TIDE
Tidal River Development

Project part-financed by the European Union (European Regional Development Fund)

The Interreg IVB North Sea Region Programme

‘Paull Holme Strays Managed Realignment’

Measure analysis 31
in the framework of the Interreg IVB project TIDE

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Disclaimer

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Part 1: Measure description

Measure Category: Biology/Ecology
Estuary: Humber
Salinity zone: polyhaline zone
Pressure: Habitat loss and degradation during the last 100 years: Intertidal, Capital dredging

Country: UK
Specific location: Middle Humber Estuary, near Saltend, East Riding of Yorkshire
Responsible authority: Environment Agency, UK
Links: http://www.abpmer.net/omreg/easycontrols/database/details1.asp?ID=22&lstInfo=1
http://www.hull.ac.uk/coastalobs/general/erosionandflooding/managedrealignment.html
Costs: £7.4M (including £1M land purchase). Monitoring costs of approx £75K pa for years 1 to 5 inclusive and approx £35K pa years 6 to 10 inclusive.

Map/Picture:

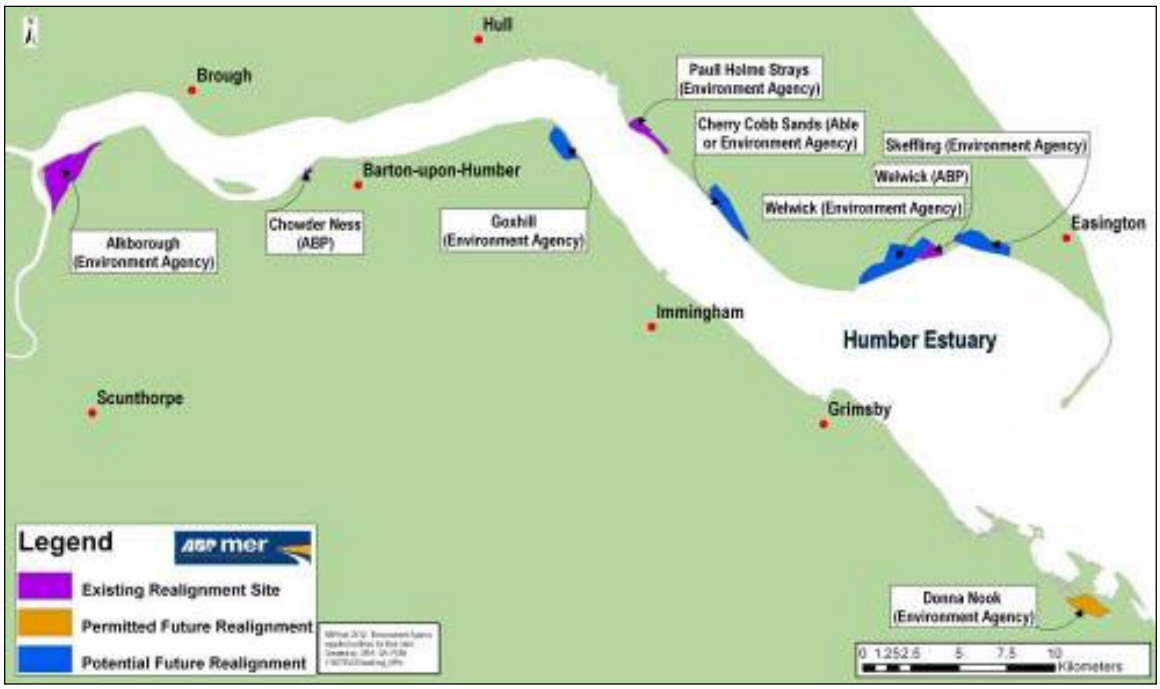

Figure 1: Location of Paull Holme Strays within the Humber Estuary

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Figure 2: Aerial photograph of project area (right) after the embankment breaches (October 2003)

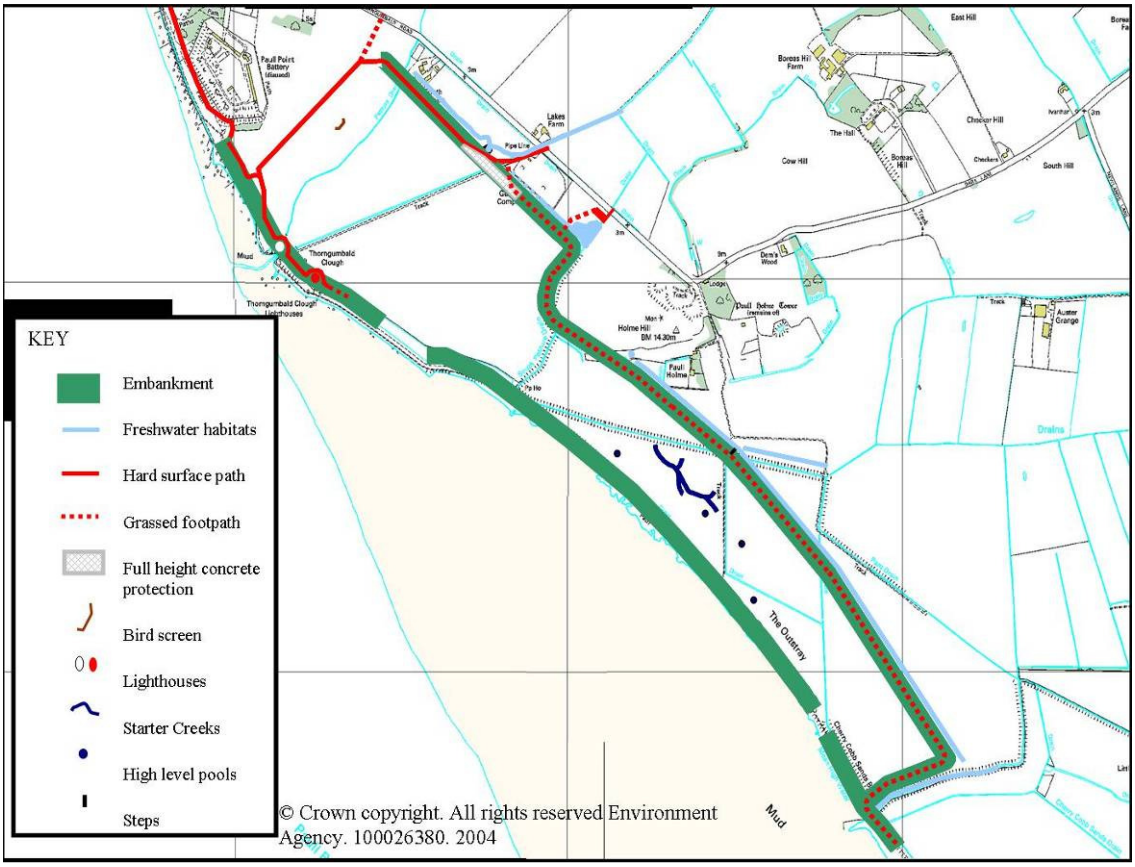

Figure 3: Location of compensation measure Paull Holme Strays

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Figure 4: View of embankment (taken by Nigel Pontee, Halcrow)

Figure 5: View of overall scheme (taken by Nigel Pontee, Halcrow)

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Figure 6: View of overall scheme (taken by Nigel Pontee, Halcrow)

1.1 Measure description

The measure 'Paull Holme Strays managed realignment' was the first major MR scheme on the Humber created by the Environment Agency as part of the Humber Flood Risk Management Strategy. The site was created to enhance and/or protect specific species as a result of the introduction of new European Directives (Natura 2000) and UK legislation. The site provides approximately 80ha of new intertidal habitat and is fronted by the extensive Paull Holme Sands mudflat. The objectives of the scheme were to provide cost effective flood risk management for the area as well as providing compensatory habitat for direct flood defence schemes losses (comprising of 1.56ha of mudflat and 0.9ha of saltmarsh) and coastal squeeze losses on the estuary (comprising of 5.58ha of mudflats and 5ha of saltmarsh). It was initially anticipated that the PHS site would ultimately create approximately 45 ha of mudflat and 35 ha of saltmarsh.

The targets for the site included the creation of mudflat which must support an invertebrate assemblage of similar species, population abundance and biomass to reference sites in the middle estuary. The developing saltmarsh habitat should support a range of species which are representative of the middle and lower saltmarsh communities in the area. Upper saltmarsh should be retained on the remnant flood bank. At least 30 foraging wintering waterbirds: Redshank (*Tringa totanus*), Dunlin (*Calidris alpina*), Shelduck (*Tadorna tadorna*) and Curlew (*Numenius arquata*) must be present; and at least 12 roosting wintering waterbirds: Golden Plover (*Pluvialis apricaria*) must be present.

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The site was formed in 2003 by creating two breaches; one 150m to the Western end of the site and another 50m wide at the eastern end. The site is inundated on approximately 80% of tides although the area around the larger breach is silting up rapidly. The smaller breach area has recently started to cut away to form creeks and has also started to erode the old bank.

Figure 7: Creek through southern breach eroding mudflat area (S.L. Brown, 2008)

Figure 8: Mudflat accretion and creek formation (S.L. Brown, 2008)

The measure was breached in September 2003.

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1.2 Monitoring

An initial 5 year monitoring programme started in late 2003. A subsequent 5 year birds and benthos survey programme has been undertaken in a second phase, but at a reduced frequency, this is currently ongoing until 2013/14. The monitoring results are reported back to the Environment Agency and the Environmental Steering Committee. Table 1 below shows the parameters monitored at Paull Holme Strays.

Table 1: Summary of monitoring programme at Paull Holme Strays

Construction	Start Date	Initial frequency	Initial duration	Adaptations to original monitoring	End date
Topographic survey	September following inundation	Every 2 weeks 2003-2004 Quarterly 2004-2008	5 years post inundation	Additional single surveys in September 2010 and 2013	2013
Saltmarsh composition	September following inundation	Every 2 weeks 2003-2004 Quarterly 2004-2008	5 years post inundation	Additional single surveys in September 2010 and 2013	2013
Changes to intertidal invertebrates	September following inundation	annually	5 years post inundation	Additional surveys in 2012 and 2013 In agreement with Natural England some sampling stations were moved for logical reasons e.g. too dry, too muddy	2013
Waterfowl	September following inundation	monthly	5 years post inundation	Additional monthly winter surveys from 2008-2013	2013

1.3 Monitoring results

The monitoring programme has been designed to determine the rate of accretion and saltmarsh development within the site, together with colonisation by benthic invertebrates (commenced September, 2004), physical development of the habitat (sedimentological properties) and use of the

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site by birds for feeding and roosting. These studies were carried out independently. Following the first five years of monitoring, it was apparent that the habitats and communities within the site were still in an early stage of development and the monitoring programme was extended to 2013 in order to fully assess whether or not the site would meet its objectives. Additionally, it was agreed that integrated analysis of the full data set was necessary to better understand the development process.

Following data collection, the general approach to the analysis has been to compare the physical and biological properties of the developing habitat (i.e. the realignment site) with those of the natural habitat (i.e. outside the realignment site) (e.g. Evans *et al.,* 1998; Garbutt *et al*. 2006; Marquiegui & Aguirrezabalaga, 2009, Franco & Mazik, 2011 and previous, referenced monitoring reports). However, this broad approach does not account for spatial heterogeneity in terms of habitat development and colonisation within created habitats and therefore does not allow a detailed understanding of site development. More recently the monitoring has aimed to assess the spatial and temporal distribution of invertebrates, vegetation and birds in relation to elevation and other physical factors. The relationships between the physical and biological parameters have been examined in order to determine the factors governing colonisation by plants and invertebrates and use of the site by birds.

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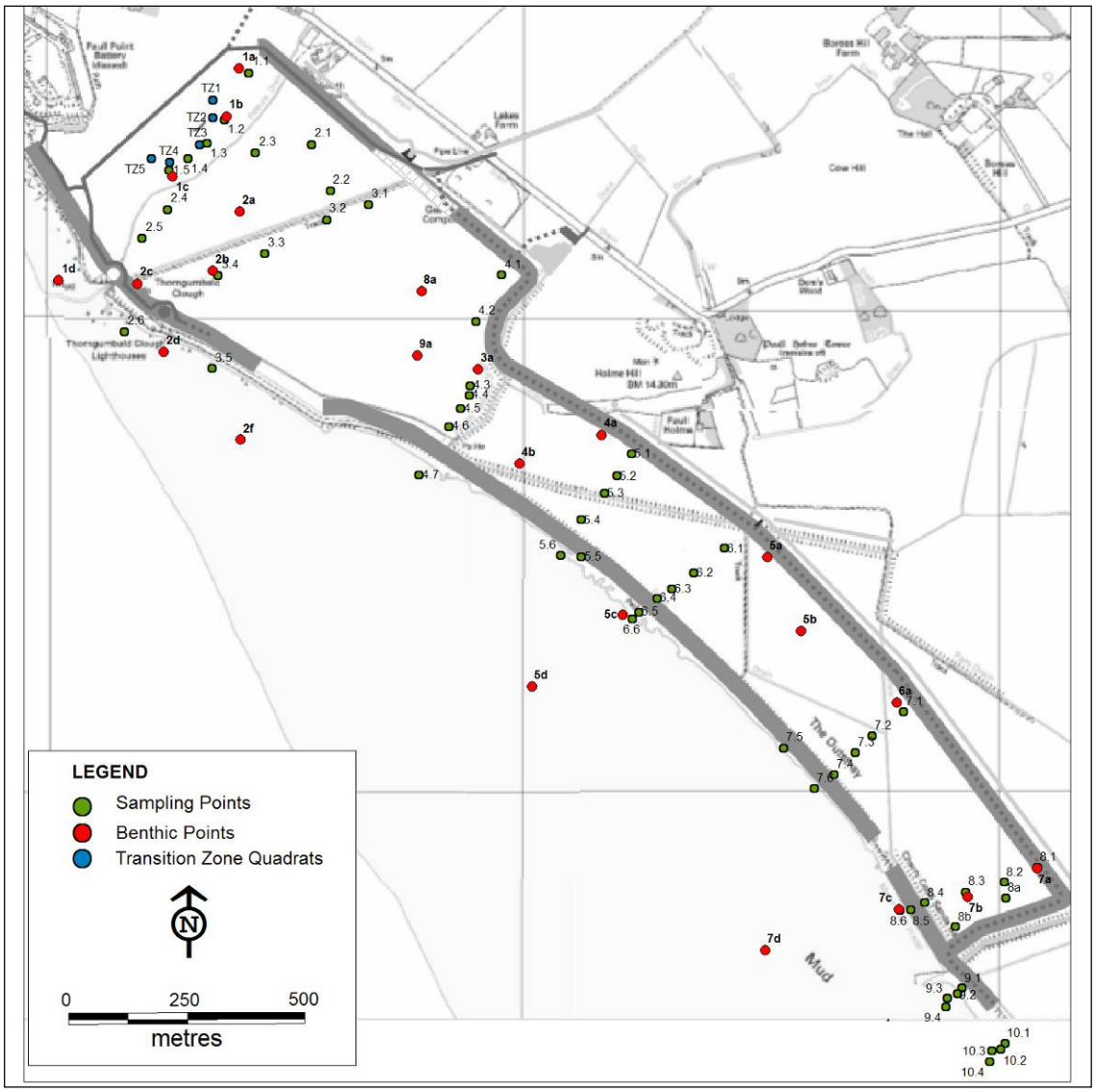

Figure 9: Sampling locations (benthic invertebrates, accretion and vegetation)

1.3.1 Accretion

The Paull Holme Strays realignment site comprises a wider northern section and a narrower southern strip. Since the site was breached sediment accretion has built up large areas of the mudflat to an elevation suitable for salt marsh development and this accretion process will continue. The shallow pools in the northern sector (present after the breach) drained after the first year or so and the vegetation that initially colonised the drier site margins below the embankments and the edges of the drains crossing the site has continued to spread out onto the mudflat. Salt marsh vegetation has also spread out from the drain edge that marks the southeastern boundary of the northern sector. Drainage creeks have developed across the mudflat which has become drier and firmer and the *Spartina anglica* (Common Cord-grass) which began to colonise parts of the central mudflat after about 2005 has continued to spread and join up to form extensive patches of continuous vegetation.

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The deep creek that formed outside the southern breach cut back through the breach in 2006. It joined up with the field drain crossing the site and cut back up the drain, deepening it considerably during 2007-8. Most of the shallow pool at the southern end of the site was draining between tides in 2008 around the back and into the field drain, and the other shallow pool half way down the southern strip now drains into the confluence of two field drains and out through the southern breach.

Since the first measurements in May 2004 (to September 2010), the level of the mudflat surface in the northern sector has built up between 4.96cm at the highest site at the base of the northern hill, to almost three quarters of a metre (73.0cm) at the lowest site. The mean value for total accretion for all sites in the northern sector between May 2004 and September 2010 was 38.9cm. All sites in the northern sector have continued to accrete sediment each year. There has been a progressive decrease of net accretion rate over time, particularly at the low-lying sites which have been accreting most rapidly. This is expected as the general surface elevation increases (and therefore duration of tidal inundation decreases).

In the first five years of monitoring, accretion was measured in spring and early autumn, and a significant seasonal pattern in accretion was shown, with greater net accretion occurring over the winter periods than during the summer, when there was a levelling off in rates. This was evident at all sites except for some of the highest sites in the southern sector where there was also no clear decline in accretion rate over time because rates were low from fewer tidal inundations.

The southern sector of the realignment site lies at a higher elevation than most of the northern sector and accretion has continued to be much lower than in the northern sector, as would be expected. The mean value for total accretion at all sites in the southern sector between May 2004 and September 2010 was 7.63cm (range 1.12-22.1cm).

Estimated total accretion from the time of breach to September 2010 gave the highest level of accretion at the lowest site of approximately 92cm, and the lowest level at the highest site of 1.5cm. The estimated mean total accretion from the time of breach to September 2010 was 46.5cm for the northern sector and 8.8cm for the southern sector.

Mean total accretion values were also calculated for sites grouped into six elevation categories because accretion is highly dependent on elevation. Elevations measured in 2007/2008 with an RTK GPS were adjusted to give the elevations for 2004 and 2010 from the accretion before and after the RTK GPS measurements were taken. In general, there has been a trend of increase in elevation, as a result of accretion, throughout the area with elevation increasing from 2.2-2.42 m and 2.46-2.6 m at stations on the foreshore between 2004 and 2010. However, accretion rates and the subsequent increase in elevation has been much more rapid inside the realignment site. Annual accretion values range from almost 0 to 30 mm at <2.2 m and 18-88 mm at 2.21-2.4 m (Figure 10). Maximum accretion occurred at 2.41-2.6 and 2.61-2.8 m (up to 91 mm in any one year) although the rate in both sectors has decreased over time.

Accretion on the developing marsh above ≈2.8mODN was shown to be comparable to rates outside the managed realignment site, but higher at lower elevations. Although accretion rates have been decreasing as the elevations have increased at lower sites, the mudflat area has built up at a much faster rate inside the realignment site compared with open mudflat outside. Sediment accretion has been much greater (2-3 times) at elevations below ≈ 2.8mODN inside the realignment.

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The high rate of accretion is thought to be due to the degree of shelter and the upper shore location of realignment sites and has been recorded from similarly sheltered areas in the middle region of the Humber (Mazik, 2004; Boyes & Allen, 2007). This is likely to be due to lower wave energy and possibly longer residence time of water, due to protection from the remaining sea wall. However this has not been formally tested.

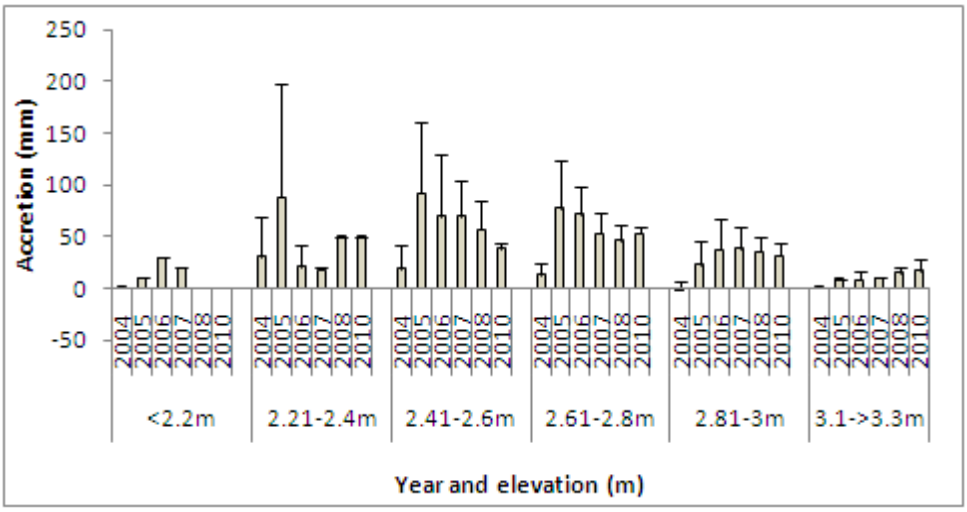

Figure 10: Temporal variability in accretion from 2004 to 2010

1.3.2 Benthic Invertebrates

The distribution of invertebrates on mudflats is governed by a variety of factors including immersion, sediment particle size, organic content, sediment porosity, drainage and consolidation, redox potential and other chemical factors, adult and larval dispersal ability and competitive and trophic interactions (Little, 2000). Many of these factors are strongly related to tidal elevation and wave energy. Hence, finer sediments tend to be present at higher elevations on intertidal mudflats and are associated with a higher organic content and, often lower oxygen content. It is therefore not surprising that the distribution of invertebrate species was strongly influenced by elevation.

Whilst all of the measured physical parameters appear to have some degree of influence over the invertebrate communities and the degree of colonisation by vegetation, elevation and accretion were consistently the most important explanatory variables in all years for the site. This was demonstrated by both univariate and multivariate techniques. In particular, *M. balthica, S. shrubsolii, P. elegans,* nematodes and several oligochaete species were negatively correlated with elevation and positively correlated with accretion. The correlation between these species and accretion is interesting since the relationship between elevation and accretion is different inside and outside the realignment site. This may be due to the fact that the site is in a state of continual development but also because of the degree of shelter and the flooding and draining patterns which differ to those on the foreshore. However, it is thought that the positive correlation between these invertebrates and accretion is due to the significant level of colonisation in the muddy area of the north western part of the realignment site. The benthic communities in this area are now representative of those on the foreshore (Mazik *et al.,* 2010).

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1.3.3 Vegetation

Most of the narrower southern sector of the realignment site was initially at an elevation suitable for salt marsh establishment (except for areas with permanent shallow water bodies), and salt marsh vegetation has established and increased in density and diversity except in waterlogged areas.
Vegetation has continued to spread across the site and has increased in cover density. It has increased in diversity at lower elevations where low- mid- marsh species have filled in and behind what was previously pioneer vegetation. Species diversity has decreased in some higher areas where perennial grasses such as *Puccinellia maritima* have become very dense, and tall grasses at upper elevations such as *Elytrigia sp*. have achieved very dense cover, shading out shorter-lived and smaller species.

The dominant species in the lower zones on and around the mudflat is *Spartina anglica*, particularly in the northern parts of the site (the annual pioneers *Salicornia europaea* and *Suaeda maritima* are more prominent in the southern part). The perennial grass *Puccinellia maritima* is dominant at mid-elevations and very dense (up to 99% cover in places), particularly in the southern part of the site. The highest areas close to the outer embankment between the breaches, the transition zone around the northern hill, and the higher parts of the drain edges, are covered with dense *Elytrigia atherica* (with some *Elytrigia repens*, and occasional patches of *Festuca rubra* and *Agrostis stolonifera*). Large patches of *Phragmites australis* and some *Scirpus maritimus* are found across the site (areas where there is some brackish water influence).

All of the salt marsh halophyte species and salt tolerant glycophytes found on the salt marsh outside the realignment were found inside the site by 2007 (24 species), with the exception of *Limonium vulgare* which is very rare in the Humber Estuary and had not been noted inside the realignment site by September 2010. Additional salt tolerant plants present outside the realignment site up to the driftline, have been found in the realignment site, making over 30 species of halophytes and salt–tolerant glycophytes.

In 2010 the species mix inside the realignment according to elevation was not very different from that outside, but there were still differences in cover abundance of many species, except at the lowest vegetation elevations where *Spartina anglica* was dominant. Some of the major species outside above 2.6mODN are now abundant inside, particularly *Puccinellia maritima*, but *Atriplex portulacoides* for example is common outside but was slow to come into the realignment site and is still rare inside. Some species that are more common inside above 2.6mODN are remnants of early colonisers of the bare ground, such as *Atriplex prostrata*, *Spergularia marina* and *Puccinellia distans* which have been in rapid decline since typical perennial salt marsh grasses such as *Puccinellia maritima* and *Elytrigia atherica* have increased in cover. It may take a few more years before the realignment site reaches a close match in community composition and abundance to the salt marsh outside at the same elevations.

Vegetation density and the distribution of saltmarsh species were also strongly related to elevation. MDS and Simper analysis (based on data collected in September, 2010 (Brown, 2011) indicated a dominance of *S. anglica* at the lower elevation (with no vegetation at the lowest elevations) and an increase in species diversity with increasing elevation. The dominant species at the higher elevations (>3.01 m) included *P. maritima* and *A. tripolium* and, above 3.2m, *A. prostrata, E. atherica* and *S. media*.

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1.3.4 Waterfowl

Cannonical Correspondence Analysis and graphical analysis indicated a clear preference for lower elevation, muddy habitats by some bird species and a strong correlation between the distribution of birds and key prey species. These results should be treated with caution. Whilst it is reasonable to assume that prey availability would strongly influence the distribution of most bird species, a number of other factors may influence site take-up and thus need to be taken into account in any detailed characterisation of habitat function.

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Part 2: Execution of main effectiveness criteria

2.1 Effectiveness according to development targets of measure

The involvement of an environmental steering group throughout all stages of this scheme was invaluable and through this, the project team was able to identify simple and low cost suggestions and opportunities to maximize the benefits both in the short term, whilst the site was developing, but also in the longer term development and progress of the site. Early landowner liaison and negotiations, along with involvement from local parishes and landowners should be undertaken as early as possible in order to come to agreements at an early stage.

2.1.1 Habitat Area

The specific targets for the Paull Holme Strays managed realignment were to create the following habitats:

- 45ha of intertidal mudflats (which must support an invertebrate assemblage of similar species, population abundance and biomass to reference sites in the middle estuary)
- 35ha of saltmarsh (which should support a range of species which are representative of the middle and lower saltmarsh communities in the area. Upper saltmarsh should be retained on the remnant flood bank).

In addition at least 30 foraging wintering waterbirds: Redshank (*Tringa totanus*), Dunlin (*Calidris alpina*), Shelduck (*Tadorna tadorna*) and Curlew (*Numenius arquata*) must be present; and at least 12 roosting wintering waterbirds: Golden Plover (*Pluvialis apricaria*) must be present.

2.1.2 Habitat quality

The Paull Holme Strays realignment site comprises a wider northern section and a narrower southern strip. Vegetation has colonised the new mudflat inside the site and except at the highest elevations, very little of the pre-breach vegetation now remains. By 2007, 23 plant species typical of saltmarsh present in this part of the realignment were noted, with all species found outside the realignment also being recorded inside it.

It was initially anticipated that the Paull Holme Strays site would ultimately creat 45ha of mudflat and 35ha of salt marsh, i.e 56% mudflat and 44% salt marsh. Estimates for 2007 from an aerial image were 64% mudflat and 36% salt marsh. Estimates from mapping the site gave 46% mudflat and 54% salt marsh in 2010. As the site is still accreting and the vegetation is spreading across the mudflat, the area of mudflat is likely to decrease further in future years, and may ultimately be only a small area opposite the breach where conditions of exposure are more similar to outside.

2.1.3 Benthos

It was reported in 2010 (IECS) that the total number of species found inside the managed realignment site is now comparable to that found outside. A total of 22 species were recorded from

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the area as a whole with all of them being found inside the site and 19 species being found outside. The mean number of species, Shannon Weiner diversity (H') and biomass inside the site is now comparable to that one outside, given the significant increase of all parameters since 2004. However, the total abundance still remains much lower inside the site, given that a large increase of this parameter has occurred also outside the site between 2008 and 2010. This increase in abundance (both inside and outside the site) is due to a large increase in the abundance of the sabellid Polychaete *Manayunkia aestuarina*. Comparison of the two areas excluding *M. aestuarina* indicates that abundance remains relatively low inside the site.

Besides the general similarity between the areas inside and outside the realignment site, there is still a high degree of spatial variation in community structure within the site, and, due to the low number of species and abundance in the south eastern sector, the realignment site as a whole cannot be considered typical mudflat habitat for this area and the communities are still not considered to be fully developed.

2.1.4 Bird Usage

The site has met its initial targets for wader usage in terms of number however, densities remain lower than adjacent areas.

2.1.5 General effectiveness

The possible long-term development of the new mudflat into saltmarsh is likely to reduce the available habitat for benthic invertebrates and foraging birds, although additional saltmarsh may provide high tide refuges for birds, as well as roosting and nesting sites.

The overall target was to create functioning intertidal habitat and to monitor progress over a 10 year period. Although all parameters monitored are on target to meet criteria set, it is feared that as the site continues to develop in the long term it may not continue to provide 'like for like' direct compensatory habitat. Discussions are ongoing with Natural England to determine what level, if any, of management is required to ensure the site continues to meet its targets and possibly include the habitat within the designated site.

2.2 Impact on ecosystem services

Step 1: Targeted ecosystem services

The key objective of this measure was to create intertidal habitat to compensate for direct losses associated with flood defence schemes as well as coastal squeeze. This is linked with ecosystem services 'flood water storage' and 'dissipation of tidal and river energy' as well as 'biodiversity'. It also provides 'opportunities for recreation and tourism' through becoming a tourist and bird watching attraction.

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Table 2: Targeted ecosystem services

Measure	
Food: animals	
Water for industrial use	
Water for navigation	
Climate regulation: carbon sequestration	X
Regulation extreme events or disturbance: flood water storage	X
Regulation extreme events or disturbance: water current reduction	
Regulation extreme events or disturbance: Wave reduction	
Water quantity regulation: drainage of river water	
Water quantity regulation: dissipation of tidal and river energy	X
Water quantity regulation: landscape maintenance	
Water quantity regulation: transportation	
Water quality regulation: transport of pollutants and excess nutrients	
Water quality regulation: reduction of excess loads coming from the catchment	
Erosion and sedimentation regulation by water bodies	
Erosion and sedimentation regulation by biological mediation	
"Biodiversity"	X
Aesthetic information	
Opportunities for recreation & tourism	X
Inspiration for culture, art and design	
Information for cognitive development	

Step 2: Involved habitats

Intertidal mudflat and saltmarsh were created as a result of this measure.

Table 3: Ecosystem services analysis for Paull Holme Strays: Indication of habitat surface and quality change, i.e. situation before versus after measure implementation

MEASURE		before		After	
		surface (%)	Quality (1-5)	surface (%)	quality (1-5)
Marsh habitat	above mean high water, floods at spring tide	**0**	**0**	**65**	**5**
Intertidal steep habitat	floods every tide, mainly steep zones at marsh edges	**0**	**0**	**5**	**4**
Intertidal flat habitat	floods every tide, flat zones	**0**	**0**	**15**	**3**
Subtidal shallow habitat	never surfaces, less deep than 2m	**0**	**0**	**5**	**4**
Subtidal moderately deep habitat	never surfaces, 2m-5m	**0**	**0**	**0**	**0**
Subtidal deep habitat	never surfaces, deeper than 5m	**0**	**0**	**0**	**0**
ADJACENT LAND	NON FLOODED LAND	**100**	**4**	**10**	**3**
		100		100	

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Quality
1 = very high quality
2 = high quality
3 = medium quality
4 = low quality
5 = very low quality

The measure Paull Holme Strays Managed Realignment in the polyhaline zone of the Humber estuary was about the creation of intertidal habitat by transforming adjacent land into mainly marshland with a very high change in the habitat quality.

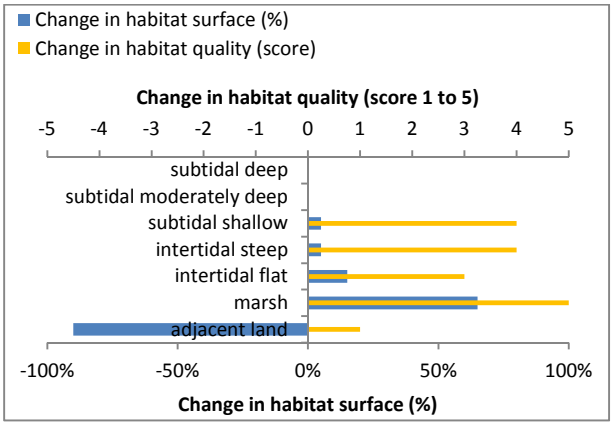

Figure 11: Ecosystem services analysis for Paull Holme Strays Managed Realignment: Indication of habitat surface and quality change, i.e. situation before versus after measure implementation.

From the ES assessment it is concluded that this measure generates overall a positive expected impact for many ES, mainly for:

- "biodiversity"
- Cultural service: Opportunities for recreation and tourism
- Some regulating services: Erosion and sedimentation regulation (by water bodies); Water quality regulation: reduction of excess loads coming from the catchment; Erosion and sedimentation regulation by biological mediation; Climate regulation: Carbon sequestration and burial.

The expected impact for the different beneficiary groups is overall positive, with a positive to very positive expected impact for indirect and future use and for local and region use.

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Table 4: Ecosystem services analysis for Paull Holme Strays Managed Realignment: (1) expected impact on ES supply in the measure site and (2) expected impact on different beneficiaries as a consequence of the measure.

Paull Holme Strays Managed Realignment – creation of ~80 ha of intertidal habitat

Cat.	Ecosystem Service	Score
S	"Biodiversity"	3
R1	Erosion and sedimentation regulation by water bodies	3
R2	Water quality regulation: reduction of excess loads coming from the catchment	3
R3	Water quality regulation: transport of polutants and excess nutriënts	1
R4	Water quantity regulation: drainage of river water	0
R5	Erosion and sedimentation regulation by biological mediation	3
R6	Water quantity regulation: transportation	0
R7	Water quantity regulation: landscape maintenance	2
R8	Climate regulation: Carbon sequestration and burial	3
R9	Water quantity regulation: dissipation of tidal and river energy	1
R10	Regulation extreme events or disturbance: Wave reduction	1
R11	Regulation extreme events or disturbance: Water current reduction	1
R12	Regulation extreme events or disturbance: Flood water storage	1
P1	Water for industrial use	0
P2	Water for navigation	0
P3	Food: Animals	0
C1	Aesthetic information	2
C2	Inspiration for culture, art and design	2
C3	Information for cognitive development	2
C4	Opportunities for recreation & tourism	3

Beneficiaries:	
Direct users	0
Indirect users	2
Future users	3
Local users	2
Regional users	2
Global users	1

X Targeted ES

Legend: expected impact*	
3	very positive
2	positive
1	slightly positive
0	neutral
-1	slightly negative
-2	negative
-3	very negative

*: Indicative screening based on ES-supply surveys and estimated impact of measures on habitat quality and quantity. Quantitative socio-economic conclusions require local supply and demand data to complement this assessment.

2.3 Degree of synergistic effects and conflicts according to uses

So far the site appears to be developing inter-tidal habitats as expected, although the proportion of saltmarsh and mudflats is not as predicted. Due to higher accretion rates the mudflat is developing into saltmarsh quicker than anticipated. However the site is broadly consistent with the conservation objectives defined as part of the consenting procedures.

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Part 3: Additional evaluation criteria in view of EU environmental law

3.1 Degree of synergistic effects and conflicts according to WFD aims

This measure was about the creation of new intertidal habitat which provides a much needed habitat in the Humber Estuary and allows land to be used as a natural flood defence, which in turn can also improve water and sediment quality and reduce sedimentation in the main channel, which in turn reduces dredging requirements. The compensation measure was not designed to meet the requirements of the Water Framework Directive (WFD). However, it covers two of five main pressures the polyhaline zone of the Humber estuary is affected by.

Table 5: Main pressures of the polyhaline zone of the Humber

Indicator	code	Main pressures **polyhaline** zone Humber	Effect?					Description
			- -	-	0	+	++	
S.I.	1.1	Habitat loss and degradation during the last 100 years: Intertidal					X	New intertidal habitats like salt marshes were created.
D.I.	2.6	Capital dredging			X			
D.I.	2.4	Maintenance dredging				X		Fewer requirements for dredging as sedimentation occurring through accretionary trends in intertidal and saltmarsh habitats.
D.I.	2.5a	Relocation on dredged material			X			
D.I.	2.12	Ports development			X			
S.I. = state indicator; D.I. = driver indicator								

3.2 Degree of synergistic effects according to Natura 2000 aims

This measure was about the creation of new intertidal habitat to compensate losses elsewhere in the Humber Estuary. Therefore, it is considered that this measure contributes to the protection and conservation of intertidal wetlands within the Internationally Designated Humber Estuary.

Table 6: Conservation objectives concerning the BHD

Conservation objectives (Humber)	**Specification**	**Effect?**					**Short explanation**
		- -	**-**	**0**	**+**	**++**	
Protected Habitats: Estuary	Intertidal wetland (brackish)					X	Newly created intertidal habitat in Internationally Designated Nature Conservation Site.

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Part 4: Crux of the matter

The "crux of the matter" refers to the basic, central or critical point of an issue. For example, in this context, the main issues relating to the development and progression of the specific measure detailed within this FAS Repost represent the crux of the matter.

In summary, additional new habitat to compensate for losses and address rising sea levels has been created at Paull Holme Strays. Vegetation cover has been increasing inside the realignment site each year and some common species outside that were initially slow to establish inside the site are now thriving at their appropriate elevations. Both intertidal salt marsh and mudflat have developed on the site, but the expected outcome in terms of area of compensatory salt marsh and mudflat habitat is proving to be different from that anticipated before the breach.

Overall, the monitoring has found an accretionary trend over the survey period between 2004 and 2010 resulting in a trend of increase in elevation. The change in elevation in subsequent years has decreased, although increases of up to 40cm have still been observed at some locations across the site between the 2009 and 2011 surveys. Over the survey period, the majority of change in elevation (accretion) has occurred in lowest (seaward) parts of the site, which were around 1.5 to 1.75mODN in 2007 - with changes in elevation of the order of 10-40cm.

Saltmarsh vegetation has generally established in areas above 2.5 to 3mODN (2.5mODN is approximately 50cm above the MHWN level). Most of the mudflat areas below 2mODN remain unvegetated.

The high rate of accretion is thought to be due to the degree of shelter and the upper shore location of realignment sites and has been recorded from similarly sheltered areas in the middle region of the Humber (Mazik, 2004; Boyes & Allen, 2007). This is likely to be due to lower wave energy and possibly longer residence time of water, due to protection from the remaining sea wall. However this has not been formally tested.

Based on the findings at this site, sites with an initial elevation of >2.2-2.4 m and sites where accretion is likely to lead to an increase in elevation above 2.2-2.4 m, are unlikely to develop into compensatory habitat for mudflat in the long term. However, there is a strong likelihood that marsh may develop suggesting that compensation for loss of this habitat could be highly effective.

Furthermore, sites should be designed to limit accretion rates (e.g. exposing sites to tidal exchange and wave action by removing the maximum length of sea wall possible) in the long term to prevent large increases in elevation and subsequent colonisation by saltmarsh. Similarly, these considerations are necessary if saltmarsh creation is the primary objective. High (>2.2-2.4 m in the context of this site) elevation sites in the Humber are unlikely to provide suitable direct compensatory habitat (e.g. for mudflat) in the long term, and instead will provide additional saltmarsh.

This raises questions about the possibility of creating sustainable mudflat in areas like the Humber estuary with high suspended sediment loads, and removal of the entire sea defences may be necessary in front of a realigment to more closely reproduce the exposure conditions on natural mudflats. Full embankment removal would not be a viable option at Paull Holme Strays as the gradient of the site between the breaches slopes downwards in a landwards direction from behind

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the sea defences which are fronted by a higher cliffed salt marsh. Attempting to create mudflat behind higher areas of salt marsh is unlikely to succeed in the long term. Furthermore, on the north side of the middle estuary a wide expanse of mudflat is now at an elevation suitable for *Spartina* colonisation and plants are spreading across the area. It may therefore be necessary to view any creation of compensatory mudflat, in this part of the estuary at least, as a temporary solution which may persist for a decade or two, depending on site-specific conditions.

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Part 5: Literature

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