TIDE

Tidal River Development

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

The Interreg IVB North Sea Region Programme

'Welwick'

Measure analysis 34
in the framework of the Interreg IVB project TIDE

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Tidal River Development

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Part 1: Measure description

Measure category: Biology/Ecology
Estuary: Humber
Salinity zone: polyhaline
Pressure: Habitat loss and degradation during the last about 100 years: Intertidal

Country: United Kingdom
Specific location: Welwick, Humber Estuary, East Riding of Yorkshire
Responsible Authority: Associated British Ports
Costs: ~£1,500,000
Links:
http://www.abpmer.net/downloads/download.asp?filename=OMReG%5Ccase%5Fstudies%5Comreg%5F2011%5Fcase%5Fstudy%5Fwelwick%2Epdf

Map/Picture:

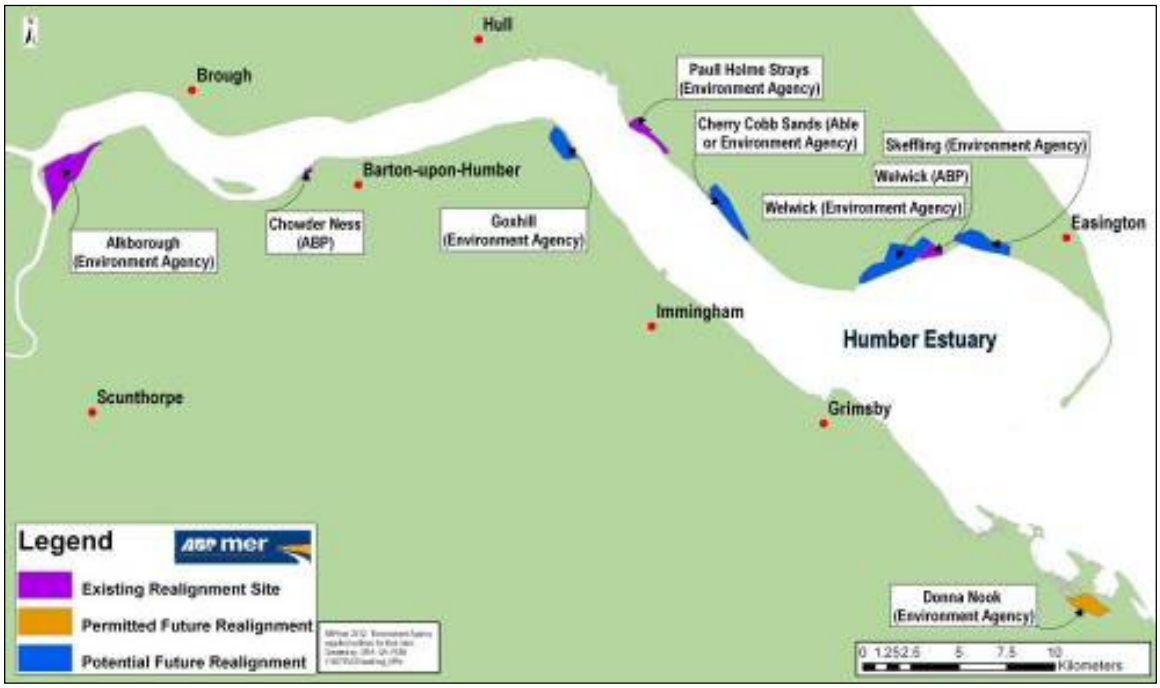

Figure 1: Location of Welwick within the Humber Estuary

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Figure 2: The managed realignment at Welwick - Google Earth derived aerial view

Figure 3: Rear embankment construction and re-profiling at Welwick in 2005 and Figure 3: Welwick shortly after seawall removal (i.e. first inundation) in December 2006

Figure 4: Panoramic view of Welwick from easterly corner of site (taken by ABPmer, August 2010)

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Figure 5: View of the site (taken by Nigel Pontee, Halcrow)

Figure 6: View of the site (taken by Nigel Pontee, Halcrow)

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Figure 7: View of the site (taken by Nigel Pontee, Halcrow)

1.1 Description of the issue and measure

Welwick was undertaken for the same purpose as another realignment on the Humber, Chowder Ness, which is presented as a separate First Analysis Step (FAS) Report. Both schemes were designed and implemented by the same organisations (Associated British Ports (ABP) and ABPmer), and to very similar timescales and principles. To inform the final design of these sites, numerical modelling was undertaken based on LiDAR elevation data. This was designed to ensure the correct balance of habitats would be achieved. As mudflat creation was the main objective of the schemes, and as the sites were largely too high for this to occur, the land was re-profiled to increase the extent of lower areas where mudflat could develop (i.e. below Mean High Water Neap (MHWN)) (see Figures 2 and 3 for an illustration of the design steps undertaken). Prior to these works, the land at Welwick had an approximate elevation of 2.8m Ordnance Datum Newlyn (ODN), some 0.4m below the level of the Mean High Water Spring (MHWS) tides. The reprofiling included the creation of a gentle slope from the fronting, existing, mudflats to the rear of the sites.

New flood defences were created at the rear of the 54ha Welwick site to a minimum height of 6.1m ODN and were designed to withstand a 1 in 50 year design event. A strip of saltmarsh was expected to develop in front of the new defences. The 70,000m^3 of material needed for this defence was obtained from within the site from a combination of reprofiling and creation of temporary borrow pits. The new embankment was seeded and left to stabilise for one year.

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The existing seawall was removed over a length of 1,400m, and the approximately 20,000m^3 of the material gained was used to fill the temporary borrow pits. The wholesale removal, rather than the creation of solitary breaches, was chosen for a number of reasons:

- It improves connectivity with the wider estuary;
- It more closely recreates the type of environments that existed prior to the land claim;
- It enables the whole cross sectional area of estuary including the realignment site, to respond to estuary wide changes; and
- It increases energy levels within the site, thereby improving the likelihood that mudflat habitat will be maintained.

The old defence was removed in a series of stages:

(1) Removal of the rear of the embankment;
(2) Removal of the rock gabions; and
(3) Undertaking an overall lowering of the embankment.

Following this, breaches were created in the existing saltmarsh in front of site. These were required as the fronting marsh is designated, and could thus not be removed completely to increase wave energy even further. As the typical elevation of this marsh was 3.2mODN, which coincides with the MHWS level, these breaches were necessary to allow the site to flood and drain sufficiently. The location of the breaches was chosen to minimise marsh losses (approximately 0.4ha). Their width had been assessed by calculating the discharge and considering the critical threshold for erosion of sediment. The suggested breach size was considered large enough for the velocities to be below the critical threshold for erosion.

Status of the measure

This measure was breached in June2006.

1.2 Monitoring

A 10 year monitoring programme was initiated to describe both changes to habitat fronting the realignment (in relation to bathymetry, saltmarsh evolution, invertebrates and waterfowl), and to the realignment site itself (in relation to topography, saltmarsh composition, changes to intertidal invertebrates and waterfowl usage).

Monitoring included:

- Topographic surveys - LiDAR/Laser;
- Waterfowl surveys - details unknown, but expected to be once monthly over the autumn/winter/spring;
- Terrestrial bird survey (including breeding bird survey) - details unknown, but likely to be during the spring and annually; and
- Fish - Student project looking at usage of site (fyke nets etc).

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Table 1 displays the parameters monitored at Welwick.

Table 1: Monitoring parameters and Welwick

Construction	Start Date	Initial frequency	Initial duration	Adaptations to original monitoring	End date
Welwick managed realignment					
Topographic Survey	1 month before inundation	annually	5 years post inundation (fronting realignment) 10 years post inundation (within realignment)	Monitored every other year since 2009 Original laser survey also changed to LiDAR survey after initial year.	2011 2016
Saltmarsh composition	Summer before construction	annually	5 years post inundation (fronting realignment) 10 years post inundation (within realignment)	Due to health and safety concerns over access a number of original transects fronting the realignment were not surveyed post breach	2011 2016
Monitoring of grassland	1st summer following inundation	annually	5 years post inundation		2011
Monitoring of saline pools	1st summer following creation	annually	5 years post inundation	Continued monitoring in progress – every other year	2013
Changes to intertidal invertebrates	Summer before construction	annually	5 years post inundation (fronting realignment) 10 years post inundation (within realignment)	Samples were originally collected in triplicate on the mudflat outside the realignment but after first couple of years only one sample has been analysed	2011 2016
Sediments	Summer before construction	annually	5 years post inundation (fronting realignment) 10 years post inundation (within realignment)		2011 2016
Waterfowl usage of realignment area	Overwinter season before construction	monthly (Sept - Mar)	5 years post inundation (fronting realignment) 10 years post inundation (within realignment)		2011-2012 2016-2017
Breeding birds	1st summer following inundation	April and May	5 years post inundation		2011

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1.3 Monitoring results

1.3.1 Accretion

The monitoring programme includes Laser/LiDAR topography surveys to determine accretion and erosion on site. The Laser surveys were undertaken for the baseline surveys. The survey was repeated in March 2007, June 2008, April 2009 and June 2011 using LiDAR and comparisons between the resulting elevation models have since been made. The comparison of these datasets required careful interpretation due to the differing accuracies of the two techniques.

Overall, the monitoring has found an accretionary trend over the survey period between 2007 and 2011, with an average difference between 2007 and 2011 of +14cm. The degree of accretion was found to have decreased over time. The main change in elevation took place in the initial year following the breach, with typical elevations increasing by between 0 and 50cm between 2006 and 2007.

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.

Erosion was initially noted in the creeks, and continually towards the rear of the site within the created saline lagoons. The latter should, however, be viewed with a degree of caution as the presence of standing water can reduce the accuracy of the LiDAR data. The higher elevations (above ca. 2.75mODN) have barely, or not at all, been subject to a net gain in elevation.

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.

1.3.2 Vegetation

At Welwick, saltmarsh colonised the site very rapidly, covering some 28ha within two years of the site being inundated. The extent of saltmarsh has also continued to increase since this time, although the rate of expansion has decreased as time has elapsed.

Species diversity has also been fairly consistent over the years monitored to date and average abundance has increased rapidly and, although variable, is still continuing to increase four years post inundation of this site.

1.3.3 Bird Usage

Breeding birds have been specifically monitored at Welwick and the number of species of breeding bird observed has been consistent across the five year monitoring period, with a five year average of 27 species (range 23 to 33). Total numbers observed have also remained consistent.

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1.3.4 Invertebrates

The invertebrate usage of the saline lagoons at Welwick, have been monitored annually since 2006 when the site was first inundated. None of the species recorded are specialists of saline lagoons (as listed by Bamber et al., 2001) and there is little indication that the pools are developing a lagoonal fauna. It is considered likely that pools on the developing saltmarsh are probably too exposed to tidal flooding to support anything other than a typical low-marsh invertebrate fauna. It was also noted that the pools were completely dry during low tides in June 2011, so conditions are probably too unstable to support a diverse invertebrate community. It has been agreed that the monitoring of saline lagoons will continue beyond the originally planned five year review period.

The monitoring has shown that invertebrates have colonised this new sediment. In 2009, between 571 and 15,429 specimens were found per m^2 (belonging to between 2 and 6 species). The abundance, diversity and biomass of species in the mudflat have been increasing since the realignment has been implemented, and are now similar to the fronting, pre-existing, mudflat sites; in fact, average abundance within the samples collected in 2008 was greater than the fronting mudflats.

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Part 2: Execution of main effectiveness criteria

2.1 Effectiveness according to development targets of measure

The specific target for Welwick was to create intertidal habitat to compensate for that lost through ABP port development on the Humber Estuary. Early discussion with stakeholders was highly beneficial throughout the whole process, including the selection of a potentially suitable site, design issues, the EIA and subsequent implementation of the scheme. An environmental steering committee also met at regular intervals to discuss issues relating to the site.

Although there was no planned timetable, it took considerably longer than anticipated to get all of the required approvals from the regulatory bodies, including the Environment Agency and Local Authorities.

The scheme was breached in June 2006 and appears to be performing as predicted at this early stage with saltmarsh development and bird usage already evident. In the medium to long term, the monitoring results will be compared with the objectives of the site to determine the success of the scheme.

2.1.1 Habitat Area

The specific targets of the Welwick Scheme were to create the following habitats:

- Between 7ha and 37ha of intertidal mudflat (and maintain this area in the long-term, over the 10 year period);
- Between 8 ha and 32ha of saltmarsh (and maintain in the long-term, over the 10 year period);
- Between 9 ha and 15ha of supralittoral grassland (which at least 50% of which should support natural plant communities comparable to local reference areas within 5 years of construction);
- 100m^2 area of stone parsley (and maintain this area in the long-term, over the 10 year period0; and
- Two saline pools within the grassland area in the north east corner of the site. Within 5 years of creation the pools should support a fauna and flora comparable to local reference pools.

Welwick has had to overcome problems relating to saline pool development and an important lesson to learn from the monitoring of saline pools was to ensure that the position of the habitat is at the right elevation with respect to the tidal frame, in order to allow specialist fauna to colonise, which also includes ensuring contractors follow exact design details. No such specialist fauna has colonised at Welwick and so the pools have continued to be monitored post the initial 5 year review period.

2.1.2 Habitat quality

Within 5 years of realignment, the mudflat created should support an invertebrate assemblage of similar species, population abundance and biomass to local reference sites.

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In particular, it was hoped to be able to support the following key species:

- Ragworm (*Hediste diversicolor*);
- Bristle Worm (*Pygospio elegans*);
- Mud Shrimp (*Corophium volutator*); and
- Baltic tellin (Clam) (*Macoma balthica*).
- Laver Spire Shell (*Hydrobia ulvae*); and
- Worm (*Streblospio shrubsolii*).

It was also hoped that invertebrate quality would be maintained over the area of mudflat in the long-term.

Monitoring the success of habitat quality was proposed to be undertaken by including descriptions of the size distribution of individuals (adult/juvenile), tidal height and sediment properties, where samples were taken, in order to determine options for remedial action, if required.

It was also hoped that within 10 years of realignment, the saltmarsh created would show a similar zonation and species composition to existing adjacent saltmarsh, which locally include species such as red fescue, sea plantain, lesser sea spurrey, sea lavender, glassworts, sea purslane, sea aster and sea couch vegetation.

With regards to the intensity of the actual monitoring that has been undertaken at Welwick, it was felt that little had been gained from the intensive invertebrate monitoring post breach. It was identified that invertebrate monitoring every year post inundation did not provide any more valuable information than would have been achieved at a less regular frequency.

2.1.3 Bird Usage

One of the targets of the Welwick scheme was for the creation of intertidal habitats with the ability to provide feeding habitat for in excess of 800 (peak mean over 5 years) feeding water birds with typical species in the following relative proportions:

- 60% dunlin;
- 20% black-tailed godwit;
- 10% redshank; and
- 10% other bird species.

Within ten years of realignment, it was hoped that the mudflat would be regularly used by approximately 607 overwintering waterfowl (peak) (166 average) based on the following species:

- Golden plover;
- Lapwing;
- Dunlin;
- Redshank;
- Black tailed godwit;
- Ringed plover;
- Curlew; and
- Shelduck.

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This estimate was based on the assumption that waterfowl would use the realignment area pro rata to the adjacent bird count sector (ISE1). This usage should be maintained in the long-term, taking account of the natural variability through comparison with relevant WeBS data.

Grassland habitat to support a range of farmland bird species including reed bunting, skylark and yellow wagtail was also created and the saltmarsh is used by breeding waterbirds and passerines, with the area behind being important for breeding Marsh Harrier.

2.1.4 Fish

Attempts to value the utilisation of managed realignment by commercial fish species have been successful elsewhere in the UK (see for example Colclough et al., 2005; Fonseca, 2009), and an initial attempt to value the fish species at the Welwick managed realignment was made by Burdon et al., (2011). This latter study provided the first evidence of the fish species using the Welwick managed realignment site and this information was linked to the potential value of commercial species landed in the North Sea (see Table 2). This data shows that the fish species found within the Humber Estuary, and within the Welwick managed realignment site, may contribute value to the demersal and pelagic commercial fishing sectors of the North Sea (Burdon et al.,, 2011). It is unlikely that the market price will change given the marginal impact of these landings in relation to the overall landings.

Table 2: North Sea landings (quantity and value) by UK vessels (in UK and abroad) in 2010 (MMO, 2011)

Species	Northern North Sea (IVa)		Central North Sea (IVb)		Southern North Sea (IVc)		Average Price per Tonne
	Quantity (tonnes)	Value (£'000)	Quantity (tonnes)	Value (£'000)	Quantity (tonnes)	Value (£'000)	
Sea Bass	-	-	17	99	134	842	£9,029
Plaice	562	413	13,576	15,961	651	673	£2,255
Saithe	11,527	10,609	360	316	-	-	£1,359
Herring	21,095	8,927	2,381	665	78	32	£838
European Flounder	-	-	41	13	46	19	£534

Information regarding utilisation of the managed realignment sites by fish species is currently being assessed by IECS on behalf of the Environment Agency. This research will provide a greater insight into the fish species present at Welwick and will give an indication of what commercial species are currently using this site.

A recent study undertaken by Burdon et al., (2011) focussed specifically on the value that saltmarsh present in the Welwick managed realignment site in the Humber Estuary provides with respect to the fish species present. Unfortunately, insufficient data was available to undertake the full analysis, however the study did provide an insight into the fish community found within the site and provided a list of data requirements in order to complete a more comprehensive site-specific analysis in the future.

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2.1.5 Carbon Sequestration

Site specific benthic biomass data from mudflats can be used as an indicator of carbon sequestration in the estuarine environment, providing an underestimate of biomass given that it does not include any mobile fish and shellfish species within the area. In order to evaluate the consequences of managed realignment for CO_2 emissions, the change in value of carbon associated with the newly created managed realignment site would need to be compared with the established mudflats outside of the site. This would enable the net gain/loss of the realignment to be measured in terms of carbon sequestration alone.

An example is presented below (Table 3) which shows that at present carbon sequestration at Welwick is much greater outside of the site than inside the site, and this equates to a carbon value of £4,252 per km2 outside the site and £408 per km^2 inside the site.

Table 3: Conversions of benthic biomass (ash free dry weight) to the value of carbon (using the 2010 traded price of £14.10) inside and outside of the Welwick managed realignment site (benthic biomass data supplied by ABPmer)

	Inside Welwick	Outside Welwick
Mean Biomass (per core)	0.147	1.529
Total Biomass (g AFDW m^{-2})	18.320	191.085
Carbon (g m^{-2})	7.877	82.167
CO_2e (g m^{-2})	28.910	301.551
Cost of Carbon (£ km^{-2})	407.633	4,251.872

2.2 Impact on ecosystem services

Targeted Ecosystem services

Partial ecosystem service valuation studies have been undertaken at Welwick (Burdon et al., 2011). However, this review will also include evidence from other managed realignment sites where lessons could be learned and applied for the ongoing of future managed realignment sites in the Humber.

The development of ecosystem service definitions, categorisations and frameworks has been reviewed, with the ecosystem services and societal benefits (ES&SB) framework. This framework has already been successfully applied to the marine environment, and has been adapted for its application to the estuarine environment, with a particular focus on managed realignment sites. The study undertaken by Burdon et al. (2011) at Welwick managed realignment site showed that there is great potential for such applications.

The key objective of this measure was to create intertidal habitat to compensate for that lost through ABP port development. This is linked with ecosystem services 'landscape maintenance' and 'biodiversity', and also 'flood water storage' and 'dissipation of tidal and river energy'. It also provides 'opportunities for recreation and tourism' through becoming a tourist and bird watching attraction.

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Table 4: Targeted ecosystem services

Measure	
Food: animals	
Water for industrial use	
Water for navigation	
Climate regulation: carbon sequestration	
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	X
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	

Involved habitats

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

Table 5: Ecosystem service analysis for Welwick: 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**	**52**	**3**
Intertidal steep habitat	floods every tide, mainly steep zones at marsh edges	**0**	**0**	**0**	**0**
Intertidal flat habitat	floods every tide, flat zones	**0**	**0**	**41**	**3**
Subtidal shallow habitat	never surfaces, less deep than 2m	**0**	**0**	**0**	**0**
Subtidal moderatily 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**	**3**	**7**	**3**
		100		100	

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

The measure Welwick in the polyhaline zone of the Humber estuary was about the creation of intertidal habitat by transforming adjacent land into marshland and intertidal flat habitat with a moderately high change in the habitat quality.

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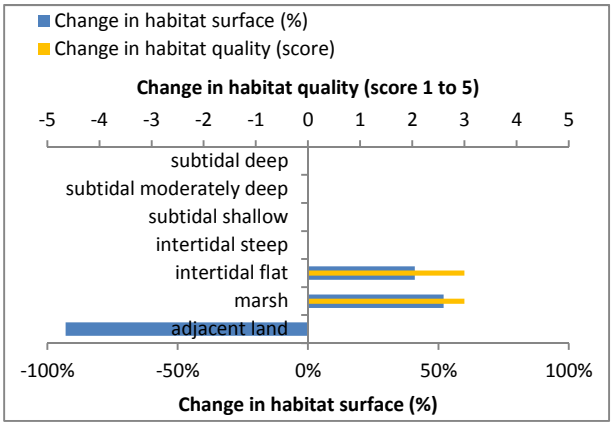

Figure 8: Ecosystem services analysis for Welwick: Indication of habitat surface and quality change, i.e. situation before versus after measure implementation.

From the ES assessment it is concluded that this measure generates overall a positive expected impact for many ES, with a very positive expected impact for "biodiversity" and a positive expected impact for:
Cultural services

- 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);
- Water quantity regulation: landscape maintenance; Climate regulation: Carbon sequestration and burial.

The expected impact for the development target "biodiversity" is very positive.
The expected impact for the different beneficiary groups is overall positive, with a positive expected impact for future use and for local use.

Table 6: Ecosystem services analysis for Welwick: (1) expected impact on ES supply in the measure site and (2) expected impact on different beneficiaries as a consequence of the measure.

Creation of ~54 ha of intertidal habitat at Welwick

Cat.	Ecosystem Service	Score
S	"Biodiversity"	3
R1	Erosion and sedimentation regulation by water bodies	2
R2	Water quality regulation: reduction of excess loads coming from the catchment	2
R3	Water quality regulation: transport of polutants and excess nutriënts	0
R4	Water quantity regulation: drainage of river water	0
R5	Erosion and sedimentation regulation by biological mediation	2
R6	Water quantity regulation: transportation	0
R7	Water quantity regulation: landscape maintenance	2
R8	Climate regulation: Carbon sequestration and burial	2
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	0
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	1
C3	Information for cognitive development	2
C4	Opportunities for recreation & tourism	2

Beneficiaries:	
Direct users	0
Indirect users	1
Future users	2
Local users	2
Regional users	1
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.

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2.3 Degree of synergistic effects and conflicts according to uses

So far the site appears to be developing as expected as anticipated.

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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 all about the creation of new intertidal habitat which provides a much needed habitat in the Humber Estuary to give land back, which can be utilised as natural flood defence and to provide extra space within the Estuary, which in turn can also improve water and sediment quality and reduce sedimentation in the main channel, which in turn reduces dredging requirements.

Table 7: Main pressures of the polyhaline zone of the Humber estuary

Indicator	code	Main pressures **polyhaline** zone Humber	Effect?					Description
			- -	-	0	+	++	
S.I.	1.1	Habitat loss and degradation during the last about 100 years: Intertidal				X		Development of intertidal habitat.
S.I.	1.5	Gross change of the hydrographic regime during the last about 100 years				X		Opportunity for additional space along the Humber Estuary.
S.I.	3.1/3.2	Decrease of water and sediment chemical quality				X		Intertidal habitat and wetland s have the potential to improve water and sediment quality.
D.I.	1.3	Land claim during the last about 100 years				X		Land given back to the Humber Estuary.
D.I.	1.7	Relative Sea Level Rise				X		Opportunity to provide natural defence against flooding in line with increased sea level rise.
D.I.	2.4	Maintenance dredging				X		Fewer requirements for dredging as sedimentation occurring through accretionary trends in intertidal and saltmarsh habitats.

S.I. = state indicator; D.I. = driver indicator

3.2 Degree of synergistic effects according to Natura 2000 aims

This measure was all 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 8: 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.

Overall, the monitoring has found an accretionary trend over the survey period between 2007 and 2011, with an average difference between 2007 and 2011 of +14cm. The degree of accretion was found to have decreased over time. The main change in elevation took place in the initial year following the breach, with typical elevations increasing by between 0 and 50cm between 2006 and 2007.

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.

Erosion was initially noted in the creeks, and continually towards the rear of the site within the created saline lagoons. The latter should, however, be viewed with a degree of caution as the presence of standing water can reduce the accuracy of the LiDAR data. The higher elevations (above ca. 2.75mODN) have barely, or not at all, been subject to a net gain in elevation.

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 un-vegetated.

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