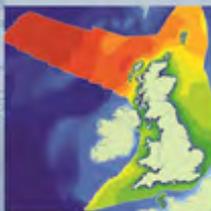


# Horsey Island Coastal Restoration - 10 Years On

Review of UK's first and largest mixed-sediment  
beneficial use projects

ABPmer Internal White Paper  
March 2016

Creating sustainable solutions for the marine environment



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# Horsey Island Coastal Restoration - 10 Years On

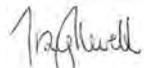
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# Contents

1	Introduction .....	1
1.1	Report background .....	1
1.2	Report aims and methods .....	2
2	Implementation of Horsey Projects.....	3
2.1	Key project phases.....	3
2.2	Thames Lighter Barges (Phase 1).....	3
2.3	Coarse sand/shingle recharge (Phase 2).....	4
2.4	Small-scale silt recharge trial on saltmarsh (Phase 3).....	7
2.5	Large-scale silt recharge over mudflat (Phases 4 and 5).....	7
2.6	Large-scale silt recharge over saltmarsh (Phase 6).....	9
3	Remote Sensing Analysis (1997 to 2015).....	13
4	Summary and Conclusions .....	15
5	References .....	17
6	Abbreviations/Acronyms .....	18

## Images

Image 1.	Location of Horsey Island with aerial view of the site.....	1
Image 2.	Six of the Thames lighter barges at Horsey Island .....	4
Image 3.	Land elevation map of north-east corner of Horsey Island .....	5
Image 4.	Migration of sand/shingle recharge from deposition during early 1990s to 2000 (date of aerial image) .....	6
Image 5.	Behaviour of the shingle barrier from 2000 to 2012 showing greater stability than preceding decade.....	6
Image 6.	Location of the 1998 silt recharge (indicated over aerial photograph from 2000) .....	8
Image 7.	Views of eastern (top) and western (bottom) parts of the large-scale silt recharge area.....	8
Image 8.	Location of the 2005/06 silt recharge (indicated over aerial photograph from 2000) .....	10
Image 9.	Views of Phase 6 silt recharge from 2005 to 2011 (top of the shoreline) .....	11
Image 10.	Views of the Phase 6 silt recharge in 2006 and 2016 (seaward marsh edge).....	11
Image 11.	Saltmarsh recharge area before and after the 2005/06 recharge .....	12
Image 12.	Approximate changes in saltmarsh extent 1997 to 2008 (green areas in SSSI Unit 8 show marsh gain or raised mudflat) .....	13
Image 13.	Difference in elevation between the 1999 and 2015.....	14

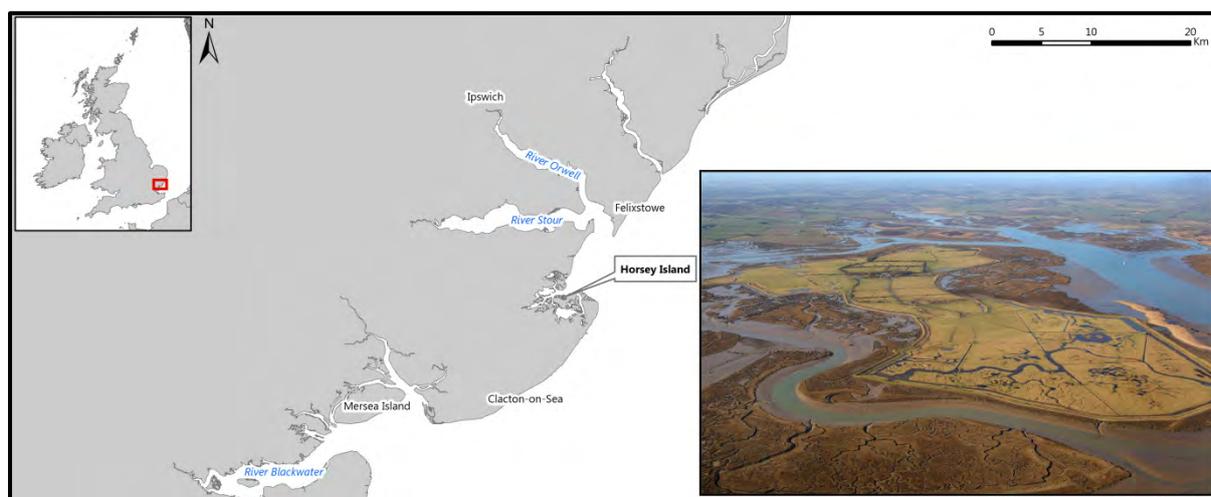
## Figures

Figure 1.	Land and intertidal elevation map using 2015 LiDAR dataset.....	20
Figure 2.	Difference in elevation between the 1999 and 2015 LiDAR datasets .....	21
Figure 3.	Difference in elevation between the 2013 and 2015 LiDAR datasets .....	22
Figure 4.	Fixed-point photographs of the site taken by ABPmer on 15 February 2016.....	23

# 1 Introduction

## 1.1 Report background

Horsey Island lies at the centre of the Hamford Water coastal inlet (Essex) on the eastern coast of the UK (Image 1). Due to its location and size, the island plays an important role in providing wave protection for the wider 'Walton Backwaters' and the shoreline behind. It therefore provides an important coastal protection function for hinterland properties as well as for socio-economic assets such as the Titchmarsh marina.



**Image 1.** Location of Horsey Island with aerial view of the site

The Hamford Water coastal embayment (including the island) is ecologically very valuable. It is designated as a Special Protection Area (EU Code UK9009131), a Ramsar Wetland (Code UK11028) and a National Nature Reserve NNR supporting breeding terns and a wide range of passage and overwintering waterbirds. In this context, the island is valuable not just because it provides habitat for feeding, nesting and roosting birds in its own right but also because it shelters the wider network of surrounding tidal creeks and intertidal habitats.

These habitats, in turn, support a rich invertebrate fauna and provide many important functions for fish, shellfish and birds. Parts of the island are also designated as a candidate Special Area of Conservation (cSAC) due to localised populations of Fisher's estuarine moth (*Gortyna borelii lunata*) which is restricted to small areas of sea-walls and coastal grassland.

Due to its situation and aspect, however, the island is inherently susceptible to wave attack (especially on its exposed northern side) and its coastal defences and habitats are vulnerable to damage and erosion. Back in the 1990s, this exposure had resulted in the northern seawalls becoming severely undermined and, from measurements made by the

At Horsey Island several major projects were undertaken over many years involving the beneficial use of dredge arisings to enhance and protect habitats and sea defences. This short report reviews the work that took place and describes how the recharged areas have developed some 10 years after the last campaign was completed.

then National Rivers Authority (NRA) (which is now the Environment Agency), around 75 ha of saltmarshes and 218 ha of foreshore had been lost at the inlet mouth between 1925 and 1983 (Dixon, 1992).

These conditions prompted the implementation of a sequence of, what were then, comparatively novel techniques to provide coastal protection through habitat restoration rather than building up the seawalls. A range of initiatives were undertaken from 1988 to 2005 to protect and enhance the fronting marshes and muds. These initiatives included the UK's first beneficial use of coarse sediment dredged arisings and some of the largest ever beneficial silt recharge campaigns on intertidal mudflat and marsh. Now that over 10 years have passed since the last phase of works was completed (and nearly 30 years since the first phases were undertaken) ABPmer has undertaken a review of all the Horsey Island projects.

## 1.2 Report aims and methods

One of the main aims of this report is to provide an updated summary of all the beneficial use work that has been undertaken at Horsey Island. A number of different campaigns were undertaken over many years and the nature and scale of these different initiatives is not always clearly and consistently stated within the available literature and online resources. This report seeks to clarify these initiatives as far as possible with reference to a number of key reviews (Carpenter and Brampton, 1996; Colenutt, 1999; ABP Research, 2001; Stevenson, 2001; Defra/Environment Agency, 2007) and by seeking advice and input from several participants who helped to realise the Horsey Island projects (see 'Acknowledgments' above).

The second aim of the report is to understand how these beneficial use projects have performed over the years since they were completed. This analysis is based on the summary results that are presented in the literature (which often describes how they had performed when they were initially undertaken) but also uses information from 2015 and 2016 to describe the conditions over the last 10 years since the last major campaign was completed.

The description about the latest on-site conditions was informed by a visit to the site that was carried out on 15 February 2016 (attended by Natural England, RSPB and ABPmer) and by using latest available Light Detection and Ranging (LiDAR) survey results (now made freely available by the Environment Agency). These LiDAR survey results have been used to describe the physical changes that have occurred over the intertidal areas to understand how the bed elevations have changed as a consequence of the beneficial use projects.

## 2 Implementation of Horsey Projects

### 2.1 Key project phases

At Horsey Island, a number of different measures were undertaken over many years to protect the island's badly deteriorating seawalls and/or restore eroding habitats. This work was carried out by the Environment Agency in partnership with Harwich Haven Authority (HHA) and the landowner. The recharge materials were derived from capital and maintenance dredging work undertaken in the navigation approach channel and ports of Harwich and Felixstowe.

To summarise, in a quite simple manner, what was a quite complex set of initiatives (and associated studies, evidence collation exercises and assessments) carried over several years, the recharge works have here been distilled down to six key elements (retrospectively referred to here as Phases 1 to 6):

- **Phase 1 1988:** Installation of Thames Lighter Barges to act as wave energy breaks;
- **Phase 2 Early 1990s:** Importation of shingle and sand (148,000 m<sup>3</sup>) over several phases (starting with 18,000 m<sup>3</sup> in 1990) to create a new barrier along the alignment of the lighter barges;
- **Phase 3 1992** Small-scale trial of silt recharge onto saltmarsh (<1,000 m<sup>3</sup>) undertaken at the south-east corner of the island;
- **Phase 4 1998:** First major importation of silt (20,000 m<sup>3</sup>) over 2.7 ha of mudflat behind the sand and shingle barrier to raise intertidal levels, stabilise the barrier and create marsh habitat;
- **Phase 5 2001 and 2003:** Second and third importation of silt in 2001 (15,750 m<sup>3</sup>) and 2003 (25,000 m<sup>3</sup>) to 'top up' intertidal area behind the sand and shingle barrier;
- **Phase 6 2005/06:** Importation of silt (47,000 m<sup>3</sup>) over two phases in November 2005 (21,000 m<sup>3</sup>) and January 2006 (26,000 m<sup>3</sup>) on to a separate area of deteriorating saltmarsh to the west of the sand/shingle barrier to raise and restore this degraded habitat and protect the sea wall.

The following sections provided summary descriptions of these key phases<sup>1</sup>.

### 2.2 Thames Lighter Barges (Phase 1)

Today, one of the most visually distinctive features of the north-eastern shoreline of Horsey Island is the alignment of 18 Thames Lighter Barges along the foreshore (see Images 2, 3 and 4 and Figure 1). In the first phase of work at this site, these were placed here in 1988 at a cost of around £40,000 and were designed to break up a large proportion of the wave energies across the shoreline behind.

These barges were aligned in a shore-parallel direction and filled with mud after they were sunk into position. They were evenly spaced and set at an elevation which ensured that they remained proud of the water surface on spring tides. The wave energy effects of this alignment were modelled and considered to remove 70% of wave energy.

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<sup>1</sup> A separate and valuable Regulated Tidal Exchange scheme was also carried out behind the sea wall on the island's south-west corner which delivered 1.2 ha of saltmarsh (ABPmer Online Marine Registry (2014) <http://www.omreg.net/query-the-database/database-results/?sid=16>). However that project is not considered within this review of the intertidal enhancement and coastal protection works.

The physical influence that they have had on the shoreline in their own right is today indicated by the 2015 LiDAR plot as presented in Figure 1. This shows that they are causing small 'tombola' like effects on the shoreline and are evidently helping to stall and slow low shore erosion in their own right.



ABPmer, Photo 15 February 2016

Image 2. Six of the Thames lighter barges at Horsey Island

## 2.3 Coarse sand/shingle recharge (Phase 2)

In the years after the barges were put in place, a series of coarse sediment recharge projects were undertaken. This series of 'Phase 2' initiatives involved using capital dredge arisings from the Harwich Approaches. This element of the work began 1990, when 18,000 m<sup>3</sup> was put in place (Dixon, 1992) and then there were further campaigns in 1992 and then after 1994 when the majority of sediment was introduced (Stevenson, 2001). The volumes from these post-1992 campaigns have been quoted at 130,000 m<sup>3</sup> (Stevenson, 2001; Colenutt, 1999) so the full volume of coarse sediment used overall (including in 1990) is understood to be around 148,000 m<sup>3</sup>.

The coarse sand and gravel was 'rainbowed' over the top of, and between, the Thames barges which were initially buried under that material. The coarse dredged materials were sprayed along the mid intertidal alignment from a 'self-load, self-empty' discharge vessel (see specifications for vessels Sospan and Sospan Dau<sup>2</sup>) at high water on spring tides. This sediment recharge work was part of a series of measures to mitigate the impact of the Harwich channel deepening (IECS 2011) and represented the first application of dredged material for beneficial purposes in the UK (Defra/Environment Agency, 2007).

Coarse sediments were used for this recharge, rather than finer material, because they were more likely to remain in place and to provide a comparatively stable wave protection function. There were also concerns that fine sediments would wash away and have potential effects on shellfisheries and navigation. This importation of coarser sands and pebbles did however change the intertidal habitats *in situ* which had previously been fairly uniform fine sediment (ABP Research 2001; Defra/Environment Agency, 2007). Therefore there was, as had been expected, a distinct change to the sedimentary, and hence ecological, character of the site. The foreshore mudflat habitat prior to the recharge was, however, mainly composed of exposed hard London clays (because much of the softer material had been eroded by on shore wave action), and was thus probably of relatively low value for invertebrates and feeding birds prior to the recharge.

<sup>2</sup> <http://www.marinetraffic.com/en/ais/details/ships/shipid:125741/mmsi:210825000/imo:9020273/vessel:SOSPAN>  
[http://www.marinetraffic.com/ais/details/ships/shipid:255239/mmsi:244990000/imo:7711062/vessel:SOSPAN\\_DAU](http://www.marinetraffic.com/ais/details/ships/shipid:255239/mmsi:244990000/imo:7711062/vessel:SOSPAN_DAU)

Benthic invertebrate sampling monitoring before and after this work (five 10 cm-diameter core samples taken), showed that this sediment shift altered the invertebrate assemblages. There was an observed switch in dominant species from those associated with muds to those associated with coarser material. In particular, the dredged material became “rapidly colonised” by the king ragworm (*Nereis virens*)<sup>3</sup>. In addition, the foreshore bathymetry changed slightly in localised areas, but there was no increase in contaminants in the sediments at the site (Defra/Environment Agency, 2007).



Environment Agency LiDAR data, 2015

**Image 3.** Land elevation map of north-east corner of Horsey Island<sup>4</sup>

More recent visits to the site during the 2012/13 winter have confirmed that the sand/shingle barrier has developed well. It appears to be reasonable stable and has a good balance between vegetated and bare areas (CJT Ecology 2013). In recent years it has also become one of the best nesting sites for Little Terns (which nest on unvegetated coarse sediment habitat) in Essex. The vegetated areas are also considered to form an important plant community given the local rarity of the habitat with key species present including *Salsola kali* (prickly saltwort), *Glaucium flavum* (yellow-horned poppy) and *Eryngium maritimum* (sea holly) (CJT Ecology 2013).

This coarse-sediment recharge scheme is considered to be one of the most successful projects of its type in the UK in terms of providing the coastal defence function for which it was designed. The abundance of the ragworm species has been identified as supporting a thriving Sea Bass fishery and bird populations and, as described further below, a new marsh habitat has formed behind the recharged material (Defra/Environment Agency, 2007).

The intention of this coarse sediment recharge had been to create an enhanced wave energy break while also forming a shingle barrier that could be used to help create a containment area for the future placement of maintenance dredge silts from the Harwich Approaches. This subsequent silt recharge (see Section 2.5) was intended to raise bed levels behind the new barrier and therefore provide further protection to the sea walls. The proposed silt recharge was also designed to have a double function by helping to retain the shingle barrier in place. However, during the period after the major placement of sand/shingle and before the importation of the silt (when the silt recharge design

<sup>3</sup> Environment Agency Website Article Foreshore or intertidal recharge <http://evidence.environment-agency.gov.uk/FCERM/en/SC060065/MeasuresList/M6/M6T1/M6T1Eff.aspx> [Accessed on 02 March 2016]

<sup>4</sup> See Figure 1 for LiDAR map of the wider area and for the full legend/key details.

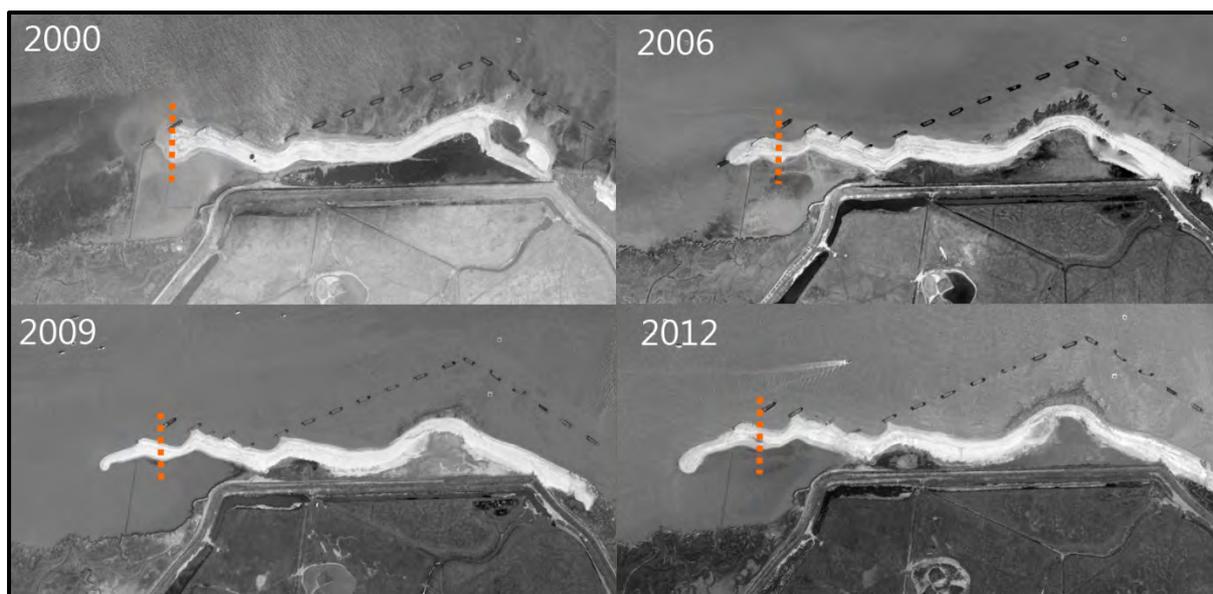
and consenting elements were being progressed), the barrier migrated landward. The direction and pattern of movement is illustrated in Image 4.



Source: Adapted from Natural England PowerPoint Image using Google Earth aerial view 2000

**Image 4.** Migration of sand/shingle recharge from deposition during early 1990s to 2000 (date of aerial image)

In 1998, 2001 and 2003, the silt recharges behind the barrier were undertaken (Phases 4 and 5) as described further in Section 2.5. After these recharges the shingle barrier evidently became much more stable. Image 5 includes aerial views that describe the alignment of shingle in 2000, 2006, 2009 and 2012. Over this period the main changes have involved a westerly extension of the barrier while some wind-blown sand has also migrated landward (southerly) over the surface of the recharged marsh habitat (IECS, 2011).



Source: Google Earth

**Image 5.** Behaviour of the shingle barrier from 2000 to 2012 showing greater stability than preceding decade

## 2.4 Small-scale silt recharge trial on saltmarsh (Phase 3)

In addition to the work undertaken on the exposed north-eastern corner of the island, in 1992 a small scale silt recharge trial was carried out in the south-east corner of the island (Defra/Environment Agency, 2007). For this work a half load of dredged silt from Harwich Harbour (1,000 m<sup>3</sup>) was deposited onto a heavily grazed saltmarsh over a 0.5 ha plot above the mean high water mark. The fine material was 'rainbowed discharged' onto the saltmarsh from a pipe connected to a self-load suction dredger. The spray extended 50 m from the fixed distributing nozzle of the dredger.

This direct application of dredged material on top of an eroding saltmarsh (dominated by *Spartina* and *Puccinellia species*) was undertaken to assess the impacts of dredged material placement on saltmarsh vegetation and to see whether a higher-level marsh community would develop in place of a low marsh community. However, there was no formal baseline or post-implementation monitoring in this case (Defra/Environment Agency, 2007) and, therefore, there is no accurate information about key aspects such as the settled depth of the initial silt deposit, or the habitat's responses. However, similar trials at Pewet Island<sup>5</sup>, Bradwell on Sea (Blackwater, Essex) using dredged material from the adjacent marina to a depth of 300 mm, did demonstrate a vegetation recovery within 12 months.

It was felt, however, that most of this small volume of silt was washed off the site over the first set of spring tides (Defra/Environment Agency, 2007) although the actual amount washed away was not known. Based on personal observations made by project team (as reviewed by ABP Research, (2001)) there was evidently no loss of plant cover, and some sediment remained in depressions on the saltmarsh surface which was quickly covered by vegetation. This was thought to be colonisation by new plants rather than regrowth of original species.

This small-scale trial demonstrated some of the challenges of working with fluid silt and the limited potential value when only recharging in small volumes. It was also recognised that more sediment may have been retained if it had initially been bunded, e.g. using hazel fencing or rolls of coconut matting which may also have facilitated further accretion.

Following this work, and the silt campaigns that followed (as described below), the value of 'de-gassing' fine sediment cargoes was also recognised as a way of producing a denser discharge material. The first boat used for this work did not have de-gassing equipment, but later sediment recharges vessels did, and this was used to raise the placed sediment densities from 1:1 to 1:1.25 tonnes/m<sup>3</sup>. This approach was also later used for the sediment recharge within the Allfleet's Marsh managed realignment<sup>6</sup> at Wallasea Island (Crouch, Essex) (Dixon *et al.*, 2008).

## 2.5 Large-scale silt recharge over mudflat (Phases 4 and 5)

The larger-scale silt recharge work at Horsey was carried out in three discrete campaigns. The initial work was carried out in 1998 (Phase 4) and the deposited sediments were later 'topped up' in both 2001 and 2003 (Phase 5). These recharge campaigns were undertaken behind the newly-placed shingle 'spit' and in front of the adjacent sea wall and this work remains (some 15 years later) one of the largest intertidal silt/mud recharge campaigns in the UK. What marks these stages out from the work that was undertaken later in 2005 (Phase 6, see Section 2.6) is that they involved the direct placement of silt over what were, largely, lower elevation mudflat habitats (rather than saltmarsh). Bed levels were raised substantially and the habitat thus converted to predominantly marsh habitat.

<sup>5</sup> ABPmer Online Marine Registry (2014) <http://www.omreg.net/query-the-database/database-results/?sid=132>

<sup>6</sup> ABPmer Online Marine Registry (2014) <http://www.omreg.net/query-the-database/database-results/?sid=134>

In February 1998 silts, again from the Port of Harwich, were discharged between the new sand/shingle barrier and the sea wall. To contain the material at the eastern and western flanks of the placement area, respectively, a brushwood fence and a line of sand bags were put in place prior to the work. These defined an area of around 2.7 ha (see Image 6). For this project around 20,000 m<sup>3</sup> of dredged fine muddy sediment was pumped ashore through a 450 mm diameter temporary steel pipeline laid from a trailing suction dredger.



Source: Google Earth

**Image 6.** Location of the 1998 silt recharge (indicated over aerial photograph from 2000)

On release, the recharge sediment emerged at quite a thick consistency and initially settled close to the discharge point before gradually ‘winnowing out’ more evenly across the site. However, even on completion the surface of the deposited sediment exhibited a sloping gradient extending to the east away from the discharge points. Overall, the project raised the bed levels by up to 1 m (and typically between by 0.5 m to 0.75 m), with limited apparent loss through the brushwood fencing (see Image 7).



Source: Stevenson, 2001 (left) and ABPmer Photos 15 February 2016 (right)

**Image 7.** Views of eastern (top) and western (bottom) parts of the large-scale silt recharge area

Within a month, active bird feeding was observed on the recharge sediments (indeed birds were feeding on the mud as it was being discharged with waders such as Redshank “swimming” in the mud<sup>7</sup>). By the end of the summer much of the mud had developed a signature cracked mosaic appearance (Stevenson, 2001) which is a symptom of the drying out that occurs in muds that are not covered by smaller neap tides (Dixon *et al.*, 2008; ABPmer 2015), and a good sign that the muds are sufficiently high to prompt marsh growth.

By November 1998 the surface elevation had also sunk/reduced by around 20 cm on average due to settlement and consolidation. However, there was considerable saltmarsh growth at this time (nine months after the recharge) especially over parts of the site that were above Mean High Water Spring (MHWS). A further year later, by November 1999, there was an even coverage of plants across much of the area (Stevenson, 2001). This project was therefore an early demonstration of how swiftly marsh vegetation can establish once conditions become favourable<sup>8</sup>.

Three years later, in January 2001, a further 15,750 m<sup>3</sup> of silt were pumped into the same area to top it up and facilitate the establishment of higher saltmarsh plants. The main difference in approach on this occasion (compared with 1998) was that the sediment was pumped from the seaward side of the area rather than from the sea walls (landward side) (Stevenson, 2001). Two years later, in 2003, a further 20,000 m<sup>3</sup> was placed on the eastern end of this recharge area behind the shingle/sand barrier. By 2016, the majority of this recharged silt material appears to have remained in place and (as described above) has helped to stabilise the migration of the shingle/sand barrier. There has been some migration of surface sand over the marsh in the central location (see Image 5); this was also highlighted by studies and surveys undertaken around 10 years after the second recharge (IECS 2011), which also confirmed that the marsh vegetation on the recharge was still present and had not been lost.

Today, there is still vegetation across most of the area although plant growth is limited because the area is grazed by sheep (CJT Ecology 2013). There are also many areas of lagoonal ponding, as the site does not appear to have formed many natural drainage channels. This could be related to the placement height and/or the presence of the fronting shingle barrier preventing channels from developing. Overall, however, this phase has demonstrated that large volumes of material can be placed and become stable marsh habitat even in exposed coastal locations.

## 2.6 Large-scale silt recharge over saltmarsh (Phase 6)

Over the 2005/06 winter, further major silt recharge campaigns were carried out (Phase 6). This work was one of several international schemes that were supported by the European Union-funded ComCoast<sup>9</sup> project, which were undertaken to examine the value of new flood defence techniques. The key distinction between this project and the preceding Horsey Island silt recharge campaigns was that the 1998 to 2003 projects largely involved pumping silts over existing mudflats to raise their elevation and create marsh. In 2005/06 the silt was pumped through and over an adjacent saltmarsh to raise both this habitat and extend the length of protection afforded to the sea defences.

<sup>7</sup> Similar ‘feeding in fluid mud’ behaviour was observed by Shelduck at the Boiler Marsh Recharge in 2012 ABPmer Online Marine Registry (2014) <http://www.omreg.net/query-the-database/database-results/?sid=142> (ABPmer 2015)

<sup>8</sup> A finding that has since become commonly recorded on many subsequent projects (e.g. Dixon *et al.*, 2008; ABPmer 2015)

<sup>9</sup> COMbined functions in COASTal defence zones

In total around 47,000 m<sup>3</sup> was imported over two stages; firstly, in November 2005 (21,000 m<sup>3</sup>) and then in January 2006 (26,000 m<sup>3</sup>). The recharged area was around 0.5-1 ha in size and is illustrated in Image 8.



Source: Google Earth

**Image 8.** Location of the 2005/06 silt recharge (indicated over aerial photograph from 2000)

To help retain the sediment in place, a series of 12 brushwood and geo-fabric mesh fences were laid across the natural drainage creeks in the marsh. The brushwood fences became rapidly covered in macroalgae after installation and this is believed to have played a useful role in helping to stem the flow of water through the fences and, therefore, to trap/filter sediment within the retaining areas. The material was then delivered to Horsey Island by a trailer dredger which connected to the site via a mix of floating, fixed and flexible pipelines. The flexible pipeline was innovatively used along the shoreline to reduce damage to existing marsh areas and allowed greater flexibility for recharging less accessible areas.

The recharge silt buried the marsh and the creek system under a layer of surface mud. The depths of deposition varied depending upon the underlying topography but was approximately around 30 cm to 1 m over the marsh surface but at greater depths (up to around 1.5 m) over the lower elevation creeks and pans. Images 9 and 10 describe the conditions on the site (from approximately comparable locations) both during and after the recharge. Post implementation monitoring showed new saltmarsh plant growth began within three months and that large amounts of sediment were retained *in situ*. This element of the project has been identified as one of the most successful schemes of its type in creating intertidal habitat and reducing flood maintenance costs (ComCoast, 2007).

In the decade since this work was completed, it is evident that the material which settled during the recharge has largely remained in place. There is no clear sign of significant sediment export or erosion. In the first instance this is indicated by visual observations on-site (see Images 9 and 10), but it is also confirmed by analysis of aerial imagery and remote sensing data. For example, Image 11 shows aerial views that describe the area before and after the recharge. They show that the recharged area remains visibly distinct over the period from 2005 to 2012. It is also evident that there was a clear area of marsh growth over former mudflat/saltpan habitat on the southern-most section of the recharge area. More recent surveys of this saltmarsh enhancement/recreation area over the 2012/13 winter have concluded that the area has developed well, with good saltmarsh plant cover (CJT Ecology 2013).

Today, there is still a full coverage of vegetation over much of the site. The area is, though, grazed by sheep and therefore the plant growth is heavily cropped and there has been compaction of the sediment and created a flattened surface. As with the recharge area behind the shingle barrier there are a number of lagoons/scrapes across the site.

On-site evidence also indicates that the mudflat in front of the recharge and behind the prograded shingle spit features has remained stable and even accreted both in front of and behind a polder fence which runs across the shoreline. This change is likely to be the result of to a combination of factors, including: the release of sediment from all previous recharges, the sheltering effect of the extended shingle barrier and the reduced volumes of tidal water exchange across this part of the foreshore following the recharge works.



2005 and 2006 Photos Environment Agency; 2011 Photo ABPmer

**Image 9. Views of Phase 6 silt recharge from 2005 to 2011 (top of the shoreline)**



2006 Photo Environment Agency; 2016 Photo ABPmer

**Image 10. Views of the Phase 6 silt recharge in 2006 and 2016 (seaward marsh edge)**



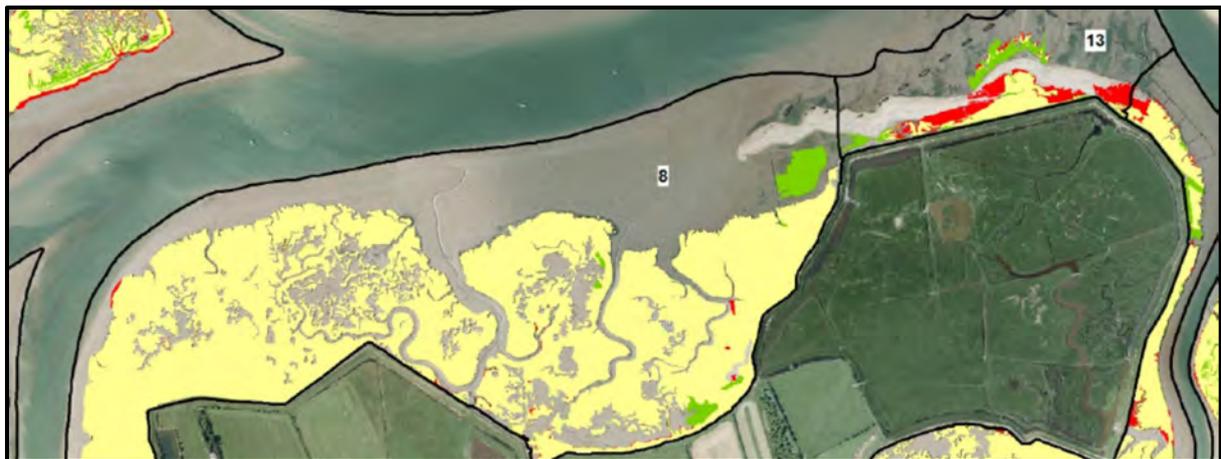
Source: Google Earth

**Image 11.** Saltmarsh recharge area before and after the 2005/06 recharge

### 3 Remote Sensing Analysis (1997 to 2015)

The preceding sections have summarised the sediment beneficial use initiatives that have been undertaken at the Horsey Island site along with a few of the key lessons learned. They have also highlighted, based on visual evidence, the persistence of the material that was placed on site during these projects. In particular, Section 2.3 has specifically described the persistence, and movement, of the sand and shingle materials which is visually very clear on site. However, to additionally verify the persistence of silt materials, additional consideration is given here to the results from available remote sensing data. For this analysis the results of available Environment Agency LiDAR data (describing intertidal bed elevations) collected in 1999, 2013 and 2015 has been reviewed by ABPmer.

Prior to considering this LiDAR data, however, it is firstly noted that the general persistence of the sediment used in the silt recharge has previously been indicated by a comparison of aerial images from 1997 to 2008 (IECS, 2011). This work was undertaken as a part of a much broader review of marsh extents throughout Essex and Suffolk but it did show an expansion of the marsh to the south and of the mudflat to the north of the 2005/-06 recharge area. This is illustrated as green patches (seen within SSSI unit 8) on Image 12.



Reproduced from IECS 2011

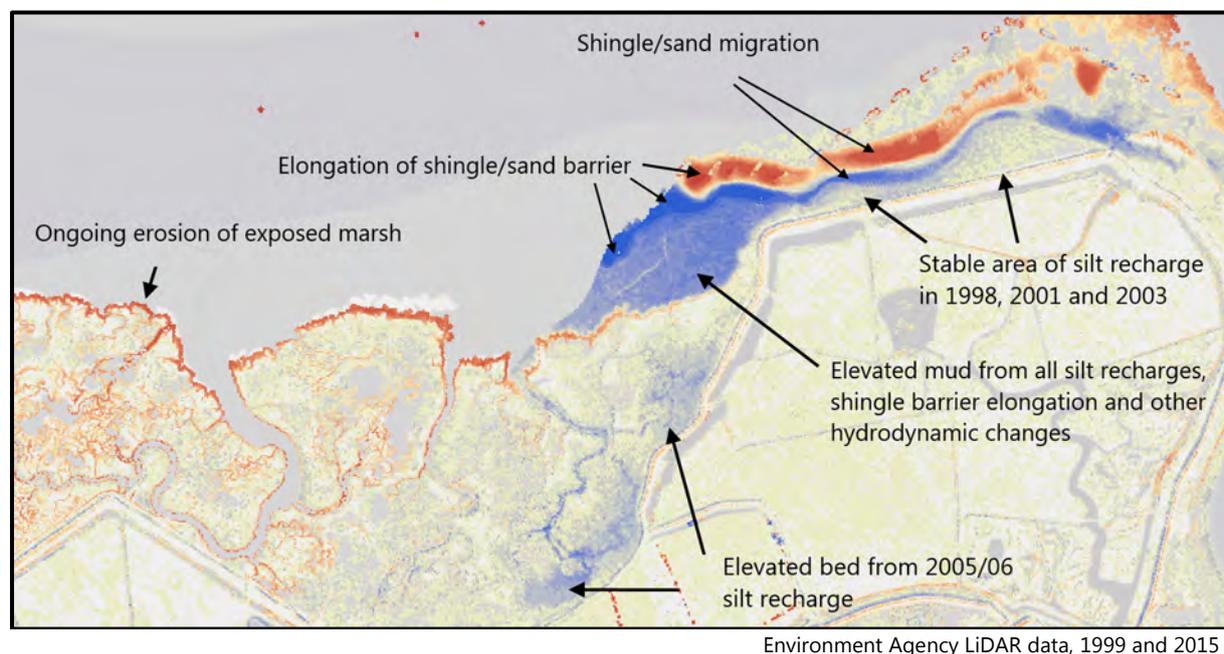
**Image 12.** Approximate changes in saltmarsh extent 1997 to 2008 (green areas in SSSI Unit 8 show marsh gain or raised mudflat)<sup>10</sup>

To take this analysis forward, ABPmer has examined the changing bed elevations using LiDAR survey data from 1999, 2013 and 2015. The results are shown in Figures 1 to 3. Figure 1 describes the latest topography of the site based on the 2015 LiDAR data, while Figure 2 shows the changes that have taken place over the 16 years between 1999 and 2015 (which includes the effects of Phases 5 and 6 when a total of around 87,750 m<sup>3</sup> of silt was recharged). These changes are described in Figure 2 as the differences in the vertical bed elevations between the two years (with red areas generally showing lower elevations over this period and blue areas generally showing higher bed levels). Using the same 'LiDAR-difference approach', Figure 3 then also describes the bed elevation changes between 2013 and 2015.

These plots provide a useful indication of the physical changes that have taken place (although the relative accuracy of this data ( $\pm 15$  cm) needs to be borne in mind and care needs to be taken when

<sup>10</sup> Within SSSI Unit 15 the area coloured red indicates sand migrating over the marsh surface (as described in Section 2.2).

interpreting long-term trends with just one or two surveys). However, Figure 2 does show how (and where) the silt recharge material has been retained. These areas are further illustrated and annotated in Image 13. In addition to showing the silt retention, this image (and the larger Figure 2) also highlights areas where the sand/shingle has migrated and extended.



**Image 13.** Difference in elevation between the 1999 and 2015<sup>11</sup>

An examination of the LiDAR data over the main intertidal areas that were affected by the Phase 5 and 6 silt recharges indicates that there is 64,000 m<sup>3</sup> more silt present in 2015 than there was in 1999. This volume represents around 73% of the full Phase 5 and 6 recharge volumes. When it is borne in mind that there will have been post-recharge settlement and compaction of the deposited material, this value on its own indicates that the majority of the sediment has been retained (or at least that there has not been a substantial net export of sediment from the site).

Some of this 64,000 m<sup>3</sup> volume may well include sediment that has been naturally imported and accreted in recent years and, certainly, the recharge work may well have helped to create conditions that promote such natural sedimentation. However, it is also true that this LiDAR-based volume calculation will probably under-represent the amount of sediment retained (and the level of natural accretion) between 1999 and 2005. This is because, as described above, the LiDAR readings are not officially sensitive enough to capture the sediment that has settled in thinner layers/veneers of less than 15 cm. It is likely, therefore, that smaller scale changes in bed elevation have not been captured and that much greater volumes of muddy sediment are present on the site. In this context it is notable that the LiDAR analysis presented within Image 13 (and Figure 2) indicates that much of the eastern section of the marsh has been subject to a net bed increase (blue coloration) over the last 16 years. This indicates that broad-scale benefits of sediment retention/accretion have occurred beyond just the recharge areas.

Figure 3 also indicates that there was limited change over the two years between 2013 and 2015. The changes observed have mainly involved a slight westerly extension to the sand/shingle barrier. This is in keeping with the observations made in Section 2.3 about the westerly movement of sand and shingle.

<sup>11</sup> See Figure 2 for full LiDAR elevation difference map of the wider area and for the full legend/key details.

## 4 Summary and Conclusions

On the north shoreline of Horsey Island around 255,000 m<sup>3</sup> of dredged sediment have been beneficially used between 1990 and 2006. In total these have included in the region of 148,000 m<sup>3</sup> of coarse sand and shingle and 107,750 m<sup>3</sup> of fine silt/mud. These projects have clearly demonstrated how both coarse and fine-grained dredged sediments can be used effectively to build up and restore intertidal habitats and enhance coastal protection. They have also shown that such benefits can persist over at least two or three decades (including a period which has seen major storm events) and provide a cost effective flood defence mechanism. Currently, there is no reason to expect these materials to be removed or for the habitats to be substantially damaged over the coming years given the general stability of the conditions indicated by this high-level review. To summarise all the work and describe the conditions on site, Figure 4 presents a selection of fixed-point photographs.

These projects have also enabled many lessons to be learned about the practical and ecological issues that need to be considered. Preparing a full list of these individual key lessons is beyond the scope of this short document but many of these are detailed within the supporting literature. However, they include, in particular, the need to consider the habitat change (both negative and positive) that will/could take place on site and also the need to introduce mechanisms to ensure the relative stability of mobile materials (especially on wave exposed coasts) to achieve a dynamic equilibrium. This work also indicates that it is best to have a full recharge plan in place, with required consents, so that sediments of all types can be used effectively and quickly when available, rather than having to wait for discrete consenting and assessment processes to take place.

The sequence of Horsey Island projects has involved the beneficial use of around 250,000 m<sup>3</sup> of coarse and fine sediments over 15 years. These materials have been used to effectively, and cost-efficiently, improve coastal protection and intertidal habitat. They have also shown that such benefits can persist over at least two or three decades.

Lessons learned - Identifying all the lessons from these projects is beyond the scope of this short document but many are available within the supporting literature. However, one key message is that, while there are concerns about the short-term environmental effects of such works, projects such as these help us to understand (and manage) these effects as well as understanding the potential longer-term environmental gains. In the future the ideal scenario should be to have 'recharge plans' in place (with required consents) for vulnerable and suitable sites so that sediments of all types can be used effectively and quickly when they are available.

Into the future, and given the requirements to adapt to sea level rise, the conditions at Horsey will continue to present challenges, but the recharge works have clearly 'bought some time' for the existing defences and for the decisions that need to be made about the longer-term management of this site. The site, which prior to the works had been an area of eroded hard foreshore muds, has been converted into a mosaic of shingle spits used by nesting birds including Little Tern and Ringed Plover, mudflats with

denser quantities of invertebrates in softer muds, and higher level saltmarsh used by overwintering wildfowl and Brent Geese, plus associated plant species.

The work at Horsey has also been a valuable precedent for work at other sites. It has provided confidence in the efficacy of recharge measures and has helped beneficial use work to occur at sites such as Allfleet's Marsh (Wallasea) and Lymington (Dixon *et al.*, 2008; ABPmer 2015).

However, while there has always been a national aspiration for dredged sediments to be beneficially used for habitat restoration where possible; there have also been many constraints to the implementation of such projects (ABPmer, 2014). Due to these constraints, most dredged sediment continues to be placed onto official offshore disposal locations rather than used for habitat enhancement or coastal protection. Therefore, only relatively few beneficial use projects have been carried out for habitat restoration and these have generally been at a comparatively small-scale. The work at Horsey continues to be an inspiration for such work and it is hoped that this summary will throw a light back onto the valuable work that was done here.

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## 6 Abbreviations/Acronyms

ABPmer	ABP Marine Environmental Research Ltd
ComCoast	COMbined functions in COASTal defence zones
cSAC	candidate Special Area of Conservation
Defra	Department for Environment Food & Rural Affairs
EU	European Union
HHA	Harwich Haven Authority
IECS	Institute of Estuarine and Coastal Studies
LiDAR	Light Detection and Ranging
MHWS	Mean High Water Spring
NE	Natural England
NNR	National Nature Reserve
Ramsar	Ramsar Wetlands of International Importance
RSPB	Royal Society for the Protection of Birds
SAC	Special Area of Conservation
SCOUP	Sediment Compatibility and Opportunistic Use Pilot
SPA	Special Protection Area_
SSSI	Site of Special Scientific Interest
UK	United Kingdom

Cardinal points/directions are used unless otherwise stated.

SI units are used unless otherwise stated.

# Figures



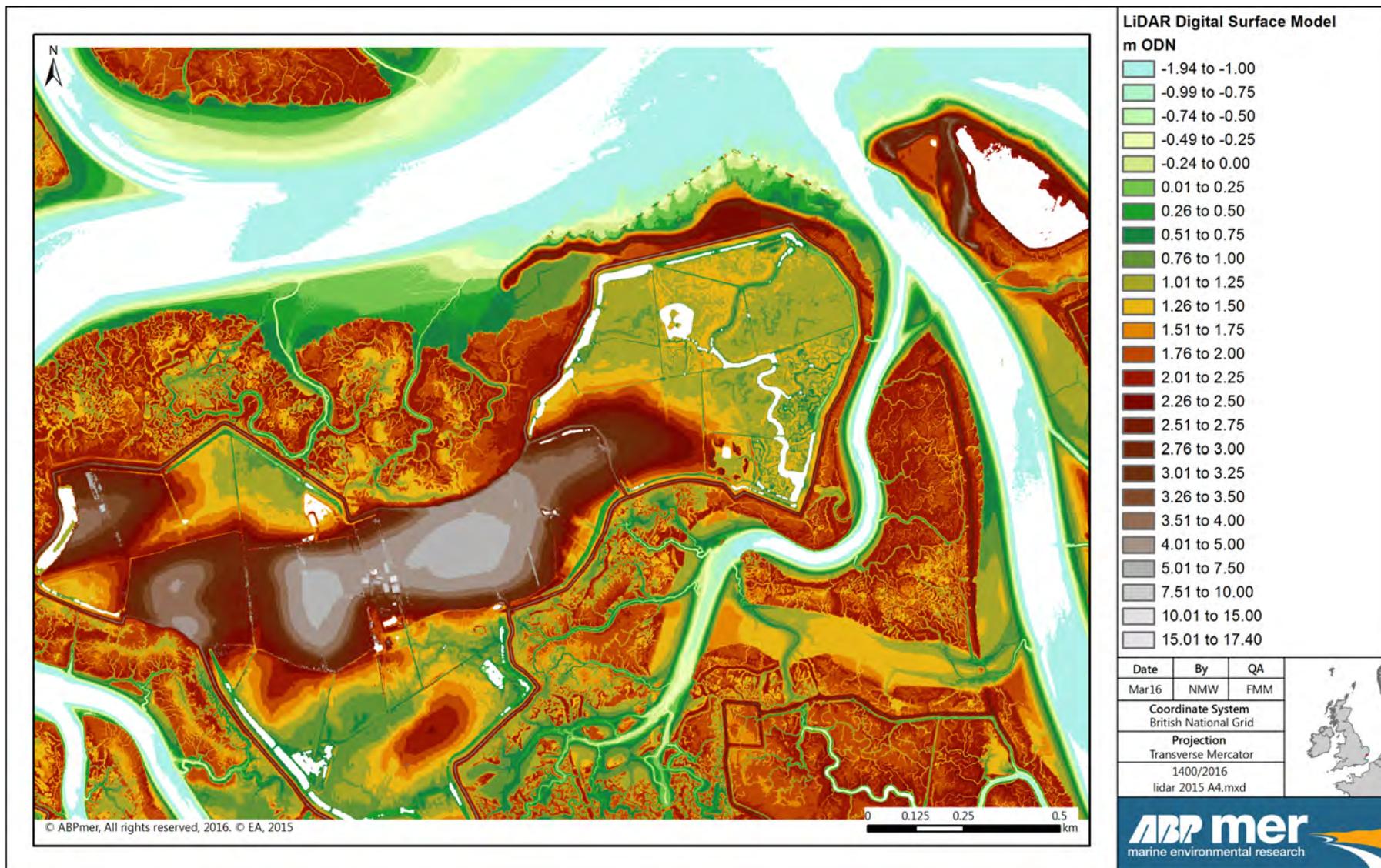


Figure 1. Land and intertidal elevation map using 2015 LiDAR dataset

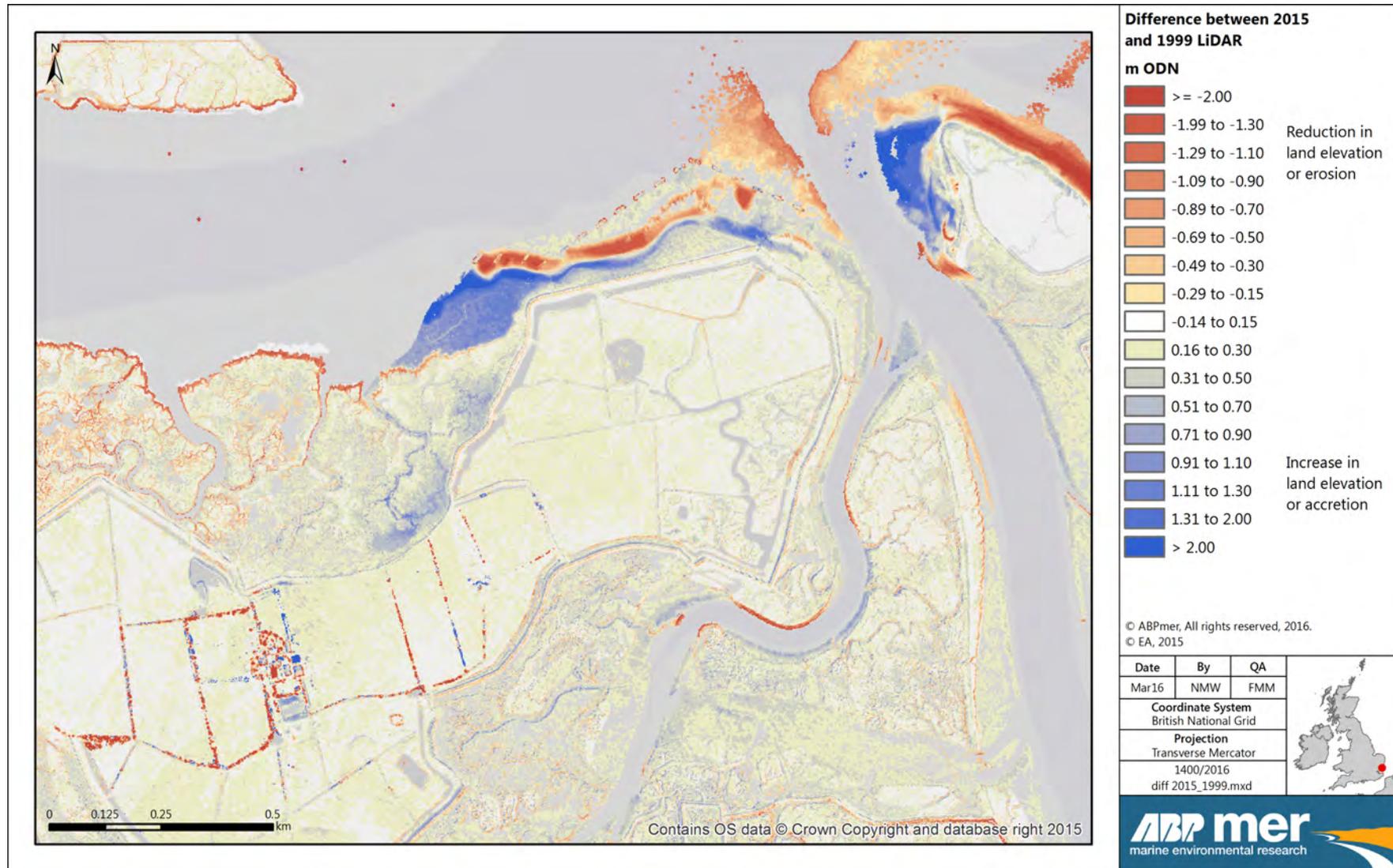


Figure 2. Difference in elevation between the 1999 and 2015 LiDAR datasets

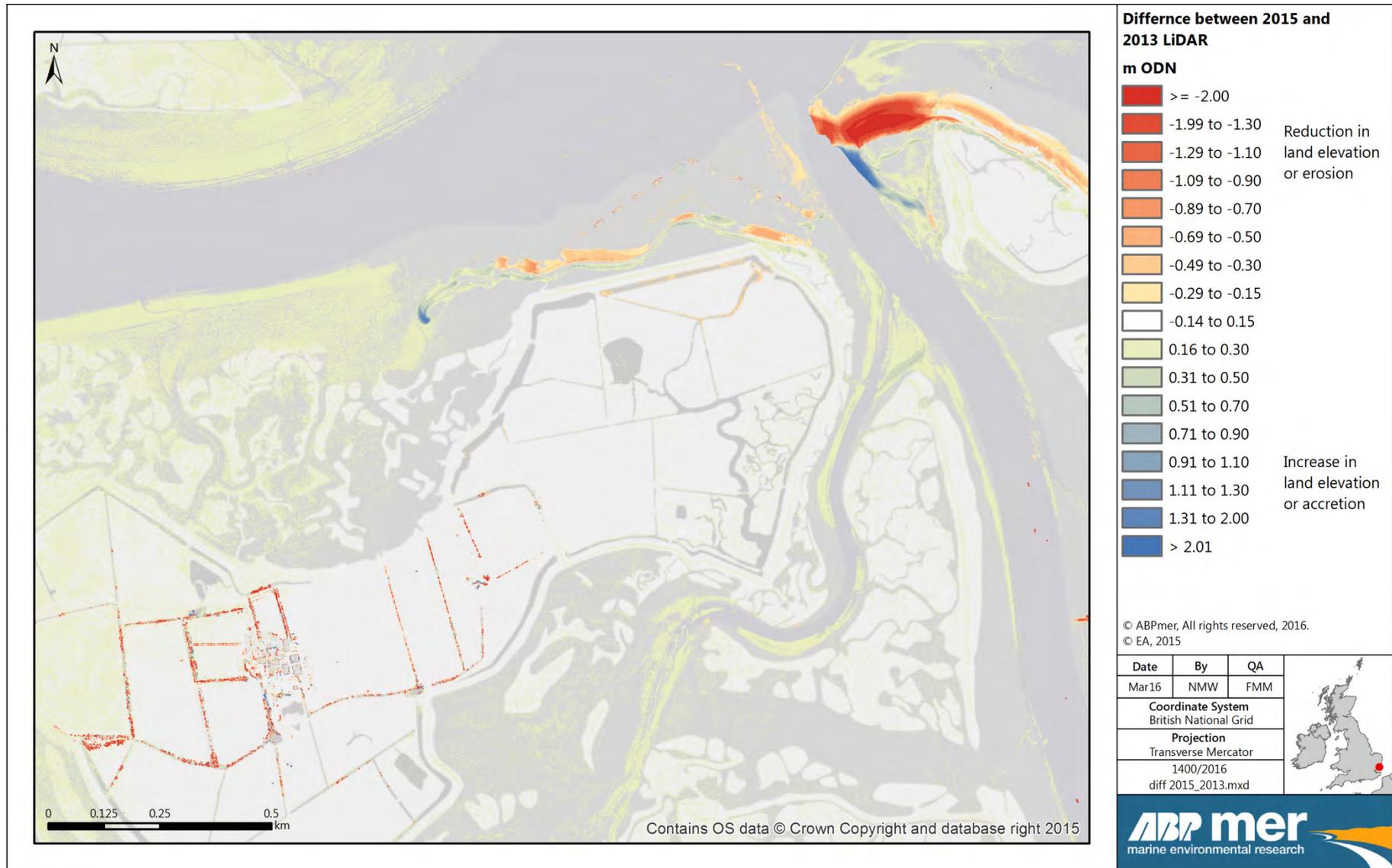


Figure 3. Difference in elevation between the 2013 and 2015 LiDAR datasets

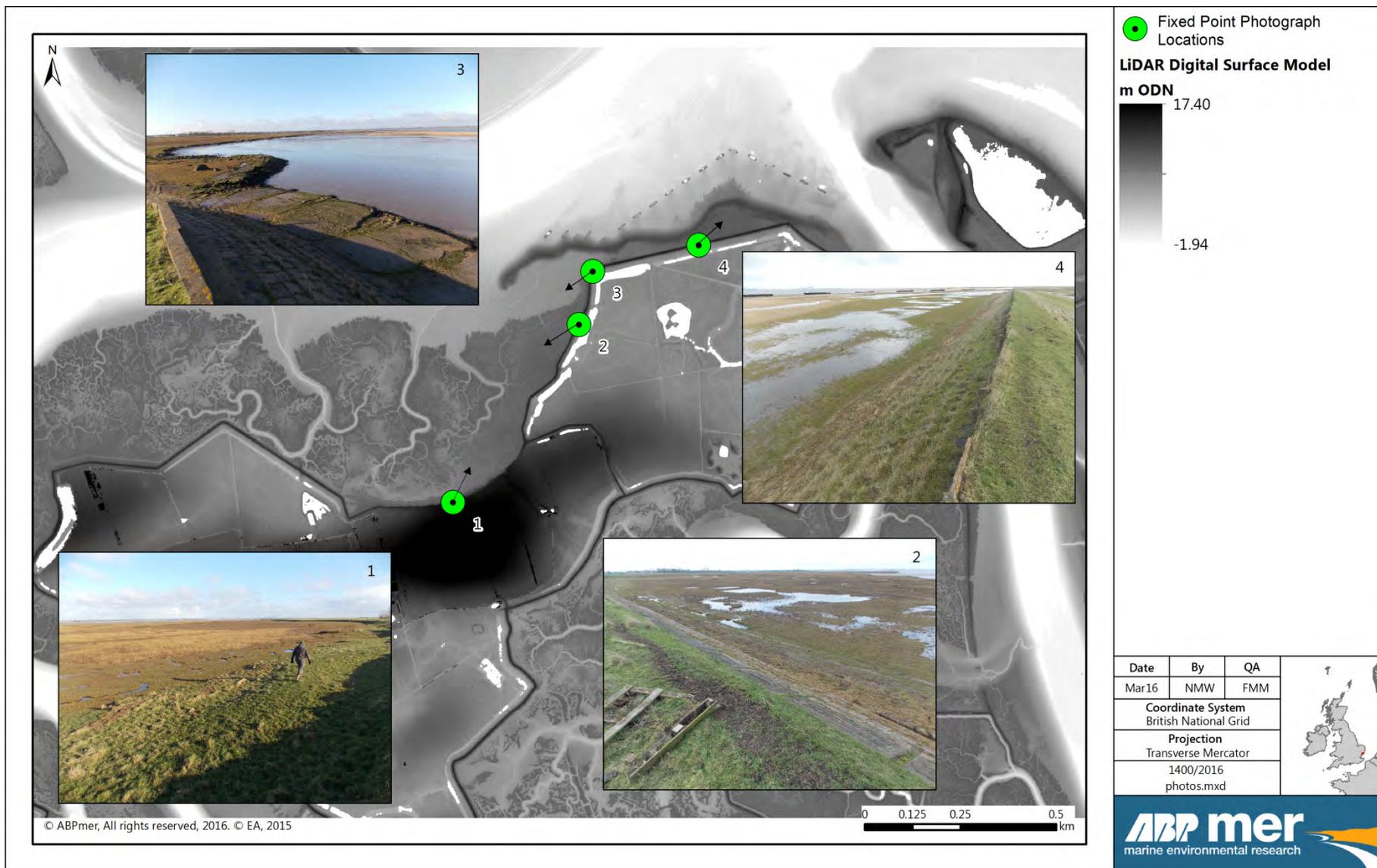


Figure 4. Fixed-point photographs of the site taken by ABPmer on 15 February 2016



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