estuaries and on the Ouse Washes. They are prodigious burrowers and are able to excavate vertical and horizontal tunnels in saltmarsh banks causing them to collapse (Natural History Museum web site). The population is continuing to undergo expansion, though there is no documented record of this species on the Deben. It has been found recently in the Blackwater estuary (personal communication).

Grazing

There is no livestock grazing on the Deben saltmarsh. Ducks, geese, rabbits and hares are known to feed on saltmarsh plants. The feeding behaviour of ducks and geese is not considered a causative factor in the erosion of saltmarsh. None of the species described below feed exclusively on saltmarsh plants.

Short grass and winter wheat are a favoured food of brent geese inside the sea wall, and grazing may occur on saltmarsh 'plateaus'. A tight, short sward can result with tillering of grass shoots, although puddling of the marsh surface may occur. However, changes in the structure of the marsh vegetation due to goose grazing can create nesting opportunities for wading birds. A flock of Canada geese frequent the upper reaches of the Deben estuary and greylag are occasional visitors. These geese feed on grasses and cereals and on a variety of aquatic plants, generally in the brackish and freshwater zones of the marsh. Wigeon return to the estuary in winter and during this time the leaves and roots of saltmarsh vegetation and grasses on freshwater marshes landward of the sea wall are the mainstay of their diet.

Conclusion

Land use changes and enclosure of former intertidal areas have modified the hydrodynamic regime of the Deben estuary changing water and sediment circulation, influencing relative sea level, and preventing landward migration of saltmarsh in response to sea level rise. These factors are likely to have led to the large scale erosion of saltmarsh which has shown considerable losses over the period that studies have been reporting on saltmarsh change. The 2010 (Boyes & Thomson) research has mapped significant erosion in the upper reaches of the estuary: between the Melton sewage works and Sutton Hoo, and the stretch of the river between Kyson Hill and Methersgate Quay. Ground observations confirm that the marshes are substantially degraded in these areas. The 1971 to 1986 Deben study also reported saltmarsh erosion on the north side of Martlesham Creek and at two locations opposite Methersgate Quay, suggesting that these areas may be particularly vulnerable. Saltmarshes in the lower reaches of the estuary appear to be more stable, according to the 2010 report, though there is evidence that wave erosion is impacting the southern end of Bawdsey marshes and changes in vegetation are evident suggesting that the saltmarshes are undergoing more frequent flooding (personal observation).

Reduced sediment supply, pollution, excavations within the saltmarsh, and possibly boat wash, may also be contributory factors.

Through the process of bioturbation and herbivory it would appear that ragworm play a vital role in the functioning of a healthy ecosystem and may help to bind sediment and reduce erosion as well reworking sediments and irrigating the mud below the surface. The development of saltmarsh on intertidal habitat creation sites, the omnivorous diet of ragworm and their various feeding strategies, suggest that they are not likely to significantly inhibit saltmarsh development. There is very little information on shore-crab burrowing habits and no reference has been found linking this with saltmarsh erosion. Burrowing by Chinese mitten crabs is however implicated in the collapse of mud banks, though this species has not been recorded in the Deben.

Recommendations for future work

The literature search suggests that the Deben Estuary is not a well-studied site with regard to saltmarsh erosion. Much of the work on erosion has been undertaken within the estuaries and open coast of Essex. Though studies have been commissioned by the Environment Agency on coastal change and predicted impacts of sea level rise in Suffolk, these have generally taken a strategic level approach as their primary function has been to inform the shoreline management plans. In order to try to address the lack of research at a local level on the Deben, some projects are suggested below.

Ground truthing of aerial studies

An obvious next step for future work would be to ground truth the results of aerial studies. A report on the status of the Deben saltmarsh is currently being prepared by Natural England and the Environment Agency to address any inconsistencies in the data collected by both agencies. It is hoped to establish a sound baseline for future work and to verify recent changes in saltmarsh extent. Findings are due to be reported during 2013. Ground truthing proved to be a worthwhile exercise in Essex (Thomson et al, 2011) and can indicate mapping anomalies and sometimes provide a helpful insight into why saltmarsh losses or gains have occurred in a particular area.

Monitoring changes in saltmarsh quality

Though aerial photography is a useful tool for examining changes in area of saltmarsh, it does not provide information regarding changes in the quality of saltmarsh vegetation, though it is possible to pick out areas where common cord-grass (*Spartina anglica*) has established, for example. Hyperspectral imaging (Compact Airborne Spectrographic Imaging) has been used by the Environment Agency to map changes in saltmarsh communities. It is not known if this type of remote sensing has been undertaken on the Suffolk estuaries. On the ground, transects and fixed-point photography can indicate changes in vegetation over time which would provide important data, which is currently unrecorded. This monitoring method could be applied on both eroding and accreting areas of marsh.

Reuse of silts to recharge eroding saltmarsh

There is already some clear evidence on the ground, and indicated in the Boyes and Thomson (2010) report, that saltmarsh is eroding rapidly in the upper estuary. The island at the Cut might be an area to consider recharging with silts. However, with limited dredging opportunities in the Deben there is no regular supply of material. Even if silts could be sourced from outside the estuary the delivery costs are likely to be prohibitively expensive.

Nevertheless, it is worth considering the beneficial use of dredgings as an option, if the opportunity arises, rather than plough dredging.

Impact of historical breaches

An unplanned (or planned) breach in a sea wall, by opening up and reflooding an area of claimed land, can effect changes in estuary processes and morphology. The storm-surge breaches in the Hemley, Waldringfield and Methersgate sea walls are likely to have altered ebb and flood patterns and affected sediment transport and estuary hydrodynamics, both locally and estuary-wide. It is likely that the estuary is continuing to adjust to these changes. A research project on the changes resulting from these breaches on the hydrodynamic regime may provide some understanding of the erosion pattern in this section of the estuary.

Boat wash

Work in America has established a correlation between boat wash and bank erosion but there does not appear to be any significant work on this subject in the UK. A study on the possible impacts of boat wash could be centred on the upper reaches of the estuary.

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