



11c10 Humphrey Head to Cark

(Technical report by Jacobs)

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Policy area: 11c10 Humphrey Head to Carl

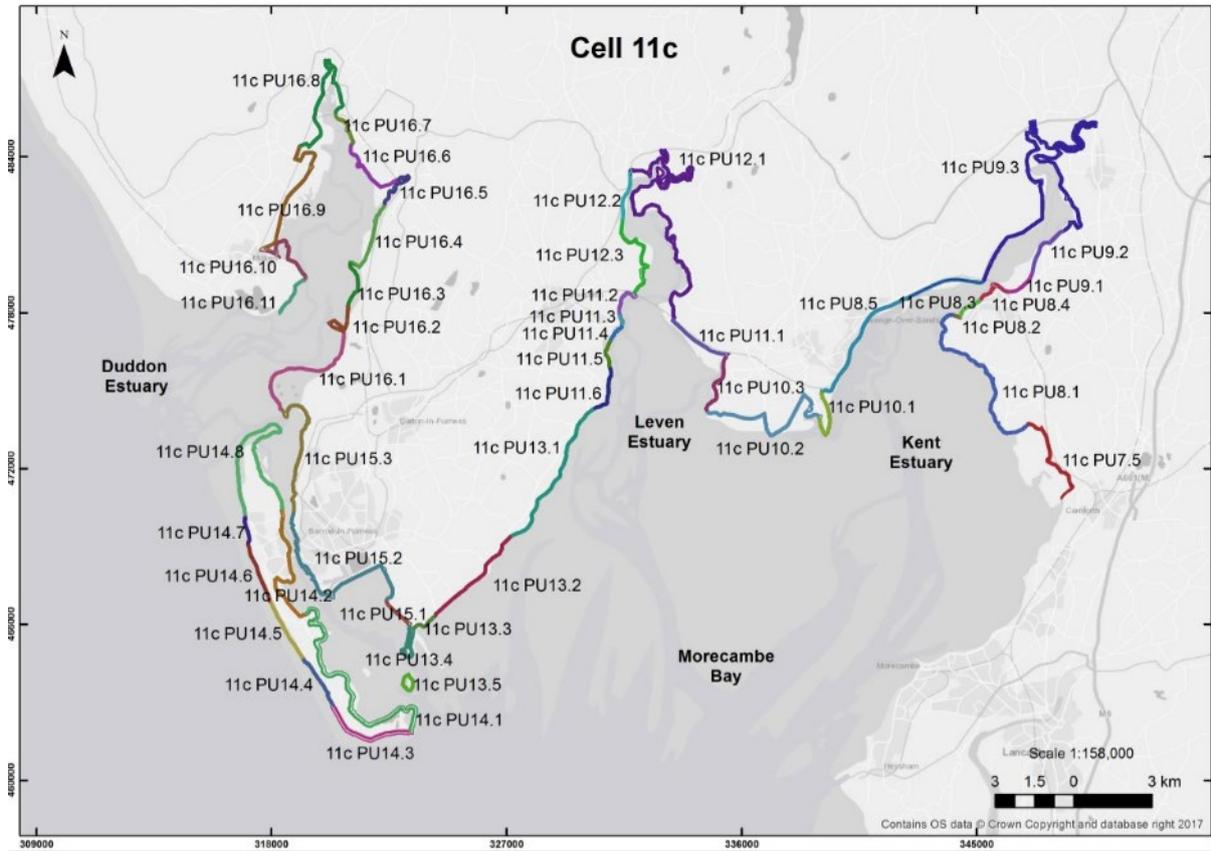


Figure 1 Sub Cell 11c Arnside to Hodbarrow Point Location Plan of policy units. Baseline mapping © Crown copyright and database rights, 2019. Ordnance Survey licence number: 1000019596.

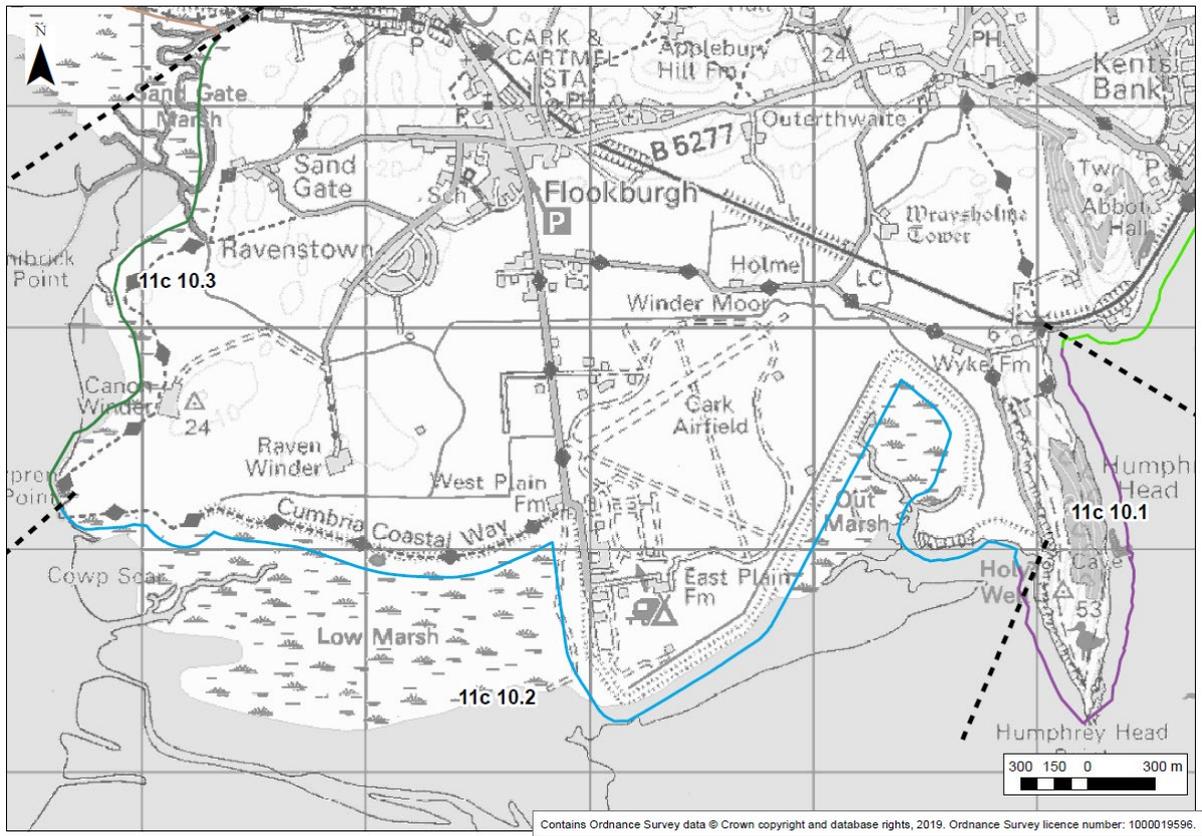


Figure 2 Location of policy area 11c10: Humphrey Head to Carlisle. Baseline mapping © Crown copyright and database rights, 2019. Ordnance Survey licence number: 1000019596.

1 Introduction

1.1 Location and site description

Policy units:	<p>11c10.1 Humphrey Head</p> <p>11c10.2 Humphrey Head to Cowpren Point (priority unit)</p> <p>11c10.3 Cowpren Point to Carke</p>
Responsibilities:	<p>South Lakeland District Council</p> <p>Environment Agency</p> <p>Bourne Leisure</p>
Location:	<p>The policy area, which is along the southern edge of the Cartmel Peninsula, extends between Humphrey Head, a limestone headland, and the village of Carke in the west. It is located within the central part of Morecambe Bay.</p>
Site overview:	<p>The key risk to the area is from flooding and currently the low-lying areas of the peninsula are protected by manmade embankments. These are fronted by saltmarsh and extensive mudflats. Although much of the area is low lying and comprised of soft sediments, there are natural hard points such as Cowpren Point and Humphrey Head.</p> <p>Historically Cartmel Peninsula has accreted southwards, due to natural infilling of Morecambe Bay resulting from the net import of sands and finer sediments. This trend has, over time, been enhanced by human activities, such as construction of embankments, groynes, training walls and viaducts (bridges and approach embankments), which have reduced the tidal prism of the Leven and Kent Estuaries. This is turn led to reclamation of areas to use initially as agricultural land.</p> <p>The shape of the Peninsula between Humphrey Head and Carke is very unnatural looking and results from historical management of the frontage. In 1807, a 5 km long embankment was present running from Humphrey Head to Cowpren Point, but failure of the western part of this embankment in 1828 resulted in the area reverting to intertidal flats before subsequently being recolonised by marsh. To protect the eastern part of the frontage a new north south embankment was constructed creating the angular shoreline present today.</p> <p>The coastal environment has high environmental value with fringing saltmarsh and intertidal flats supporting a wide range of habitats and qualifying species. As such, international designations cover the intertidal zone and adjoining terrestrial areas. Any policy options involving any advance of the shoreline or that encroach into the intertidal area are likely to be environmentally unacceptable.</p>

1.2 Current SMP policy

The policy details for the whole policy area are shown here taken directly from the SMP2 (Halcrow, 2011), but non priority units have been greyed out.

Overview: *The long term vision here is to set back from the present frontage, but to continue to manage flood risk to the railway and other assets and agricultural land where economically justifiable and allowing additional saltmarsh development and habitat creation. By carrying out realignment to part or all of the frontage in a phased and controlled manner, managed flood risk to people and property is maintained whilst also creating a more sustainable and natural alignment therefore achieving a range of the social and environmental objectives.*

Location		Policy and Approach (from 2010)		
		0-20 years	20-50 years	50-100 years
11c10.1	Humphrey Head	No active intervention – No defences present, allow natural processes to continue.	No active intervention – No defences present, allow natural processes to continue.	No active intervention – No defences present, allow natural processes to continue.
11c10.2	Humphrey Head to Cowpren Point	Hold the line – Manage flood risk by maintaining existing defences to an adequate standard. Investigate opportunities for phased realignment to address flood risk when defences become uneconomic to maintain in their current alignment.	Managed realignment AND Local Hold the line – Subject to study findings, monitoring of the defences and shoreline evolution, implement opportunities for phased realignment when defences become uneconomical and establish a more natural and sustainable defence alignment. Localised Hold the line should be allowed for private defences, subject to landowner agreement and appropriate consents. Caravan Park defences are likely to be viable to maintain up to the end of the period.	Managed realignment – Phased realignment of remaining defences towards a more natural and sustainable defence alignment. Localised Hold the line should be allowed for private defences, subject to landowner agreement and appropriate consents.
11c10.3	Cowpren Point to Cark	No active intervention – Allow shoreline to continue to evolve under natural processes.	No active intervention – Allow shoreline to continue to evolve under natural processes.	No active intervention – Allow shoreline to continue to evolve under natural processes.

2 Appraisal of priority units

One unit within this area has been defined as a priority unit:

- 11c10.2 Humphrey Head to Cowpren Point

2.1 Existing approach to flood and coastal erosion risk management

2.1.1 Justification of current SMP policy

Section 2.1 sets out the SMP policies for this priority unit. The primary justifications for the policies at the SMP level for 11c10.2 were as follows:

- **Social:** Phased realignment will allow for adaptation and roll back of assets such as the caravan park within the risk zone to more sustainable locations.
- **Environmental:** Realigning the defence line will create a more naturally functioning coast line and will provide a large area of intertidal habitat creation. Further consideration of the value of Cark Airfield Scheduled Monument in this location will be required in liaison with English Heritage (now Historic England).
- **Economic:** Long term phased management realignment is economically viable. Allowing for habitat creation and private contributions will significantly increase the viability of delivery of the overall policy for this frontage.

2.1.2 Current defences

There are currently approximately 6 km of embankments (see Figure 2): West Plain Embankment, Cross Embankment (Lower Marsh), East Plain Embankment (including revetment section), Roughholme Embankment and Humphrey Head Embankment, known collectively as the Windermoor Embankment.

The embankments are located on privately owned land, but the Environment Agency is responsible for their maintenance. Lakeland Leisure Park owners, Bourne Leisure, have been involved in recent works to maintain and improve the defences and have contributed to the cost of such works.

Refurbishment of the coastal defences was undertaken in the early 1990s, which involved raising the level of all embankments, increasing crest width and improving the seaward face of the embankments, turf protection was provided to all embankments apart from East Plain; here the embankment was refaced with armour stone and bedstone and small rock groynes were constructed at the ends of the pitched length of the East Plain embankment. No changes were made to the rear face slopes.

Following issues of undercutting along the toe of defences at Lakeland Leisure Park (Figure 3), emergency works were undertaken, completed in Spring 2008. More recently, maintenance works have been undertaken by the Environment Agency (2015 – 2019) to prevent animal poaching and vermin infestation. The work includes wire meshing and returfing, which should improve the condition of the defence and help extend residual life.

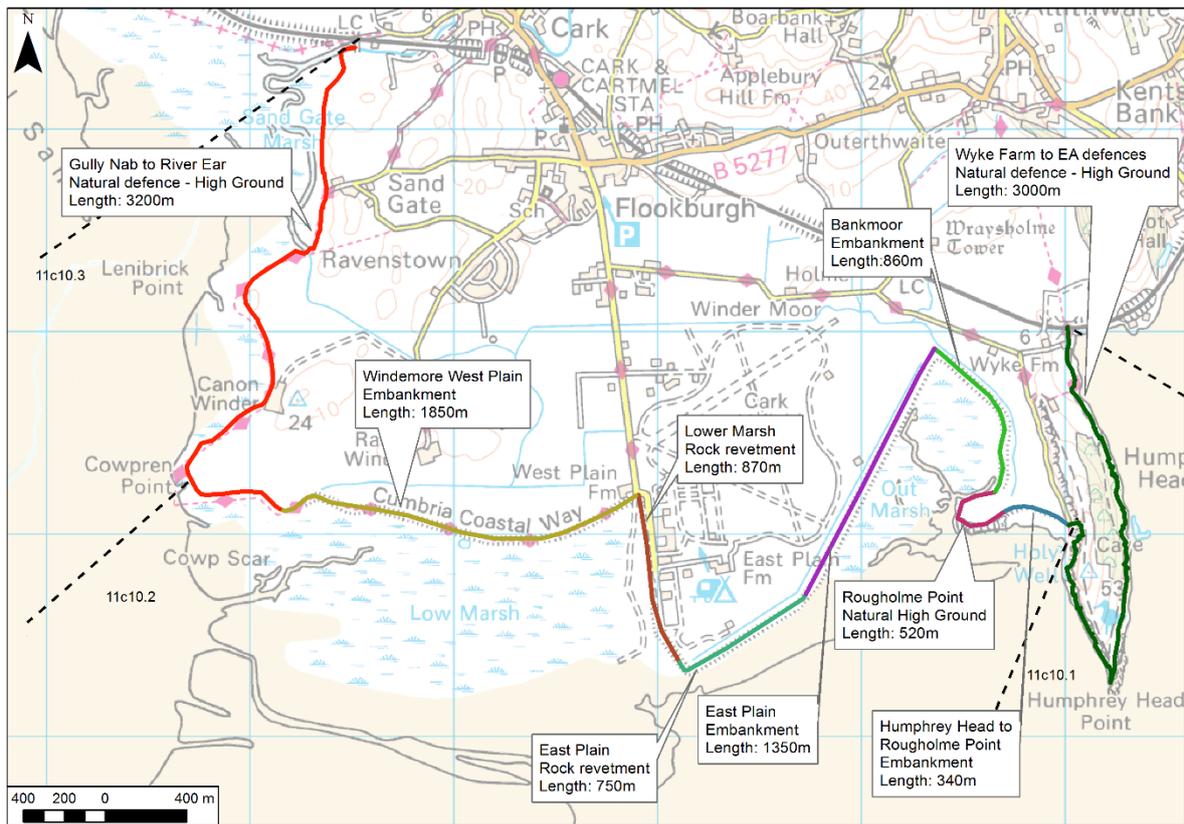


Figure 3 Policy units and summary of defence lengths between Humphrey Head and Carl. Baseline mapping © Crown copyright and database rights, 2019. Ordnance Survey licence number: 1000019596.



Figure 4 Aerial photographs of policy area 11c10. Photograph courtesy of North West Monitoring Programme.

The following design details (Table 1) have been taken from the strategy document produced by Patrick Parsons & Shoreline Management Partnership (2009):

Table 1 Design details taken from Patrick Parsons & Shoreline Management Partnership (2009):

Location	1990 design details						Emergency works (2007/8)
	Length (m)	Crest level (mOD)	Crest width (m)	Front face slope	Back face slope	Facing	
Humphrey Head Embankment	400 m	2 m wide strip of stone facing above existing, additional stone placed over vulnerable sections of existing stone.					

Rougholme Embankment	850	8.5	5.0	1 in 4	1 in 2	All faces turfed	
East Plain Embankment	800	8.5	5.0	1 in 2.5	1 in 2	Front face rock armour, all other faces turfed. Small rock groynes built out from end of embankment.	Bedstone (200/400) toe constructed. 5.0 m wide bedstone crest reinforcement infilled with smaller stone to facilitate access.
Cross Embankment	900	8.5	5.0	1 in 4	1 in 2	All faces turfed	Armour stone or bedstone slope protection and trenched toe (2.0 m deep. 5.0 m wide bedstone crest reinforcement infilled with smaller stone to facilitate access.
West Plain Embankment	1,800	8.5	5.0	1 in 4	1 in 2	All faces turfed	

A recent asset inspection has been undertaken as part of the North West Regional Monitoring Programme (CH2M, 2018), the conclusions of this are summarised in Table 2 below:

Table 2 Condition of existing defences (CH2M, 2018).

Unit	Location	EA Asset Ref	Defence Type	Condition	Residual Life
11c10.1	Wyke Farm to EA defences	011KC90200101C01	Natural high ground	Fair	20 - 50 years
11c10.2	Humphrey Head to Rougholme Point	011KC90200201C01	Embankment	Good	10 – 20 years
11c10.2	Rougholme Point to Bankmoor Embankment	011KC90200201C06	Natural high ground	Fair	20 - 50 years
11c10.2	Bankmoor Embankment	011KC90200201C02	Embankment	Fair	0 – 20 years
11c10.2	Hollywell Bridge to Rock Armour defence	011KC90200201C03	Embankment	Fair	0 – 20 years
11c10.2	Flookburgh Outfall 1	011KC90200201C03001	Flapped outfall	Fair	10 – 20 years
11c10.2	Flookburgh Outfall 2	011KC90200201C03002	Outfall with screen	Fair	10 – 20 years
11c10.2	Rock armour pitching up to Groyne behind Caravan park	011KC90200201C07	Embankment	Fair	10 – 20 years
11c10.2	Flookburgh Groyne 1	011KC90200201C07001	Rock groyne	Good	20 - 50 years
11c10.2	Flookburgh Groyne 2	011KC90200201C07004	Rock groyne	Fair	20 - 50 years
11c10.2	Flookburgh Outfall 3	011KC90200201C07005	Double flapped outfall	Fair	10 – 20 years
11c10.2	Low Marsh Embankment	011KC90200201C04	Embankment	Fair	10 – 20 years
11c10.2	West Plain Embankment	011KC90200201C05	Embankment	Fair	10 – 20 years
11c10.2/3	Gully Nab to River Eea	011KC90200301C01	Natural high ground	Fair	20 - 50 years

Most of the assets have a residual life of more than 10 years, the exception being parts of the Bankmoor embankment, and between Hollywell Bridge and Rock Armour defence, where residual life is 0 to 20 years, depending on maintenance regime and exposure conditions.

It should be noted, however, that the performance of the estuarine defences and their future deterioration and maintenance requirements is dependent on the protection provided by fronting marshes and how this natural protection may vary in the future due to natural meandering of the low water channels, changes due to ongoing general sediment accretion and the impacts of future climate change and associated sea level rise.

Figure 4 shows defence drawings from 1992, taken from Patrick Parsons & Shoreline Management Partnership (2009), for the East Plain embankment groyne.

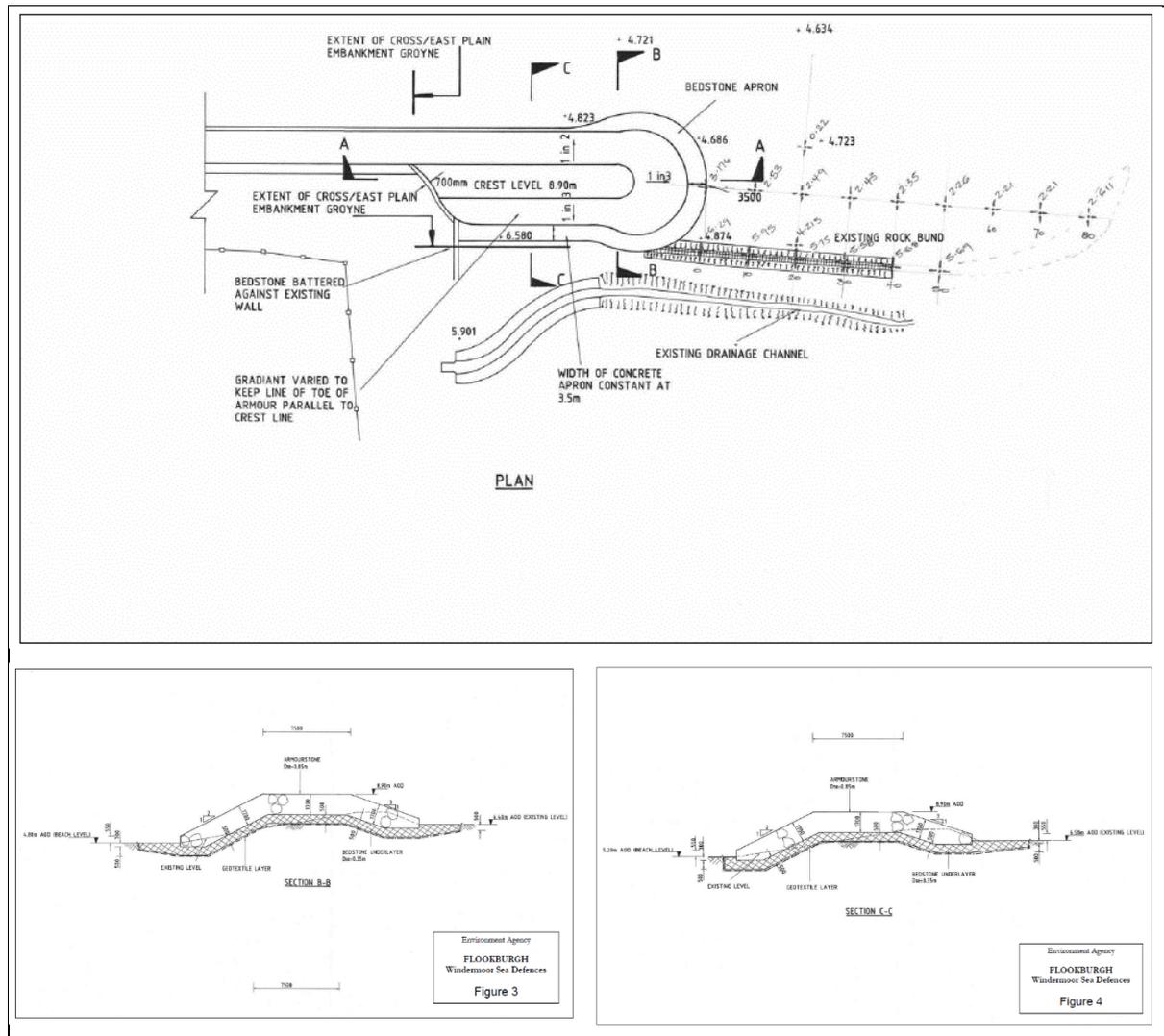


Figure 5 Defence drawings from original refurbishment in 1992. Taken from Patrick Parsons & Shoreline Management Partnership (2009).

The strategy by Patrick Parsons & Shoreline Management Partnership (2009) reports that the coastal defences currently provide defence against a 1 in 100 year storm event and that the defences could be adapted to address future sea level rise over the 50 year strategy by increasing the crest height by 1.0 m without the need to increase the defence footprint. From the report it is uncertain, however, what climate change scenario has been used to assess this.

To reappraise the standard of protection for this strategy, an estimation of the current standards of protection based on the crest levels detailed in Table 1 and 2018 water levels has been undertaken using data available for the project. The analysis is based upon the crest levels required to stop

inundation behind the defences (breach) but does not consider the resistance of the defences to hydraulic actions. This is, however, a high level assessment and to improve confidence in the estimates an analysis of toe levels would be required to establish water depth at structure and associated waves transformed shoreward.

Two scenarios have been considered, for both present day and year 2120:

- Scenario 1: this is based upon Joint Probability Analysis (JPA) water levels and $\frac{1}{2}$ JPA wave height – considers the joint probability of a wave and water level occurring simultaneously for a given return period, although the wave height itself is likely to be conservative due to use of nearshore wave height rather than being taken at the toe of the structure.
- Scenario 2: this is based on the marginal extreme water levels established for project + an arbitrary allowance for freeboard. 1 m freeboard has been established by considering the toe levels of the structures detailed in Figure 4 along with the marginal extreme water levels and a breaker index of 0.7 and then considering the amplitude of the waves.

Marginal extreme water levels were obtained directly from the National Coastal Flood Boundary Conditions dataset published by the Environmental Agency (EA, 2011). Marginal extreme significant wave heights were published by Halcrow (Halcrow, 2011), based on the JPS nearshore wave transformation model simulations. The joint probability analysis of waves was published by Halcrow (Halcrow, 2011). For the 2120 projections, water levels are based on the UKCP09 95% medium climate change scenario.

Table 3 shows that if scenario 1 is used then the current embankments may already provide less than a 1 in 50 (2%) standard of protection each year, but for scenario 2 the estimate is >1 in 200 (0.5%). By 2120, under both scenarios the current defences provide less than a 1 in 20 (5%) standard of protection. It is estimated that under scenario 1 the crest level would need to be above 9.7 mOD, whilst under scenario 2 the crest level would need to be above 8.97 mOD to provide a 1 in 100 standard in 2120. This appears to conform well with the previous recommendation in the Patrick Parsons & Shoreline Management Partnership (2009) report which indicated that the defences could be adapted for 50 years of sea level rise by raising the crest by up to 1 m.

Table 3 Estimated standard of protection provided by existing embankments for both present day (2018) and 2120

	Current crest level of embankments (mOD)	2018		2120	
		Estimated SoP	Equivalent crest level (mOD)	Estimated SoP	Equivalent crest level (mOD)
Scenario 1 (2018): JPA (JPA WL + $\frac{1}{2}$ JPA Wave)	8.5	< 1 in 50	8.8	< 1 in 5	8.7
Scenario 2 (2018): Extreme Still Water Level + Freeboard Allowance	8.5	> 1 in 200	8.3	< 1 in 20	8.6

2.1.3 Shoreline change

The Lakeland Leisure Park Strategy (Patrick Parsons & Shoreline Management Partnership, 2009) includes a detailed appraisal of how this shoreline has evolved over time, including data covering up to 2007. As part of this current appraisal, more recent LiDAR, aerial images and beach profile data have been used to assess how the coast has changed more recently (this is reported as a separate note at the end of this chapter).

Previous data (reported in Patrick Parsons & Shoreline Management Partnership, 2009) and Mason *et al.* (2010), indicates that in recent decades (Mason *et al.* suggest as early as 1970s) there has been a gradual but substantial migration of the Ulverston Channel across the intertidal banks offshore of this frontage, known as Cartmel Wharf. By 2005, this channel appears to have become decoupled from the main channel of the River Leven, becoming a flood dominant feature. This means that the

channel is not sustained by river discharge and as such its future evolution will be dependent upon tidal conditions and sandbank or channel movements within Morecambe Bay.

There was continued movement of this channel shoreward and eastwards, creating a 'hook shaped' channel, which abutted the south western corner of the Windermoor Embankment. This channel has acted as a conduit for waves and currents, resulting in undercutting of the defences and also erosion of the fringing marsh either side of Lakeland Leisure Park. The extent of erosion that has occurred along the West Plain fringing marsh is shown by beach profile 11C02805, which lies to the west of Lakeland Leisure Park (see Figure F (b) in the accompanying technical note). This indicates that between 2006 and 2014 there was progressive cutback of the marsh edge, as a channel advanced towards to the shoreline, with lateral retreat of around 150 m.

The Lakeland Leisure Park Strategy (Patrick Parsons & Shoreline Management Partnership, 2009) suggested that there is the potential for the channel to naturally start moving away from the coast in the future. The more recent beach profile data suggests that the marsh edge along the West Plain changed very little between 2014 and the latest data in 2017, which may indicate some reduction in energy conditions along this frontage; however more data will be required to confirm this trend.

Along the East Plain, unfortunately the beach profile does not extend far enough seaward to capture the edge of the marsh. The data do, however, indicate that there may have been some increase in marsh elevation since 2006 and aerial images from 2010 and 2014 (see Figure H in the accompanying technical note) indicate that along the eastern end of East Plain Out Marsh, there has been some recent lateral accretion.

Further monitoring is required to monitor the situation, but there are some early signs that the exposure conditions along the site may be improving.

2.1.4 Impact of current defences

At a wider scale, it can be concluded that the majority of changes observed along this frontage result from changes in the location of banks and channels, driven by larger scale processes within the Leven Estuary and Morecambe Bay. Changes in tidal flats and channel positions in Morecambe Bay have been extensively studied previously (including: Kestner, 1970; Pringle, 1987; McClaren, 1989; Mason *et al.*, 1999; Mason and Garg, 2001; Mason *et al.*, 2010). Appraisals of shoreline change have also been undertaken by HR Wallingford (2006; on behalf of Natural England) and Shoreline Management Partnership (various dates; on behalf of Bourne Leisure) as supporting evidence accompanying the Lakeland Leisure Park Strategy (Patrick Parsons & Shoreline Management Partnership, 2009).

It has previously been suggested (HR Wallingford 2006 report to Natural England) that the channel has been "attracted" to the embankment toe and that by preventing its continued movement, causes the channel to deepen and become more attached to the toe. It has also been inferred by HR Wallingford, from site inspections, that the Windermoor Embankment shields the West plain saltmarsh by prevent channel migration towards it, whilst accelerating the saltmarsh erosion at East Plain. From the data available, it is difficult to define if this is actually the case. The marsh edge position (from 2014 aerial) either side of the Windermoor Embankment is approximately equal, which may infer that the Embankment has had a limited effect on marsh erosion, otherwise it may have been expected that erosion on one side should be greater than on the other. West Plain has shown some recent signs of recovery or stabilisation, which could be the result of emergency works, but could equally be due to naturally infilling of the low water channel from the western end following its decoupling from the main Leven Channel. Similarly changes along the East Plain were much smaller between 2010 and 2014 than 2004 and 2010, which may be an indication that exposure conditions here have reduced. However, the beach profile is along the eastern extremity of East Plain, so does not pick up changes along and in front of the embankment. More data are also required to confirm current trends.

2.2 Outline of the problem

2.2.1 Background

A key asset along the frontage is Lakeland Leisure Park, owned by Bourne Leisure Ltd. This site, together with mainly agricultural land, is currently protected from flooding by an embankment. The embankment is the responsibility of the Environment Agency, but Bourne Leisure have contributed to its maintenance (Patrick Parsons & Shoreline Management Partnership, 2009).

Prior to improvements made to the defences in the early 1990s, the embankments were vulnerable to overtopping during storm events, with breach due to backface erosion a potential failure mechanism. The embankments were also at risk from front face erosion over a longer period of time, during less severe events.

Since improvements were made to the defences, the risk of overtopping and breach has been reduced. However, a key risk to the integrity of this defence is the change in exposure conditions that result from natural movements of the Leven low water channel. As this channel moves closer to the shoreline it acts as a conduit for larger waves and currents, resulting in erosion and subsequent undercutting of the marsh, bed lowering and ultimately destabilisation of the revetment. Between 1992 and 1997 the Leven low water channel reportedly migrated north eastwards toward this coastline, by around 2 km (HR Wallingford, 2006). A flood channel opened up from the eastern side of the main low water channel and this continued to migrate east and north as it has evolved, migrating up to 1350 m between December 2002 and September 2004.

Emergency works were undertaken, completed Spring 2008, to address the issue of lowering beach levels and the associated deteriorating coastal defences. Following this a strategy to address future management (50 years) of the Lakeland Leisure Park was produced in 2010 (Patrick Parsons & Shoreline Management Partnership, 2009). This recommended the continued maintenance of the existing defences, through repair and replacement of the defence profile and extension of East Plain breakwater and Cross Embankment as required to maintain a 20.0 m lead over saltmarsh erosion.

2.2.2 Issues, constraints and opportunities

The current embankments provide flood protection to around 730 ha of land, comprising Lakeland Leisure Park, large tracts of agricultural land and farmsteads and a section of the Furness Line railway. Cark Airfield is also used for parachuting and recreational flying. There are a number of properties and amenities, including a business park, and associated services and link roads, with only a single highway access that links the Leisure Park to Flookburgh and beyond. Among the facilities in this area, Bay Search & Rescue's base is located at the southern end of Moor Lane and the new Flookburgh Community Playground opened in October 2017 at a cost of over £200,000 also located on Moor Lane, Flookburgh. There has been continual development and expansion of the businesses in this area, with three caravan parks having planning permission for static caravans. The Leisure Park itself is an important tourism facility for the area and whilst the caravans themselves are non-permanent, there are associated services and fixed buildings on the site, such as Airfield Approach Business Park. The embankments remain vulnerable to natural channel migration which can rapidly increase exposure conditions. Any breach in the defences would result in flooding of the hinterland.

The coastline is currently held in an unnatural configuration, seaward of where the shoreline would lie naturally (Patrick Parsons & Shoreline Management Partnership, 2009), although it has been maintained in this planform since 1828. A previous report (HR Wallingford, 2006) has suggested that the southern apex of the East Plain embankment is a focus for hydrodynamic forces. Without the defences in place, it has been recognised that the migration pathway of the low water channel would have entered the leisure park area resulting in loss of saltmarsh and gain of intertidal sand or mudflats, but that once the channel meandered back into the Bay, away from the shoreline, saltmarsh would be expected to have recolonised the intertidal sand and mudflats (Patrick Parsons & Shoreline Management Partnership, 2009).

There may be opportunities for improving habitat within the policy area, which also has the potential to increase nature-based tourism. The intertidal areas are highly designated and are included within the following statutory nature conservation designations: Morecambe Bay Ramsar, Morecambe Bay and Duddon SPA, Morecambe Bay SAC, Witherslack Mosses SAC, Morecambe Bay SSSI, Foulshaw Moss SSSI, Humphrey Head SSSI. The whole estuarine complex of Morecambe Bay is of international significance for wintering wading birds and of national significance for wintering wildfowl. The saltmarshes are particularly important for their vegetation which is diverse, supporting a number of rare and uncommon plants, as well as a variety of nationally scarce invertebrate species. The limestone outcrop of Humphrey Head is also designated for its geological features as well as supporting nationally scarce vegetation.

Carl Airfield, located behind the current defences, is a scheduled monument notified for World War II fighter pens and other RAF Carl airfield remains and defences. It provides a landing strip for light aircraft, a parachute centre and is the location for the annual Cumbria Steam Gathering, attracting up to 40,000 visitors. Some artefacts are located along the sea defences, so would be affected if these were lost or removed. There are also seven listed buildings at Raven Winder, Canon Winder and further inland within Flookburgh.

2.2.3 Strategy considerations and general approach

Key considerations

Since the Lakeland Leisure Park Strategy was produced in 2009, further monitoring data has been collated. Appraisal for the Cumbria Coastal Strategy has considered this more recent data to appraise:

- current conditions and level of risk
- recent shoreline change
- effectiveness of the existing approach to managing coastal flood and erosion risk and their potential impact on shoreline change
- future management options.

A feasibility study, commissioned by Holker Estates, for creating an area of coastal saline lagoon habitat for waders and breeding birds has been now consented by MMO. This covers the area of West Plain Marsh coastline adjacent to the Lakeland Leisure Park and to seaward of the Environment Agency flood defence embankment. This is discussed below.

Strategy approach

Given that current maintenance of defences is through contribution from Bourne Leisure this frontage will be addressed as follows:

- Privately owned or funded defences – these are locations where the SMP policy may allow Hold the line subject to private funding or investment. The strategy will investigate the performance and impact of the defences and make recommendations on measures to ensure a strategic solution along the frontage. It is unlikely that these locations will attract significant FDGiA funding – here the focus will be on considering varying costs of approaches, environmental impacts on the wider coast and making recommendations accordingly.

2.3 Options development and appraisal

The main Options Development report defined the long list options, each of these has been screened at a high level against technical, economic and environmental criteria to develop a list for final detailed appraisal. For the single priority unit of 11c10.2, the following have been considered for initial screening:

- Do nothing

- Do minimum
- Hold the line: maintain through proactive maintenance
- Hold the line: maintain through reinforcing existing defences
- Hold the line: sustain through reinforcing and raising existing defences
- Managed realignment: construct defences once set back
- Managed realignment: construct secondary embankments

As part of these options, it is also recognised that there is potential for:

- habitat creation sites
- adaptive management of assets

The second stage has been to appraise the short listed options, section 2.4 outlines the shortlisted options and approaches (measures) that could be adopted to achieve these.

Do nothing has been appraised as a baseline in all frontages. This option assumes that no further works would be undertaken and the existing defences would deteriorate over time, resulting in failure.

Additional information on environmental impacts will be provided in a **Strategic Environmental Assessment: Environmental Report** which systematically appraises the potential environmental consequences of the proposed strategy and recommends any actions needed to mitigate and monitor identified adverse effects.

The economic feasibility of implementing a particular option has been appraised through considering the packages of measures required for its implementation which have then been costed and the benefits of the strategic options identified and evaluated. The No active intervention option provides the baseline for the economic appraisal. This is reported in the **Economic assessment** report.

2.4 11c10.2 Humphrey Head to Cowpren Point

2.4.1 11c10.2 - Initial screening of options

It should be noted that a previous study (Bullen and Partners, 1990) considered the possibility of constructing a flood storage lagoon, to provide relief against tidal overtopping, rather than improving the Cross and East Plain Embankments. However, it was concluded that the most suitable location for a flood storage lagoon would be behind the turfed length of East Plain Embankment and that it would need extensive containment bunds. As the location is remote from the vulnerable lengths of embankment, the option was considered impractical. This option has not been considered further.

Options involving substantial construction across the intertidal area have also been dismissed due to the international importance of this area. This does not however, exclude some extension of current defences to address outflanking issues if adjacent marsh areas erode. This will be considered as part of the Hold the line options.

Although not a flood and coastal risk management option, the coastal saline lagoon habitat creation scheme proposed for West Marsh, and now consented by MMO, is considered in the Discussion section (section 2.4.3).

Table 4 below summarises the rationale for taking long list options forward to the short list stage.

Table 4 Screening of long list options

Long list options	Description	Short-listed?	Rationale
Do nothing	No further works undertaken, defences left to deteriorate and fail	Baseline only	This option would not manage flood risk and could result in economic write off of the Lakeland Leisure Park in the short to medium term. There could also be potential pollution issues due to uncontrolled flooding and erosion of the Park site. It has been assessed for comparative purposes only.
Do minimum	Reactive patch and repair of defences only	Baseline only	This option would not address any further undermining of the embankments due to channel migration. The option would revert to Do nothing once the embankment fails due to undermining. The flood risk due to overtopping would also increase over time. However, this may become the default option if funding is no longer available.
Hold the line: maintain through proactive maintenance	Measures to maintain current defences.	Yes	This will continue to manage the flood risk due to breaching, but would not address the risk of localised flooding due to overtopping. It may be necessary to regularly replace rock; therefore, substantial costs could be involved. The defended frontage would continue to form an unnatural shoreline configuration.
Hold the line: maintain through reinforcing existing defences	For this frontage, the measures involved are likely to be the same as those considered above, so this has not been considered further as a separate option.		
Hold the line: sustain through reinforcing existing defences	Measures to sustain the existing standard of protection, taking account of any sea level rise through raising defences.	Yes	It may be necessary to regularly maintain the rock armour; therefore, substantial costs could be involved. Schemes to raise the embankments would incur additional costs.
Managed realignment: construct defences once set back	For this frontage, the approach would be the same as the option presented below (Managed realignment: construct secondary embankments). Therefore, this has not been considered further as a separate option.		
Managed realignment: construct secondary embankments	Construct a new defence inland of the current embankment to create a more natural shoreline	Yes	Although this is unlikely to be recommended in the short to medium term due to investment in current defences, it should be considered beyond the medium term. This could allow a more continuous extent of marsh to develop (depend upon channel position), bringing environmental benefits. The presence of a marsh in front of defences would also dissipate wave energy and reduce pressure on new defences. Depending on alignment this may involve relocation or closure of the Lakeland Leisure Park, and associated costs, as well as the costs of the new embankments.

2.4.2 11c10.2 - Development and appraisal of short listed options

Do nothing (Option 1)

This is considered as a baseline against which other options can be appraised. Under this option all maintenance and management of the defences would cease and defences would be allowed to fail.

Technical	<p>The future lifespan of the existing defences would depend upon changes in exposure conditions due to migration of the low water channel. Should the channel start to infill or move away from the coast, there is potential for accretion of the fronting flats and recolonization of marsh. This would add protection to defences and effectively prolong their life. Conversely, should the channel continue to migrate onshore, the risk of undermining will remain and potentially increase. This will destabilise the rock armour, eventually leading to erosion of the embankment itself with a breach likely to form fairly rapidly, as the bank consists of poorly cemented sandy material. Without works to address this defences would be anticipated to fail along the exposed frontage of Lakeland Leisure Park and possibly within the next 10 years.</p> <p>Saltmarsh extent has also been reducing to either side of Lakeland Leisure Park, increasing vulnerability to the embankments here, increasing the risk of both overtopping and a breach formation. Once a breach has formed it is anticipated that tidal flows would result in a channel opening up through the fronting marsh.</p>
Environmental	<p>Any further bank migration landwards would cause erosion of the flats and marsh, resulting in net loss. However, it is anticipated that should the low water channel either infill or move seawards there would be accretion of the area and subsequent recolonization by marsh.</p> <p>Prior to this, failure of the embankments would result in uncontrolled tidal inundation of the currently defended low lying area, with the area up to the naturally rising land potentially at risk from regular flooding. This would impact on the viability of agricultural land and Lakeland Leisure Park, require the re-routing of the Cumbrian Coastal Way and failure of the armoured defences along this site would remain an eyesore for some time. A short section of the Furness Railway could periodically be flooded, with impacts on operations.</p> <p>The presently defended area could remain in a transitional state for some time before vegetation starts to re-establish. Ultimately a more natural shoreline would be established, which is likely to benefit the Morecambe Bay SPA, Ramsar, SAC and SSSI. However, the extent of intertidal habitat created would depend upon the location and future change in position of the low water channel. Further consideration would need to be given to the Habitats and Species Conservation Regulations 2017, and the potential requirement to assess significant effects on the integrity of the Natura sites. Additionally, further assessment may be required to consider any changes to the SSSIs under the Countryside and Rights of Way Act 2000.</p> <p>This option is likely to be beneficial for the maritime cliffs and slopes (BAP habitat) at Humphrey Head, and the geological features within the SSSI, allowing natural retreat of the cliffs.</p> <p>Cark Airfield (a scheduled monument) and a number of Listed Buildings within Flookburgh and the surrounding area would be at risk of damage from increased flooding. Additionally, due to its historic use as a wartime airfield, there is some risk of contaminated material being present at the site, which may be released as a result of increased flooding to the area. The historic landfill on the coastline would also be subjected to increased flooding which may lead to damage and increased risk of breach.</p>
Cost	<p>There are no costs associated with Do nothing.</p>
Damages	<p>Damages would be predominately associated with forced closure of the Leisure Park and damage to agricultural land. There are also properties (commercial and residential) at risk from flooding further inland. The damages are estimated to be £30,510 k. There may be additional local or national economic damages that have not been valued in monetary terms as part of the strategy, including recently expanded and redeveloped non-residential properties on the Airfield Approach Business Park and surrounding area.</p>

Do minimum (Option 2)

<p>This is also considered as a baseline against which other options can be appraised. Under this option only reactive patch and repair maintenance would be undertaken, with no works to address any increase in risk due to sea level rise. It is also assumed that East Plain Embankment and Cross Embankment would <u>not</u> be extended.</p>	
Technical	<p>As works would be low cost and reactive only, with no capital schemes, as for Do nothing, the future lifespan of the existing defences would depend upon changes in exposure conditions due to migration of the low water channel.</p> <p>In the worst case scenario, whereby the channel continues to move landwards and erode the existing marsh, without further works sections of East Plain Embankment and Cross Embankment would become vulnerable to failure due to undercutting, after which the approach reverts to Do nothing. As for the Do nothing option, should sea levels start to rise, exposure conditions would increase and the risk of overtopping would also increase meaning defences may be expected to become overtopped more frequently.</p>

Environmental	Once embankments fail, the impacts would be as for the Do nothing option. See Option 1 for further information.
Costs	There are no Present Value Capital Works, since works are restricted to patch and repair works only. The Present Value Total Cost with Optimism Bias (PV(OB)c) is estimated to be £8,750 k.
Damages	Damages would be predominately associated with delaying the forced closure of the Leisure Park and damage to agricultural land when compared to Do nothing (Option 1). The damages are estimated to be £26,980 k.

Hold the line: maintain through proactive maintenance (Option 3)

Measures to maintain the existing standard of protection. This is would be a continuation of current activities involving the addition of (stockpiled) rock to the revetment toe to prevent it from being undercut.	
Technical	<p>The sustainability of this option will depend upon changes in exposure conditions due to migration of the low water channel. Under the worst case scenario, should the channel continue to move closer to the shoreline, the revetment toe will become eroded and collapse into the channel. Additional rock will be required and it may become increasingly difficult to hold the existing defence line in the longer term, unless there is a change in channel location. However, it is assumed that this option is viable for up to 40 years, in accordance with the Lakeland Leisure Park 2009 Strategy.</p> <p>With no improvements to the structure, the overtopping risk may increase with any increase in sea level rise, meaning overtopping events may become more frequent.</p> <p>This would not involve works to Humphrey Head frontage.</p>
Environmental	<p>Should the exposure conditions remain the same, the current situation will continue. Any increase in exposure would result in additional marsh loss due to channel undercutting. Along the earth embankment section of West Plain, the situation would initially be similar to that under a Do nothing. Along the armoured embankments of Cross and East Plain, the rock may exacerbate habitat loss, but this needs to be considered against the potential protection the existing breakwater provides to West Plain marsh.</p> <p>It is estimated that defences currently provide protection against storms with 1 in 100 annual chance, but should sea levels start to rise, exposure conditions would increase and the risk of overtopping would also increase meaning defences may be expected to become overtopped more frequently, in the absence of works to address this. Any increase in overtopping frequency will affect the agricultural hinterland and Lakeland Leisure Park, although it is likely that operations would remain viable for some time given the current level of protection.</p> <p>Further consideration would need to be given to the Habitats and Species Conservation Regulations 2017, and the requirement to assess the potential for significant effects on the integrity of the Natura sites. Additionally, further assessment may be required to consider any changes to the SSSIs under the Countryside and Rights of Way Act 2000.</p> <p>This option is also likely to be beneficial for the maritime cliffs and slopes (BAP habitat) at Humphrey Head, and the geological features within the SSSI, allowing natural retreat of the cliffs.</p> <p>With no additional works once defences become beyond reasonable repair, the outcomes will eventually become the same as Option 1.</p>
Costs	<p>It may be necessary to regularly replace rock; therefore, substantial costs could be involved.</p> <p>The Present Value Capital Works are estimated to be £3,120 k and the Present Value Total Cost with Optimism Bias (PV(OB)c) is estimated to be £16,450 k.</p>
Benefits	<p>Damages would be limited but in the longer term there could be economic impacts of any increase in overtopping flooding, due to any increase in sea level. The benefits are estimated to be £27,120 k. There may be additional local or national benefits that have not been valued in monetary terms as part of the strategy, including recently expanded and redeveloped non-residential properties on the Airfield Approach Business Park and surrounding area</p>

Hold the line: sustain through reinforcing existing defences (Option 4)

This would involve measures to sustain the existing standard of protection, to keep pace with sea level rise. This would be a continuation of existing works involving the addition of (stockpiled) rock to the revetment toe to prevent it from being undercut but would also include works to increase the crest level of the embankments to address any increased risk of overtopping due to sea level rise. Works may also include further extension of current embankments.	
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Technical	<p>The sustainability of this option will depend upon changes in exposure conditions due to migration of the low water channel. Under the worst case scenario, should the channel continue to move closer to the shoreline, the revetment toe will become eroded and collapse into the channel. Additional rock will be required and it may become increasingly difficult to hold the existing defence line in the longer term, unless there is a change in channel location.</p> <p>The overtopping risk will be minimised through increasing the crest level, if and when required.</p>
Environmental	<p>Should the exposure conditions remain the same, the current situation will continue. Any increase in exposure would result in additional marsh loss due to channel undercutting. Along the earth embankment section of West Plain, the situation would initially be similar to that under a No active intervention. Along the armoured embankments of Cross and East Plain, the rock may exacerbate the loss, but this needs to be considered against the potential protection the existing breakwater provides to West Plain marsh.</p> <p>Any extension of the current footprint of the embankments as a result of this option would directly impact on the saltmarsh habitat within international and national designated sites. Further consideration would need to be given to the Habitats and Species Conservation Regulations 2017, to assess the potential for significant effects on the integrity of the Natura sites. Additionally, further assessment may be required to consider any changes to the SSSI under the Countryside and Rights of Way Act 2000.</p> <p>The extension of existing embankments and additional toe protection works may encroach on the adjacent waterbody, increasing hydromorphological pressure on the waterbody – impacts would need to be considered further as part of a WFD assessment.</p> <p>There will be no increase in overtopping frequency, therefore the agricultural hinterland and Lakeland Leisure Park will remain protected.</p> <p>Viability of this option long term is uncertain due to the uncertainty regarding the future movements of the channel.</p>
Costs	<p>It may be necessary to regularly replace (reprofile) the rock armour; therefore, substantial costs could be involved. Raising the crest will also incur additional costs compared to Option 3a.</p> <p>The Present Value Capital Works are estimated to be £24,650 k and the Present Value Total Cost with Optimism Bias (PV(OB)c) is estimated to be £52,200 k.</p>
Benefits	<p>Existing hinterland assets would remain protected from tidal flooding. The benefits are estimated to be £27,120 k. There may be additional local or national benefits that have not been valued in monetary terms as part of the strategy, including recently expanded and redeveloped non-residential properties on the Airfield Approach Business Park and surrounding area.</p>

Managed realignment: construct secondary embankments (Option 5)

<p>A range of realignments could be possible (note 2 in Supporting Information considers a few possibilities, although there would be variations based on these). All concepts would require new embankments to be constructed, with subsequent removal (either partial or complete) of the current ones, but some could use existing high ground (natural and man-made).</p>	
Technical	<p>Construction of new, set back embankments would ensure continued protection to some low lying areas. Creating breaches in the existing embankment would allow the tidal inundation of the currently defended hinterland, through the creation of channels to connect the creeks to the fronting marsh. Works may also be required to break the linear drainage system and reinstate a ‘natural’ creek network.</p> <p>The local outcrops, such as Humphrey Head and Cark, would remain and continue to exert some influence on local processes. The site would, however, remain vulnerable to channel migration, which would continue to be a key factor in saltmarsh erosion and accretion patterns. The wider width of marsh would, however, provide greater protection to set back embankments making the defence more resilient to future channel changes. Previous studies suggest that both the Leven and the Kent are in a state of dynamic equilibrium in terms of the extent of mudflat and saltmarsh area, such that there is a redistribution of sediment within the system rather than a net gain or loss over time.</p> <p>The range of possible realignments would open up differing extents. Whilst locally the impact on tidal volume may not be significant, the combined impact, given potential for schemes elsewhere within the Leven and Kent Estuaries means there are potential wider scales risks, for example to infrastructure such as the railway viaduct that may be subject to greater tidal flows as tidal volumes increase. Further study is required to assess this.</p> <p>Prior to any scheme, there would therefore need to be detailed hydrodynamic modelling to understand possible changes in flows and resultant morphological changes. This relies on a thorough and robust evidence base as recommended by previous studies (see Halcrow, 2013a, b), which needs to include better topographic and bathymetric data, collection of process data to allow validation and testing of models, and studies to quantify sediment sources, transport pathways and fluxes to the estuary. There</p>

	would also need to be technical studies to assess the feasibility of and costs and benefits of new setback embankments. This would depend upon the extent of sea level rise to be catered for as it may be possible to link together areas of slightly higher natural topography.
Environmental	<p>All of the potential concepts would maintain protection to main communities of Flookburgh and Cark but will result in the eventual loss of various residential, commercial and agricultural properties or land from flooding and erosion. There would be a requirement for extensive consultation with affected landowners to optimise defence alignments and minimise impacts.</p> <p>It is desirable to minimise the use of new materials in the area with a preference to recycle material from existing defences where at all possible. Construction of new defences would have temporary construction related impacts on the surrounding area and impacts on landscape character and visual amenity. The footprint of the new defences would result in the loss of 'coastal and floodplain grazing marsh' (a priority habitat). Mitigation strategies to avoid, minimise and where required, offset loss of this habitat would be required.</p> <p>Dependant on the final preferred concept, works would have to be undertaken to secure or remediate the historic landfill present on the southernmost point of the Bourne Leisure site or remove risk of breach. Similarly, investigations would have to be undertaken to ascertain the ground conditions of Cark Airfield. Consultation with Historic England regarding potential loss of this monument would have to be undertaken, and potential costs of recording the site considered.</p> <p>Any changes in sedimentation and coastal processes brought about by Managed realignment have the potential to affect the condition of the shellfish beds located off Humphrey Head, which would require further consideration.</p> <p>However, this option would allow for a more natural regime in the area, which would benefit the adjacent waterbody and result in a potential increase in intertidal habitat that would be beneficial to the nature conservation sites. Further consideration would need to be given to the Habitats and Species Conservation Regulations 2017, and the requirement to assess the potential for significant effects on the integrity of the Natura sites. Additionally, further assessment may be required to consider any changes to the SSSIs under the Countryside and Rights of Way Act 2000.</p> <p>This option is also likely to be beneficial for the maritime cliffs and slopes (BAP habitat) at Humphrey Head, and the geological features within the SSSI, allowing natural retreat of the cliffs.</p>
Costs	<p>a) Removal of defences: The Present Value Capital Works are estimated to be £960 k and the Present Value Total Cost with Optimism Bias (PV(OB)c) is estimated to be £1,540 k.</p> <p>b) Construction of secondary embankments: The Present Value Capital Works are estimated to be £38,090 k and the Present Value Total Cost with Optimism Bias (PV(OB)c) is estimated to be £61,740 k.</p> <p>c) A limited realignment: The Present Value Capital Works are estimated to be £29,780 k and the Present Value Total Cost with Optimism Bias (PV(OB)c) is estimated to be £50,090 k.</p>
Benefits	Not determined at this stage due to uncertainty regarding realignments.

2.4.3 11c10.2 - Discussion

Table 5 summaries the cost and benefit calculations for the various options presented above and indicates that Option 3 (hold the line through proactive management) has the highest benefit/cost ratio and would be the economically preferred option, but only applies to the medium term. It should be noted, however, that there has been no evaluation of benefits for the Managed realignment options, due to the high level of uncertainty regarding possible alignments, therefore no benefit-cost ratio can be determined at this stage.

The vision of the SMP was to create a create a more sustainable and natural alignment, through carrying realignment along part or all of the frontage. Since the SMP there has, however, been further investment in the existing defences undertaken by Lakeland Leisure Park to address issues of undercutting along their site resulting from the landward migration of a low water channel. Concerns have been raised regarding the potential impact of these defences on adjacent frontages (and designated habitats), but analysis of recent shoreline change suggests that observed changes are part of the larger scale coastal evolution and are unlikely to have been caused by the defences themselves (although ongoing monitoring is recommended to confirm this). Given the recent investment in defences and the damage that could result from uncontrolled failure of defences, Options 1 and 2 are not considered suitable approaches to future management due to the current

risk posed by previous migration of a low water channel towards this shoreline. The environmental assessment of the options identified that Option 5 as the environmentally preferred option in the longer term. However, managed realignment along this coastline would require further extensive studies (beyond the scope of this strategy) and engagement to determine suitable alignments for the set back defences. Whilst environmentally preferred the high costs and limited economic benefits mean it would be difficult to justify funding realignment at the present time.

The preferred approach in the short term is therefore to continue to hold the line. This would allow time for investigation of alternative long term solutions, such as partial realignment of the defences. It would also enable the success of the proposed saline lagoon scheme to be appraised, as there may be potential to extend the scheme. Of the two options presented, Option 3 (hold the line through proactive management) would be more cost-effective and should prolong the life of the current defence for several decades.

The long term viability of maintaining existing defences, considered in Options 3 and 4, will depend upon future changes in exposure conditions due to migration of the low water channel. There is some evidence to suggest that this channel has started to infill from its western end, but further monitoring is required to confirm this. The current approach, using stockpiles of rock to address undermining is likely to remain sustainable for some time, which may allow time for the situation to naturally improve. The current standard of protection is estimated to be between 1 in 50 and 1 in 200 years, but long term increase in sea level may require crest levels to be increased in order to sustain the current level of protection against flooding, possibly by over a metre.

Any future reinforcement of existing rock protection (Option 4) would need careful consideration with regard to the effect on the high value sensitive habitats within the Morecambe SPA, SAC and SSSI, due to the dynamic nature of the low water channels and tidal currents in the area. Consultation with Natural England would be required at early stages to ensure minimal impacts on the protected habitats and species.

Managed realignment, through construction of set back defences, remains a viable option for the longer term; this could involve different configurations, with different outcomes. Most realignment concepts considered would require relocation or loss of the Lakeland Leisure Park. Although Concept 4 (presented in note 2, Supporting Information) would continue protection to the Park, the benefits in terms of flood and coastal erosion risk management would be less significant as a similar length of setback embankment would be required as currently present. There may, however, be justification for a smaller scheme, such as this, to compensate for habitat loss elsewhere. Any Managed realignment scheme would, however, require further, more detailed investigations to consider impacts on flows, water levels, shear stress and resultant morphological change, both near field and far field.

Table 5 Policy unit 11c10.2 Summary of economics

Option		Present Value Capital Works £m	Present Value Total cost (PVC)* £m	PV Benefit (Damage Avoided) £m	Average Benefit Cost Ratio
Option 1 Do nothing		0.00	0.00	0.00	-
Option 2 Do minimum		0.00	8.75	0.14	0.02
Option 3 Hold the line: maintain through proactive maintenance		3.12	16.45	27.12	1.65
Option 4 Hold the line: sustain through reinforcing existing defences		24.65	52.2	27.12	0.52
Option 5 Managed realignment: construct secondary embankments	a	0.96	1.54	+	+
	b	38.09	61.74	+	+
	c	29.78	50.09	+	+
*Present Value cost (PVC) inclusive of 60% optimism bias					
+ not defined due to various possible alignments and assets protected					

Coastal saline lagoon habitat creation

Aside from options for managing flood and coastal erosion risk along the frontage, there is currently a consented proposal looking at the possibility of creating an area of coastal saline lagoon habitat for waders and breeding birds. This would cover an area within the existing fronting marsh, immediately west of the Lakeland Leisure Park, approximately 1 km in length and 2.5 km in width. The concept design involves excavating a series of shallow open water lagoons in the existing saltmarsh to promote biodiversity enhancements. It is understood that material excavated would be used to create a small bund around the site, infilled to 5.85 mOD, and small elevated islands within the lagoons.

The proposal site lies within an area that in the recent past has undergone erosion due to migration of the low water channel towards the site. Although the most recent data suggest there has been some recovery of the marsh and tidal flats along this frontage, between 2006 and 2014 there was progressive cutback of the marsh edge, as a channel advanced towards the shoreline, with lateral retreat of around 150 m. Should the channel start to migrate towards the shoreline again, the scheme could therefore erode. As well as resulting in the loss of any newly created habitat areas, there is also potential that the lagoon areas could mean increased risk to the existing defence, compared to currently, due to the lower areas created along its toe providing less wave attenuation. In addition, the environmental impact assessment for the proposed scheme should consider long term change and need for future interventions to take account of potential sea level rise, as this will affect the water levels at which the surrounding bund becomes overtopped and therefore frequency of inundation and rates of siltation within the lagoons. The proposal has been consented by MMO at the time of writing.

2.4.4 11c10.2 - Strategic way forward

Whilst the SMP2 vision was to create a more sustainable and natural alignment from the medium term, through carrying out realignment along part or all of the frontage, studies to support this have not yet been undertaken. There has also been further investment in the existing defences undertaken by Lakeland Leisure Park, since the SMP2, to address issues of undercutting along their site, which will prolong their life beyond that assumed by the SMP2. Although the current defences are holding the shoreline locally in an unnatural position, there is limited evidence to suggest that they are substantially affecting shoreline change along adjacent areas; erosion and accretion trends are predominately driven by the movement of the low water channel.

Therefore, the recommended strategic approach for this stretch of coast is to continue to hold the line, whilst further studies and monitoring are undertaken and a long-term solution developed. The

preferred approach is Option 3 (hold the line through proactive management), which will extend the life of existing defences and address the ongoing issues of undercutting. The use of rock means a flexible approach to management can be adopted, informed by continued monitoring to assess how the channel is continuing to change and to monitor the related level of risk along this frontage.

In the longer term, it is likely that defences would need to be improved to address increasing levels of risk due to sea level rise, but options will need to be reappraised at this stage, particularly as there is potential that the current situation could dramatically alter if the low water channel infills or moves away from the frontage. Any improvement works are likely to require consent from Natural England, due to the importance of the intertidal habitats and may require a MMO licence if they extend below high tide level.

The environmental assessment of alternative options for the SEA report identified Option 5 (Managed realignment: construct secondary embankments) as the environmentally preferred option in the longer term. Positive impacts include minimising the risk of flooding to the community, assets and infrastructure, habitat creation, encouraging natural shoreline evolution and defending historical assets. This could be a realistic option in the longer term, subject to further studies, and could potentially be funded as compensation for longer term habitat losses elsewhere in the estuary. However, this should take account of the success of the coastal saline lagoon habitat creation, which, if successful, could possibly be extended and also would affect decisions regarding future habitat creation needs and opportunities.

Future activities include:

- Inspection and maintenance of the existing structures, with repairs and remedial works undertaken as necessary. This will involve engagement between Environment Agency and Lakeland Leisure Park.
- Implementation (privately funded) and monitoring of recently consented scheme to create an area of coastal saline lagoon habitat for waders and breeding birds. The success, or otherwise, of this scheme could inform suitability of extending the scheme.
- Development of a management plan to indicate the need for advance planning of works (beyond next 10 years) for defence improvements if required, including identification of possible funding sources. This should be developed through engagement and consultation with AONB Partnership, Natural England and Lakeland Leisure Park.
- Further studies to fully understand the impacts of realigning or abandoning sections of defences. Associated with this, additional studies would be required to explore the potential for habitat creation.
- An estuary-wide scale geomorphological study looking at current and potential future gains and losses in marsh and flats. This would improve understanding of how the estuary is changing and help in the identification of sites where future Managed realignment could be considered. It would also provide baseline data for future Habitat Regulations Assessments. Engagement with AONB Partnership and Natural England as part of such a study is recommended.

Further details on actions and responsibilities are provided in the **Action Plan**.

3 Appraisal of non priority units

There are two additional units within this area, which have been defined as non priority units:

- 11c10.1 Humphrey Head
- 11c10.3 Cowpren Point to Carl

A light touch review has been undertaken of current SMP recommendations, taking into account conclusions from option appraisals for the adjacent frontages, where appropriate.

3.1 11c10.1 Humphrey Head

3.1.1 11c10.1 - Existing approach to flood and coastal erosion risk management

The SMP policy for 11c10.1 Humphrey Head is for No active intervention from the short term. There are no defences present and the intention of the policy is to allow natural processes to continue.

Justification for this policy was to maintain the value of the natural shoreline recognising that there were minimal assets at risk.

This unit simply covers the outcrop of Humphrey Head: the possible flood route between the Head and the adjacent outcrop of Kirkhead is included with unit 11c8.5.

3.1.2 11c10.1 - Strategy considerations

The whole estuarine complex of Morecambe Bay is of international significance for wintering wading birds and of national significance for wintering wildfowl. The saltmarshes are particularly important for their vegetation which is diverse, supporting a number of rare and uncommon plants, as well as a variety of nationally scarce invertebrate species. Designated sites in the area are: Morecambe Bay Ramsar, SSSI, SPA and SAC and Witherslack Mosses SAC, Foulshaw Moss SSSI. There may be opportunities for improving habitat within the policy area.

The limestone outcrop of Humphrey Head is also designated as a SSSI for its geological features as well as supporting nationally scarce vegetation.

A highway asset (U5168) runs along the base of the cliff at the back of the reclaimed agricultural land and lies in the SSSI impact zone. The key risk to this road is from flooding.

Since the SMP2 was adopted there have been no changes in environmental designations. There is a single beach monitoring location along this frontage, but as the surveys have not extended to the edge of the marsh (potentially due to safety reasons) it is not possible to identify any lateral saltmarsh edge erosion here, although the data do show minor vertical accretion over the past 10 years. Based on this, no significant change in risk level has been assumed.

3.1.3 11c10.1 - Discussion

There is no justification for any change in policy, which supports the environmental designations for this frontage. Therefore, the recommendation would be for the policy to remain. This could have impact on the highway asset – this may need to be occasionally closed at certain periods.

3.1.4 11c10.1 - Strategic way forward

The preferred strategic approach is to implement the SMP policy of No Active Intervention through Do nothing.

Future activities include:

- Continued monitoring of changes in the extent of marsh and intertidal areas, as part of the Northwest Regional Monitoring Programme. Extending the profile seawards is recommended (subject to health and safety issues) in order to identify any change in the marsh edge.
- Monitoring of the highway condition and safe operation – it may be necessary to close the road on occasions for health and safety reasons.
- Safe siting of the England Coast Path taking account of future risks; Natural England is working on proposals to improve public access to the coast between Silecroft and Silverdale, which includes this section (see <https://www.gov.uk/government/publications/england-coast-path-in-the-north-west-of-england>).

Further details on actions and responsibilities are provided in the **Action Plan**.

3.2 11c10.3 Cowpren Point to Cark

3.2.1 11c10.3 - Existing approach to flood and coastal erosion risk management

The SMP policy for 11c10.3 Cowpren Point to Cark is for No active intervention from the short term. There are no defences present and the intention of the policy is to allow natural processes to continue.

Justification for this policy was to maintain the value of the natural shoreline recognising that there were minimal assets at risk.

Although there are no formal defences here, the most recent defence inspection (CH2M, 2018) identifies an area of naturally higher land fronted by fringing high marsh (see Figure 6).



Figure 6 Policy unit 11c10.3, showing the outcrop of Cowpren Point and Canon Winder in the foreground and Lenibrick Point beyond.

3.2.2 11c10.3 - Strategy considerations

Although the hinterland is slightly higher than in 11c10.2, there remains a flood risk along this frontage, which would affect agricultural land, isolated properties and the access roads, although the main farm buildings are located on slightly higher ground.

The whole estuarine complex of Morecambe Bay is of international significance for wintering wading birds and of national significance for wintering wildfowl. The saltmarshes are particularly important for their vegetation which is diverse, supporting a number of rare and uncommon plants, as well as a variety of nationally scarce invertebrate species. Designated sites in the area are: Morecambe Bay Ramsar, SSSI, SPA and SAC and Witherslack Mosses SAC, Foulshaw Moss SSSI. There may be opportunities for improving habitat within the policy area. Since the SMP2 was adopted there have been no changes in environmental designations.

There are listed buildings potentially at risk, at Canon Winder and Strand Bridge and also potential for buried archaeology in the area.

The route of the England Coastal Path is yet to be confirmed, but there are a number of existing tracks across the area.

3.2.3 11c10.3 - Discussion

Whilst there is no justification for a change in policy at the present time, this area is identified as a possible flood risk route to 11c10.2, therefore monitoring is required to assess levels of flood risk in the future; also considering implications of channel migration in the area.

3.2.4 11c10.3 - Strategic way forward

The preferred strategic approach is to implement the SMP policy of No Active Intervention through Do nothing. There are no formal defences current present.

However, if Managed realignment options are considered for unit 11c10.2 in the longer term, this may require a policy boundary change. Therefore this may need to be considered again in the future reviews of the strategy.

Future activities include:

- Continued monitoring of the marsh and channel movements, as part of the Northwest Regional Monitoring Programme, along this frontage to identify any increase in risk.
- Any review of policy for unit 11c10.2 would need to take account of impacts on this frontage.
- Safe siting of the England Coast Path taking account of future risks; Natural England is working on proposals to improve public access to the coast between Silecroft and Silverdale, which includes this section (see <https://www.gov.uk/government/publications/england-coast-path-in-the-north-west-of-england>).

Further details on actions and responsibilities are provided in the **Action Plan**.

4 Summary of proposed strategy: 11c10

Preferred strategic approach: Environmental enhancement – allow the area to function as naturally as possible and look for environmental opportunities within the estuary, whilst maintaining protection to core communities and infrastructure.

		Next 10 years	Beyond 10 years
11c10.1	Humphrey Head	Allow area to function as naturally as possible, through implementing no active intervention (no new defences).	
11c10.2	Humphrey Head to Cowpren Point	Continue to reduce flood risk to hinterland assets in the short and medium term, whilst opportunities for longer term realignment are explored, recognising the potential saline lagoon scheme to the west of Lakeland Leisure Park.	
11c10.3	Cowpren Point to Cark	Allow area to function as naturally as possible, through implementing no active intervention (no new defences).	

Key actions and activities (next 10 years):



- Monitor condition of defences
- Monitor marsh, intertidal change and channel movement
- Monitoring of highway condition and safe operation



- Patch and repair degradation/damage of defence assets if required



- Management plan to indicate the need for advance planning of works (and funding sources)
- Estuary-wide scale geomorphological study looking at current and potential future gains and losses in marsh and flats
- Further studies to fully understand the impacts of realigning or abandoning sections of defences



- Implementation (and monitoring) of recently consented scheme to create an area of coastal saline lagoon habitat

Further details on actions and responsibilities are provided in the **Action Plan**.

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Supporting information

1. Assessment of recent shoreline change: Humphrey Head to Cowpren Point

Introduction

This unit was identified as a priority area with regards to potential impacts of private defences on adjacent marshland fronting the Bourne Leisure Caravan Park. The area lies within designated sites, such as Ramsar, SAC (Special Areas of Conservation) and SSSIs (Site of Special Scientific Interest) designated sites: Morecambe Bay SAC, Ramsar and SSSI, and Humphrey Head SSSI.

This frontage comprises saltmarshes and mudflats, together with reclaimed land protected by embankments and revetments built over 200 years ago. Refurbishment of the coastal defences was undertaken in the early 1990s, raising the standard of protection. More recently (2007 to 2008), emergency works have been undertaken to address issues of undercutting along the toe of defences at Lakeland Leisure Park.

To support the current strategy, an assessment of recent shoreline change has been undertaken to appraise whether these defences appear to be having a detrimental impact on adjacent frontages.

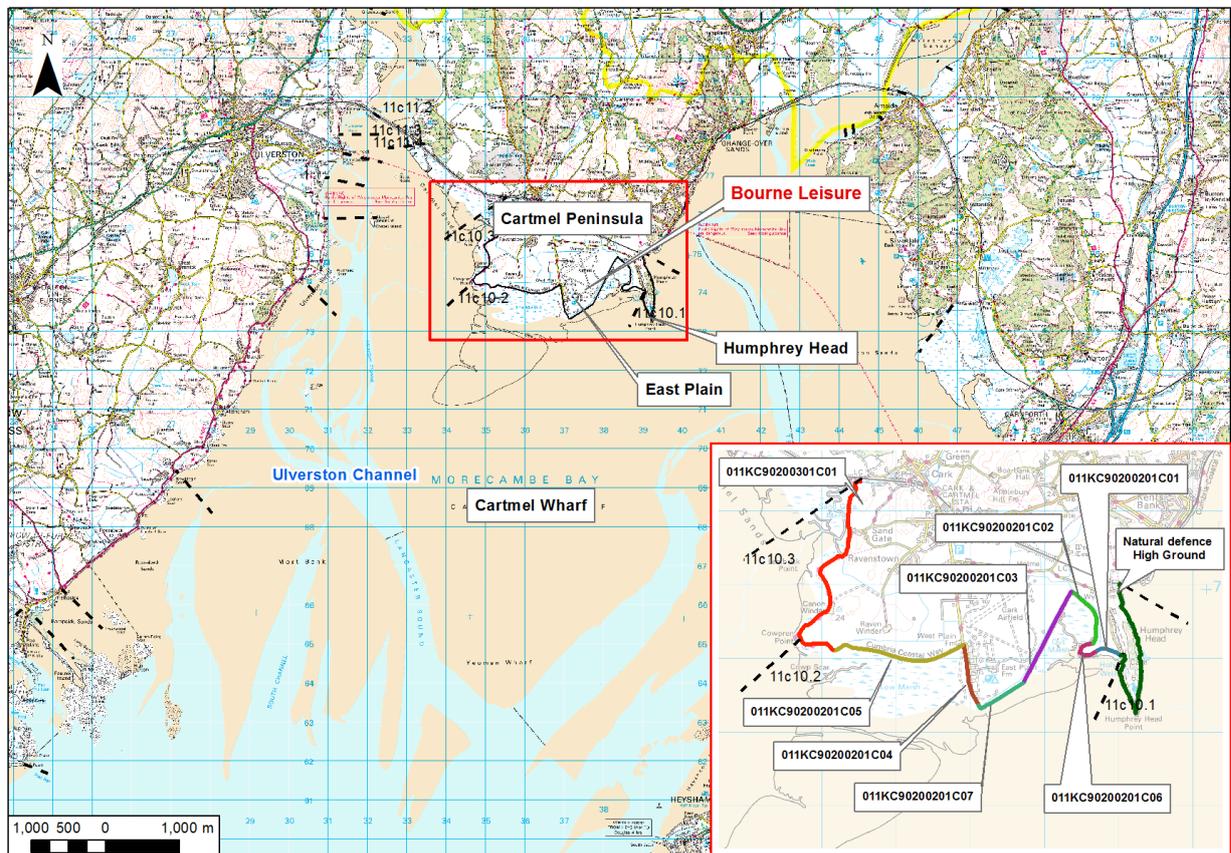


Figure A: Location of policy unit 11c10.2 (note: the channels are subject to constant change; therefore, this figure does not represent the current situation). Baseline mapping © Crown copyright and database rights, 2019. Ordnance Survey licence number: 1000019596. For this study, a number of data sources were appraised; these are listed in Table A.

Table A: Data sources used.

Data type	Year	Resolution	Provider
LiDAR – DTM ¹	2004 and 2010	Horizontal: ± 2 m Vertical: ± 0.15 m	Environment Agency
Vertical aerial photographs	1984 and 2014	Unknown	Google Earth Pro
Oblique aerial photographs	2015	Unknown	North West Coastal Monitoring Group
Defence site inspection photographs	2018	Unknown	North West Coastal Monitoring Group (CH2M, 2016)
Old Ordnance Survey Maps	1850s to 1970s	-	
Beach profiles (11C02827, 11C02805 and 11C02706)	11C02827: 2012 to 2016 11C02805: 2006 to 2016 11C02706: 2006 to 2016	Vertical: ± 0.15 m assumed	North West Coastal Monitoring Group

¹ Digital Terrain Model: gives a topographic model of the bare earth or underlying terrain of the earth's surface. They are usually derived from DSM's (Digital Surface Model) by digitally removing the cultural (man-made) and vegetation features.

LiDAR images have been obtained from the Government Open Data website (<https://data.gov.uk/publisher/environment-agency>); from these mosaics have been generated to produce a single DTM for both 2004 and 2010. A surface difference plot comparing 2004 and 2010 DTMs has been produced and tidal contours (Mean Water Level – MWL, Mean High Water Neap – MHWN, and Mean High Water Spring – MHWS) extracted from both datasets.

Elevations (in Ordnance Datum Newlyn – ODN) from DTMs 2004 and 2010 have been extracted for a total of five transects (see Figure B for location of transects). a and graphs were produced in order to provide a cross sectional analysis of the differences in leading marsh edge extent and height.

Vertical aerial photographs from Google Earth Pro have been used to provide a visual comparison of the extent of the saltmarshes over 20 years (1984 and 2014). Old Ordnance Survey (OS) maps from the 1850s to the 1970s have been appraised to understand the historical evolution of the tidal water levels mainly MHWS and MHWN.

Oblique aerial and defence site inspection photographs, available from the North West Monitoring Programme have been used to support the conclusions obtained with the analysis and discussion of LiDAR and vertical aerial photographs. Beach profiles have been collected in the south frontage of the Cartmel Peninsula and the location of the ones used in this assessment are shown in Figure B.

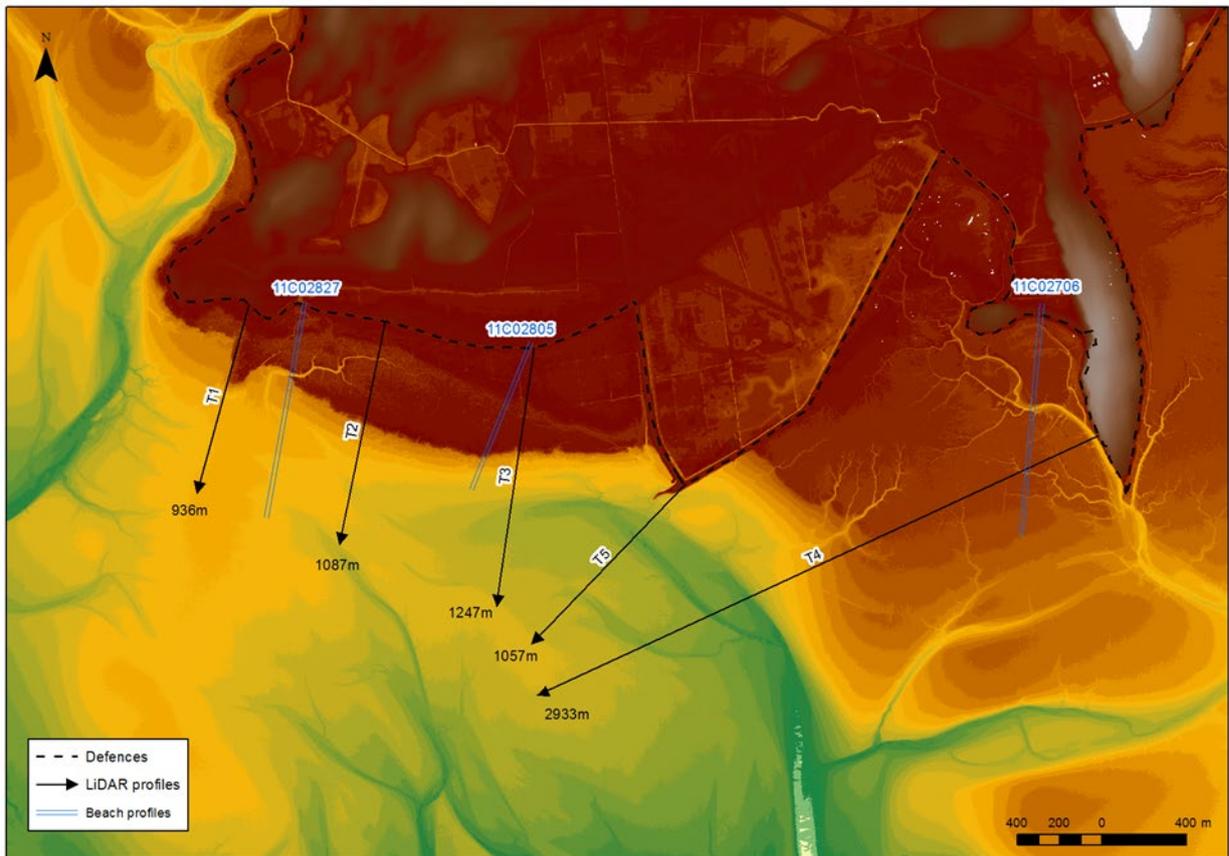


Figure B: Location of transects extracted from LiDAR images and beach profiles analysed in this report.

Results

Figure C shows the mosaic LiDAR DTMs from 2004 and 2010 and the difference in elevation between those two datasets. Figure D shows changes in position of tidal levels, i.e. MWL, MHWN and MHWS, between 2004 and 2010, based on extracting data from the mosaic LiDAR DTMs. Figure E shows the profile graphs extracted from the LiDAR data, illustrating elevation changes between 2004 and 2010 for five transects (see Figure B for locations).

Figure F shows beach profile data, collected as part of the North West Monitoring Programme, which shows changes for selected dates between 2006 to 2012 and 2016, for three locations: 11C02828, 11C02805, 11C02706.

Observations from the LiDAR data are described below:

- Ulverston channel, located to the southwest of Cartmel Peninsula in 2004, relocated westwards by 2010, becoming an almost straight channel into the Leven Estuary. This could be observed through the relocation of the MWL further west between 2004 and 2010 (Figure D - top). This relocation caused a general shallowing of up to 3.6 m across all the transects from below MWL to around MHWN, as observed in Figure E. The difference plot also shows a shallowing (in red) in the 2004 channel to the south of Cartmel Peninsula and a deepening (in blue) in the foreshore adjacent and fronting the defences at this location (Figure C).
- This deepening infers that a new channel seems to have been migrating closer inshore to the south of Cartmel Peninsula, with a meander bend located at the tip to the Bourne Leisure defences (Lower Marsh and East Plain embankments, 011KC90200201C04 and 011KC90200201C07, respectively). The deepening resulted in up 2.7 m drop in bed elevation across all transects between MHWS and MHWN, with the exception of Transect 1, which shows a shallowing at MHWS of 0.75 m (Figure E). Therefore, the position of MHWN relocated closer inshore at Transect 1, but further offshore towards the west, creating an

“inverted U shape” intertidal area (above MHWN) south of the Cartmel Peninsula, with a deeper channel in the middle (see light blue line in Figure D middle). MHWS, however, relocated further inshore across the whole southern frontage.

- This deepening trend also meant a general retreat of MHWS ranging between 100 m and 680 m (Transects 1, 2, 3 and 5), increasing in an eastward direction; meaning greater retreat closer to the Lakeland Leisure Park defences. Transect 4, which has a NE-SW orientation, shows a retreat of MHWS of around 1200 m over the same period.
- The advancement of the MHWS closer inshore was observed to occur on both sides of the Bourne Leisure defences. The position of MHWS, if the defences were not in place, has been estimated across the East Plain and it is shown by the dashed line in Figure C (middle).

More recent change is illustrated by the beach profiles 11C02827, 11C02805, 11C02706 (for locations see Figure B):

- At the western end of the frontage (profile 11C02827; Figure F (a)), close to Cowpren Scar, there has been cutback of the marsh edge since 2009. Bed levels along the fronting mudflat have varied over the same period, due to the presence of a small creek, which the profile crosses. There is some evidence that this creek has started in infill. The profiles do not extend far enough offshore to determine wider scale changes.
- Along the central section (profile 11C02805; Figure F (b)), the data indicate that between 2006 and 2014 there was progressive cutback of the marsh edge, as a channel advanced towards to the shoreline, with lateral retreat of around 150 m. But since 2014, the marsh edge has remained in the same position. The elevation of the marsh along its edge has increased over time by up to 0.7 m since 2012. There has been progressive shallowing of fronting flat, the onset of which occurred sometime between 2008 and 2012 (no data is available for this period).
- Between 2006 and 2016, the position of MHWS at the most western profile (11C02827; and the central profile (11C02805; Figure F (b)) retreated by around 20 m and 150 m, respectively. However, marsh levels between MHWN and MHWS have accreted by up to, which is more evident closer to the Lakeland Leisure Park defences.
- To the east of the Lakeland Leisure Park defences, at profile 11C02706 (Figure F (c)), between 2006 and 2008 there was little change, but since 2006 marsh levels above MHWS have accreted by up to 0.4 m. The profiles do not extend far enough offshore to assess any changes in the position of the marsh edge.

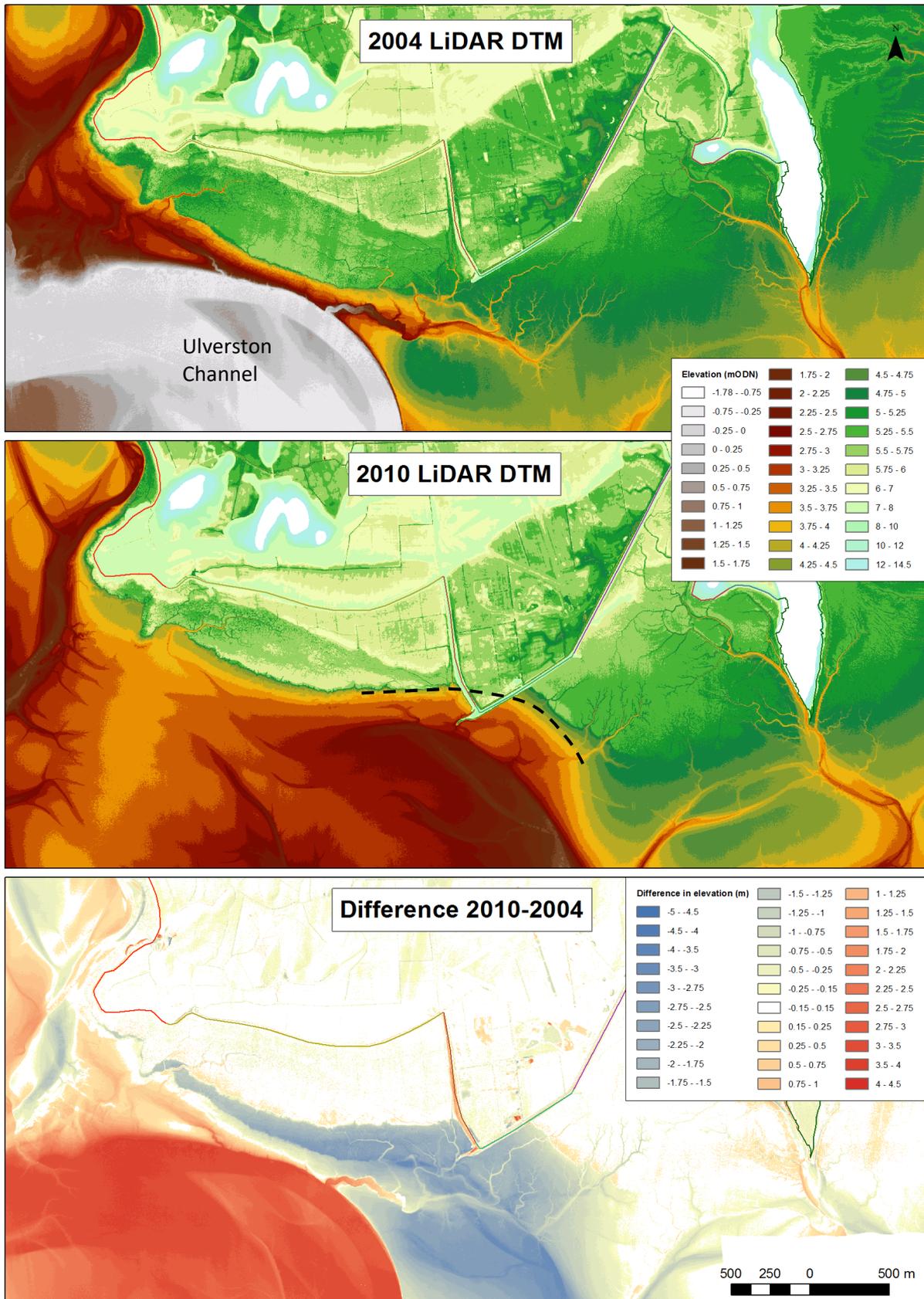


Figure C: LiDAR DTM 2004 (top), 2010 (middle) and difference in elevations (bottom) between 2004 and 2010. The dashed line in the middle plot shows the estimated position of the MHWS, if defences were not in place.

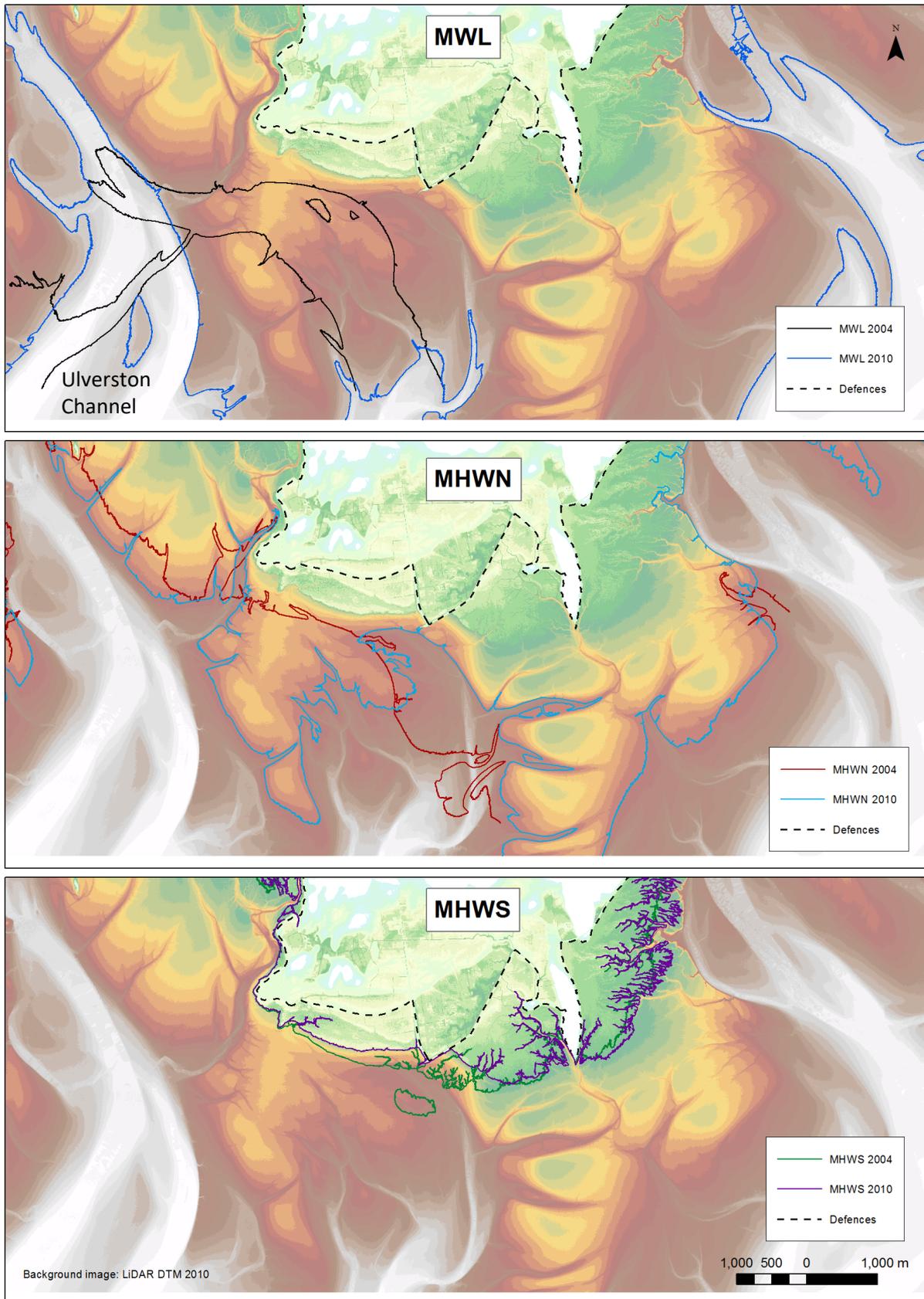
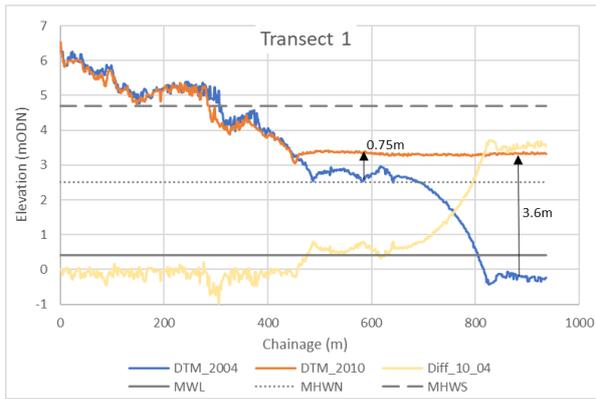
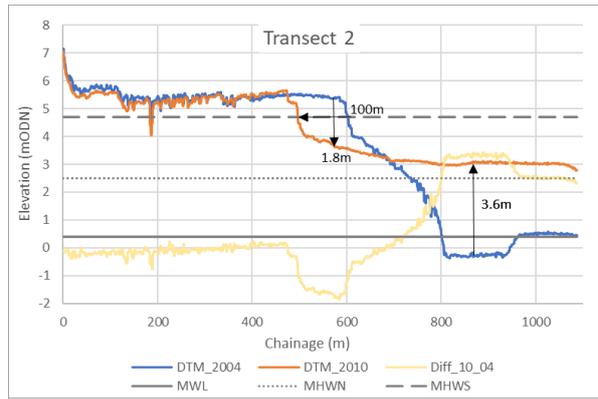


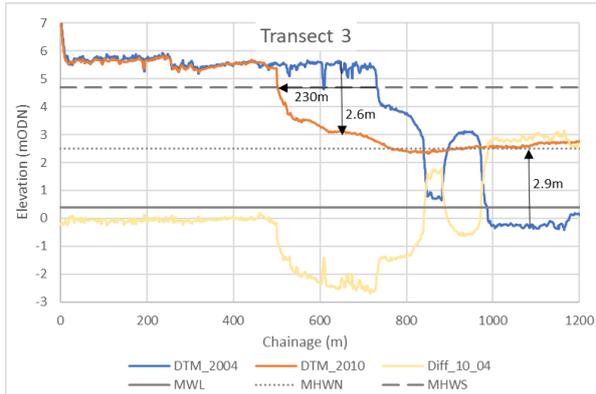
Figure D: Changes in position of MWL (top), MHWN (middle) and MHWS (bottom) between 2004 and 2010



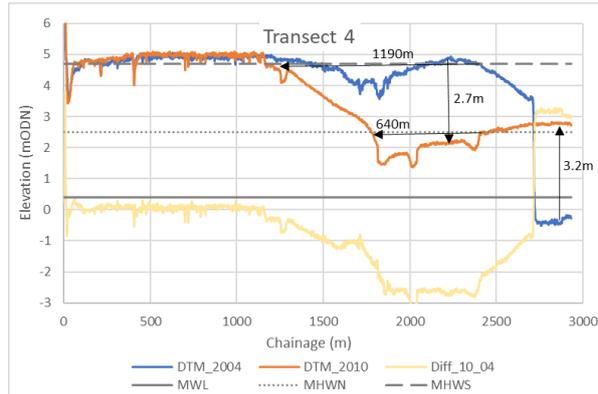
a) LiDAR Transect 1



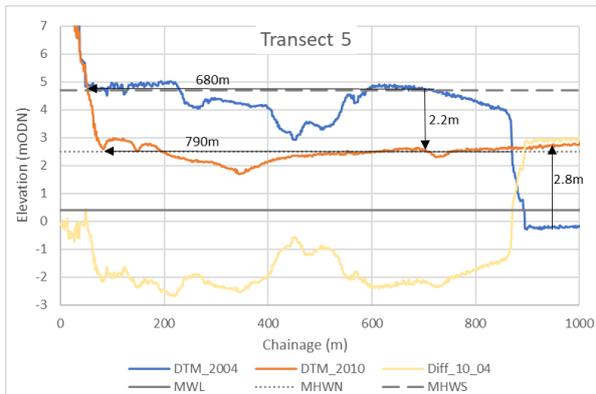
b) LiDAR Transect 2



c) LiDAR Transect 3

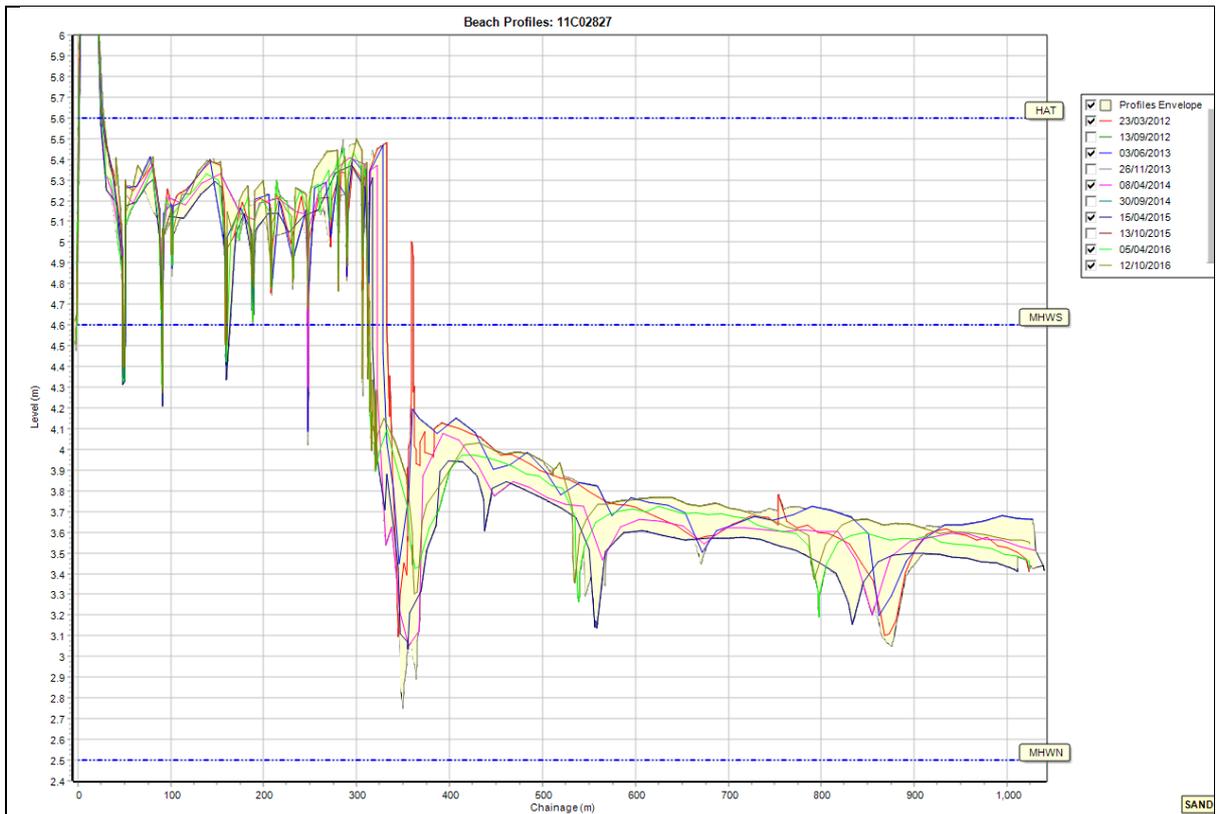


d) LiDAR Transect 4

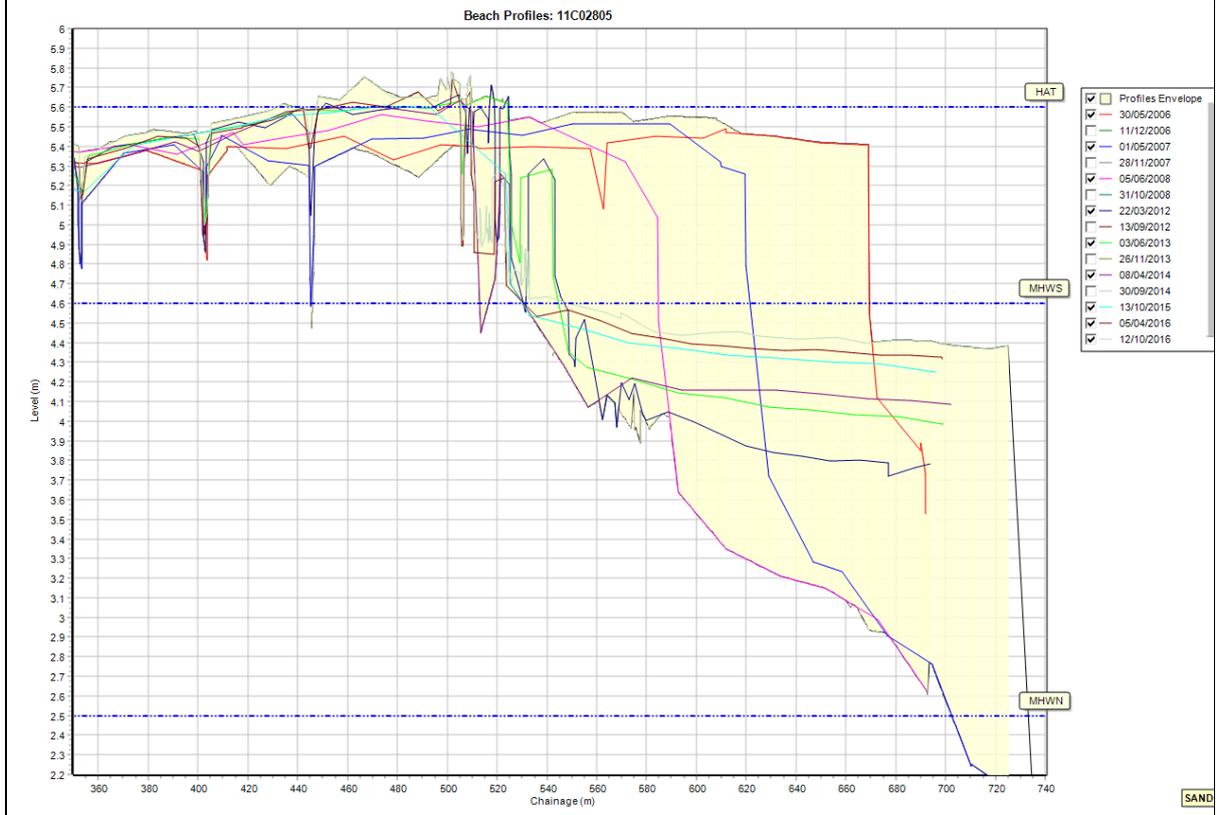


e) LiDAR Transect 5

Figure E: LiDAR transects 1 to 5, showing changes in the intertidal area between 2004 and 2010 fronting 11c10.2



(a) Beach profile 11C02827 (near Cowpren Point, West Plain)



(b) Beach profile 11C02805 (west of Lakeland Leisure Park, central West Plain)

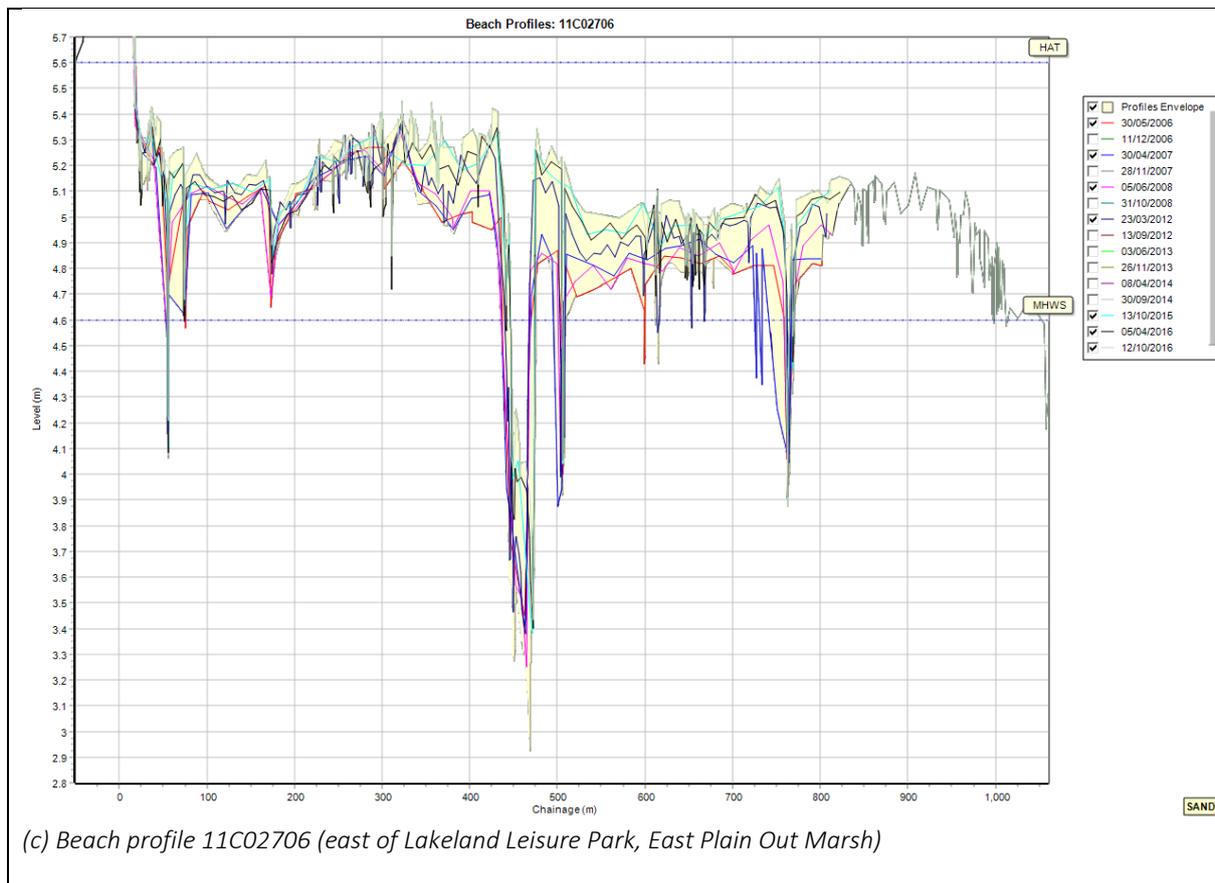


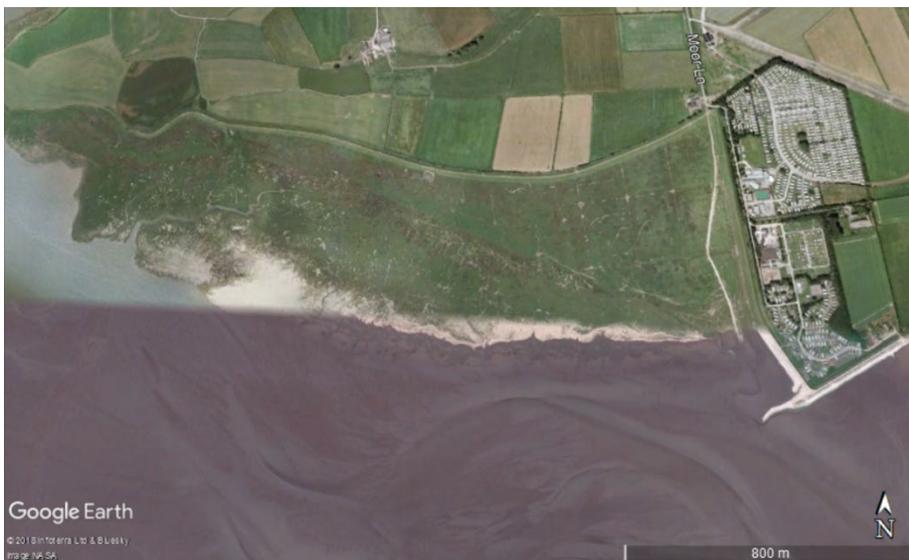
Figure F: Beach profiles (collected as part of the North West Monitoring Programme). See Figure B for locations of the profiles.

Figures G and H show a visual comparison of aerial photographs obtained from Google Earth Pro between for 2004, 2010 and 2014. The images show that along the West plain frontage there was rapid loss of saltmarsh between 2004 and 2010, but that the erosion rate between 2010 and 2014 was much slower (even when taking account of the smaller time period). Similarly, along the East Plain, greater losses were experienced between 2004 and 2010, than between 2010 and 2014. There has been some lateral accretion along the eastern extremity of the marsh between 2010 and 2014.

These changes are consistent with the historical evolution of the channel and tidal flats system in Morecambe Bay, as shown in Figure I. Oscillations in the position of the Mean High Water Mark of Ordinary Tides and in the leading edge of the saltmarshes has been occurring at least since 1850s (Epoch 1), which corroborates the mobile nature of this environment. As shown in Figure I (a), an embankment originally fronted the West Plain in 1817; this was damaged due to increased exposure, probably due to channel migration, and was destroyed by 1828.



(a) West Plain: 2004



(b) West Plain: 2010

(note: appears to be a composite image).



(c) West Plain: 2014

Figure G West Plain marsh. The approximate marsh edge position is shown for 2004 (yellow) and the 2010 (orange).



(a) East Plain 2004



(b) East Plain 2010



(c) East Plain 2014

Figure H East Plain marsh. The approximate marsh edge position is shown for 2004 (yellow) and 2010 (orange).

TECHNICAL NOTE

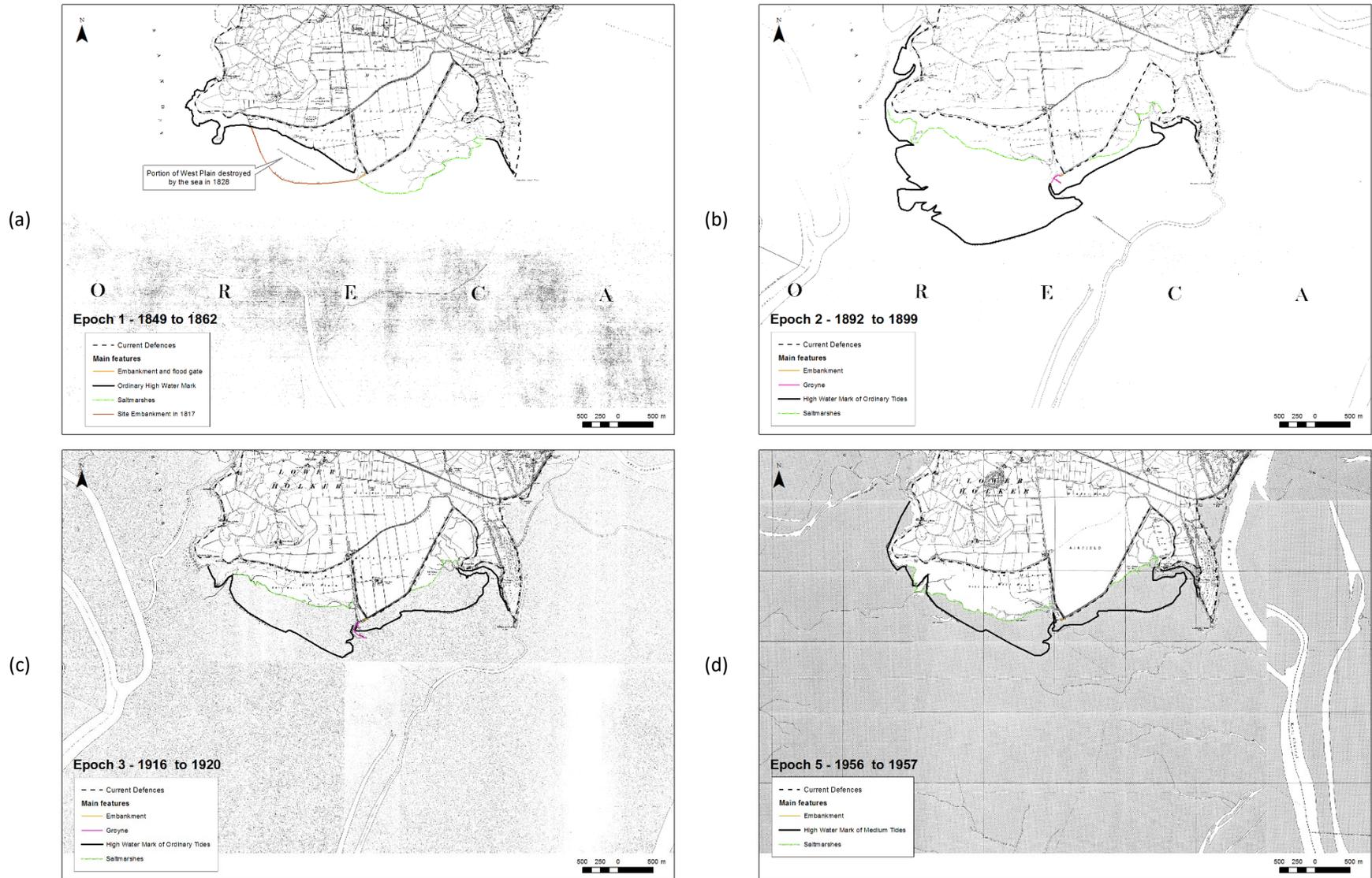


Figure 1: Historical Ordnance Survey maps in four different epochs (1849-1862; 1892-1899; 1916-1920; and 1956-1957). Source: Futurecoast (Halcrow, 2002).

Discussion

Quantitative and qualitative changes in tidal flats and channel positions in Morecambe Bay have been extensively studied previously (including Kestner, 1970; Pringle, 1987; McClaren, 1989; Mason *et al.*, 1999; Mason and Garg, 2001; Mason *et al.*, 2010). Appraisals of shoreline change have also been undertaken by HR Wallingford (2006; on behalf of Natural England) and Shoreline Management Partnership (various dates; on behalf of Bourne Leisure) as supporting evidence accompanying the Lakeland Leisure Park Strategy (Patrick Parsons & Shoreline Management Partnership, 2009).

The most recent of these studies, by Mason *et al.* (2010), reported morphological changes in the intertidal areas of Morecambe Bay, specifically close to the Cartmel Peninsula using remote sensing imagery between 1991 and 2007. This study concluded that there had been a gradual but substantial migration of the Ulverston Channel by about 5 km cutting through Cartmel Wharf between 1991 and 2004. It was proposed that this movement had been occurring since the 1970s. The study showed that by November 2005, a straighter Ulverston channel had developed to the west, leaving the previous curved channel decoupled from the River Leven. Within Cartmel Wharf, higher land was observed to form a barrier between the end of this cul-de-sac and the new channel of the Leven.

Reports by HR Wallingford (2006) and Shoreline Management Partnership (2007) also noted that in recent decades, the shoreward and eastwards migration of a “hook shaped” low water channel has resulted in the shoreline becoming steeper and muddier, and, as such, more exposed to wave action. HR Wallingford (2006) suggests that this is probably a flood dominant channel. It was reported that at the time of writing (2006), the channel had extended northward to abut the south western corner of the Windermoor Embankment and was still actively migrating onshore. In 2007, Shoreline Management Partnership suggested that there had been a change in the low water channel, such that “energy along the Park frontage appears to have reduced”. The note also suggests that “the shoreline channel is no longer continuously subtidal as it reaches the Leven Estuary”, which may concur with the findings of Mason *et al.* (2010).

Both the position of Ulverston Channel by 2004 and the migration of this channel to the west after 2004 were also observed through the current analysis of LiDAR DTM (Figures C and D). The present analysis also showed a new, shallower channel advanced from the south towards the Cartmel Peninsula between 2004 and 2010, which meant the position of MHWN and MHWS moved further inshore immediately adjacent to the Lakeland Leisure Park defences. By 2010, the change in position of MHWN had created intertidal areas (above MHWN) in an “inverted U shape” (Figure D) with the new, shallower channel in the middle.

More recent beach profiles (between 2006 and 2016) show that the marsh edge close to the Lakeland Leisure Park defences (beach profile 11C02805) has remained stable since 2014, although there has been some lateral accretion along this edge, resulting in an increase in elevation of up to 0.7 m since 2012. This could infer a recovery of foreshore levels close to the Lakeland Leisure Park defences and potentially the infilling of the channel that formed prior to 2010. Further data will be required to confirm this trend. The beach profile across the marsh to the east of the Lakeland Leisure Park indicates recent vertical accretion, but again it is uncertain whether this is seasonal recovery or vegetation growth, or an ongoing trend. Unfortunately, profiles here do not extend far enough offshore to appraise changes to the marsh edge. Along this section, Transect 4, extracted from the 2004 and 2010 LiDAR data shows that there was erosion of the marsh during this period but the data shows a rounded marsh edge rather than vertical cliffs, which may be indicative of some recovery. In support of this, a saltmarsh survey undertaken in 2008 and included as an appendix to the Lakeland Leisure Park Strategy (Appendix XIV, Patrick Parsons & Shoreline Management Partnership, 2009), concluded that towards Humphrey Head there were signs of recent marsh accretion. Further data is, however, required to confirm any ongoing trend.

Tidal asymmetry has been described previously (Pringle, 1987) as the dominant cause of morphological change in Morecambe Bay, with the higher currents associated with the flood tide being the main agency moulding the channel system. The higher currents on the flood tide (as is present in Morecambe Bay) have been described to induce a land directed sediment transport, which may have led to increased sedimentation on Cartmel Wharf (Mason *et al.*, 2010) and deposition sediments in areas where flows are slower (such as on both southwest and southeast of Cartmel Peninsula). Although there has been a shallowing across the intertidal areas to the southwest and southeast of Cartmel Peninsula, the deepening to the middle of it retreated the MHWS in a similar degree on both sides of Lakeland Leisure Park defences, eroding the leading edge of the saltmarshes to the south and on both sides of the tip of the defences. If these structures were non-existent, the position of MHWS could be estimated across East Plain (see Figure C - middle plot), creating a uniform cut back of the saltmarshes at this location. Therefore, it is considered likely that the current defences are not causing erosion of saltmarshes immediately adjacent to them nor influencing major patterns of sediment transport specifically at this location. Instead the observed changes are part of a large scale estuarine process of channel migration as previously documented.

The shoreline continues to evolve and the most recent data for the frontage suggest that there has been recent stabilisation of the marsh edge to the west of Lakeland Leisure Park, with an increase in marsh elevation observed. Shoreline Management Partnership (2007) also identified that there was “the prospect of the low water channel moving off the Park frontage to find an ‘easier’ route to open water”, but at the time of writing (2007) this was not evident. From the data available to date is not possible to conclude this is a trend at present, but future data should confirm or otherwise.

Conclusions

The main conclusions drawn from this geomorphological assessment are:

- Movement of low water channels and sandbanks within Morecambe Bay have been studied and described in previous studies. These conclude that this is a very dynamic environment, driven by large scale changes within the Bay that are largely unpredictable. Saltmarsh within the Bay is subject to alternating patterns of erosion and accretion associated with changes in bank channel configurations, and it is this phenomenon that has been the key cause of saltmarsh erosion and undercutting of defences along the Humphrey Head to Cowpren Point frontage.
- Whilst the Ulverston Channel has migrated west offshore of Cartmel Peninsula (evidence by the change in position of MWL), another, shallower channel formed over time, which has been advancing from the south. This channel movement has meant that the intertidal zone, including both marsh and tidal flat, has narrowed along the Humphrey Head to Cowpren Point frontage, resulting in lateral erosion of the saltmarsh edge and increasing exposure along the toe of defences along the Lakeland Leisure Park. In a six year timeframe (between 2004 and 2010), both MHWN and MHWS shifted inshore by around 700 to 800 m.
- This trend has been evident on both sides of the Bourne Leisure defences, suggesting that the defences themselves have had a limited impact on this larger scale change.
- More recent beach profile data suggest that there has been some recovery of the marsh and tidal flats. To the west of the Lakeland Leisure Park, the data indicates that the position of the marsh edge has remained the same over the past 2 years and has been accompanied by vertical marsh accretion and shallowing of the fronting tidal flat. To the east of the Lakeland Leisure Park, the marsh surface has been accreting since 2008, with a net increase in height of around 0.3 m. The profiles do not extend far enough offshore to allow appraisal of how the edge of the marsh has changed over time.

- Shallowing across the intertidal areas close to MHWN on both southwest and southeast of the Cartmel Peninsula and deepening of the south are likely to be caused by tidal asymmetry and strong flood flows, which are known by the literature to influence sediment transport in Morecambe Bay;
- It is likely that current erosion patterns to the south of Cartmel Peninsula are associated to the changes in position of tidal flats and channels within Morecambe Bay.

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- Lakeland Leisure Park
- Cark Airfield (a scheduled monument)
- Properties and businesses at Raven Winder

There would also be flood risk to:

- Properties at the southern edge of Flookburgh
- Businesses and properties to the south of the drain along Moor Lane
- Farms and properties along Winder Lane and Canon Winder
- A section of the railway line.

Access roads to other properties, such as Wyke Farm and Humphrey Head Outdoor Centre, would also be affected.

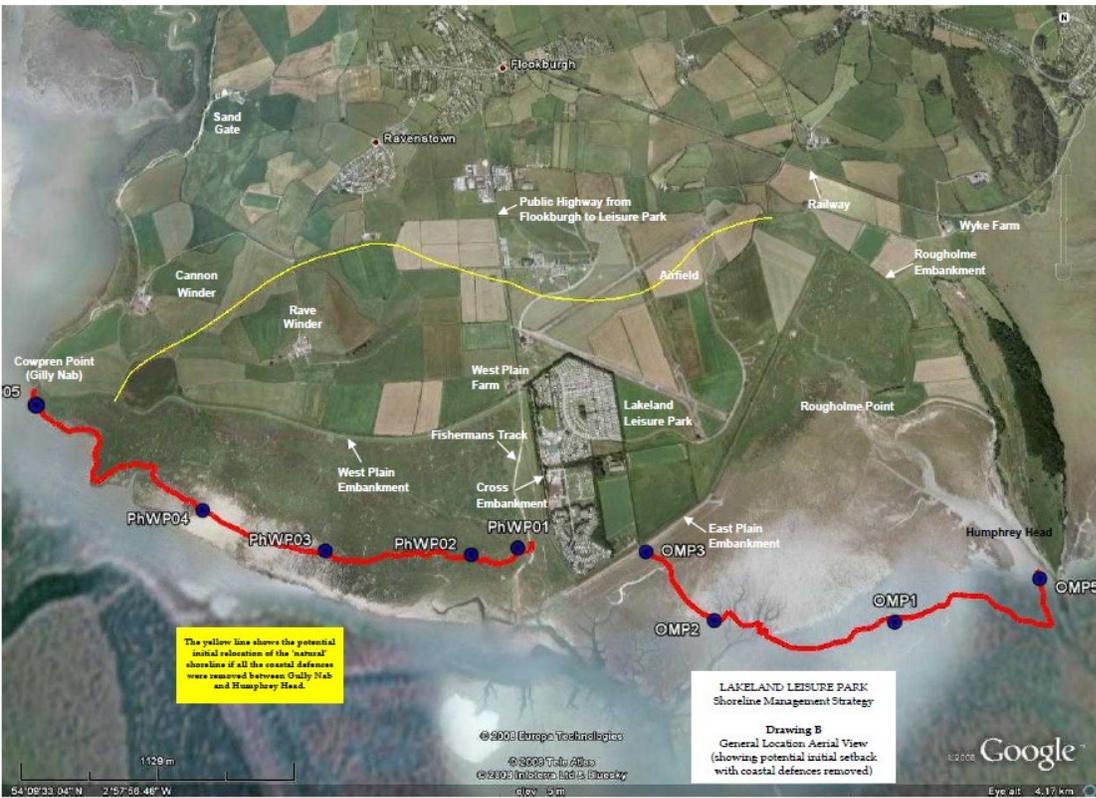


Figure K Estimated location of a natural shoreline, if defences were removed between Cowpren Point and Humphrey Head. Taken from Patrick Parsons & Shoreline Management Partnership (2009).

Concept 2

This would involve construction of new embankments inland to continue to manage flood risk to the inner hinterland. Under this concept, these would broadly follow the alignment of the existing main drain running from west to east across the peninsula as the boundary linking up to existing defences at Bankmoor Embankment. There are a number of possible variations on the alignment, such as to address the need to maintain links to isolated properties such as those at Winder Canon.

Under this concept there would be continued management of flood risk to:

- Properties at Flookburgh

- West Coast railway
- Businesses and property to the north of the drain along Moor Lane
- Access to Humphrey Head

This arrangement would lead to (but not limited to) the following assets being at significant flood risk or needing to relocate in the long term:

- Cark Airfield and scheduled monument
- Lakeland Leisure Park
- Businesses and property at Raven Winder Cottage
- Businesses and property to the south of the drain along Moor Lane
- Farms and property along Winder Lane.

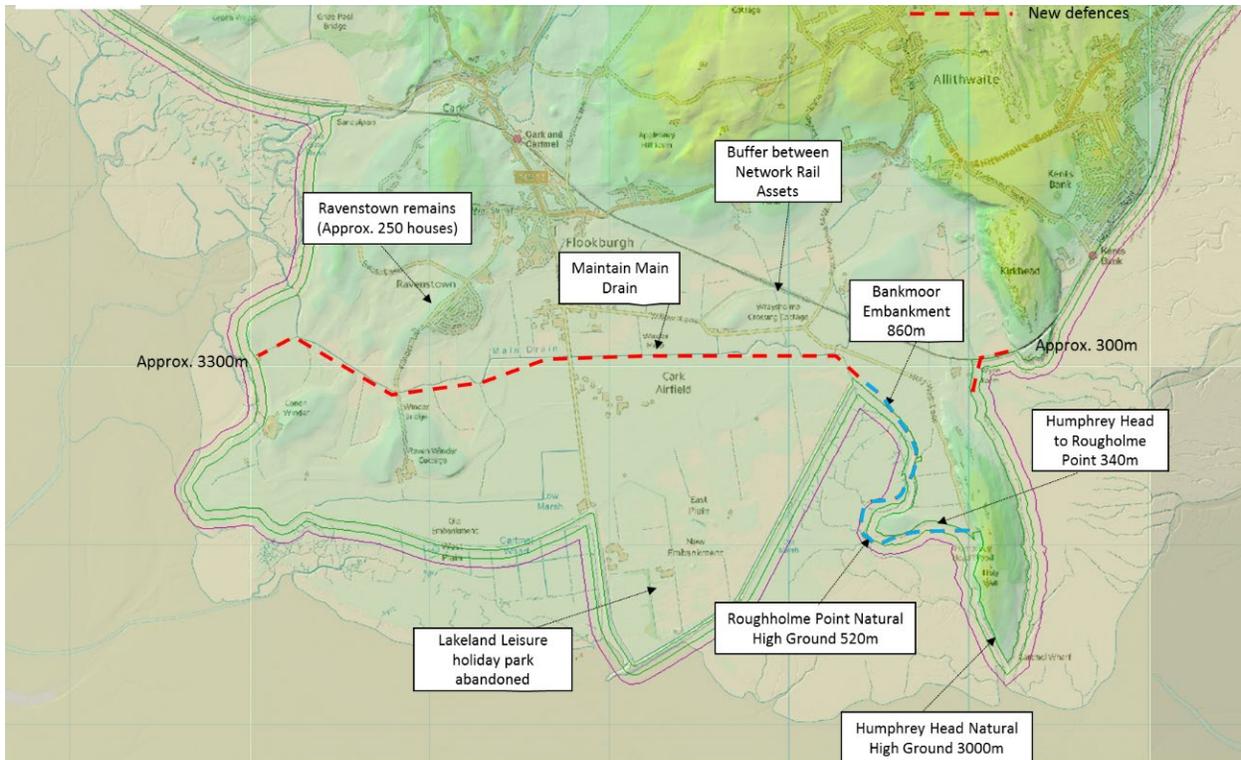


Figure K Concept 2 – Shows an indicative realignment line to continue to provide flood risk protection beyond the ‘natural’ shoreline position (see concept 1); there are several variations possible, which could involve linking into higher land at Canon Winder and Raven Winder. Baseline mapping © Crown copyright and database rights, 2019. Ordnance Survey licence number: 1000019596.

Concept 3

Concept 3 uses the existing defences from Humphrey Head to the western boundary of Lakeland Leisure with the setback defence following the main drain to the west coast of the peninsula. As for concept 2, there are a number of possible variations on the alignment, such as to address the need to maintain links to isolated properties, e.g. those at Winder Canon.

Under this concept there would be continued management of flood risk to:

- Cark Airfield and scheduled monument

- Lakeland Leisure Park
- Businesses and properties to the north of the drain, including those in Flookburgh
- Access to Humphrey Head

This arrangement would lead to (but not limited to) the following properties being left at risk of tidal flooding or becoming isolated during flood events in the long term:

- Businesses and property at Raven Winder
- Farms and properties along Winder Lane

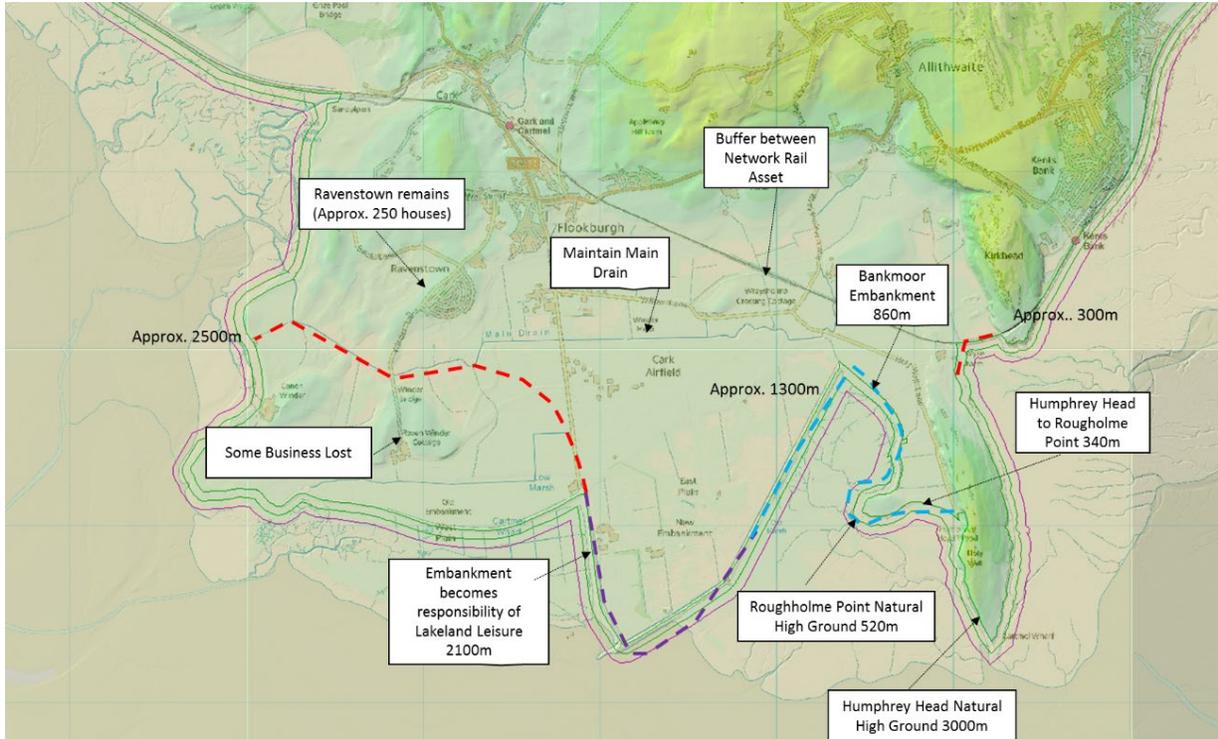


Figure L Concept 2 - Shows an indicative realignment line to the west of the Lakeland Leisure Park; there are several variations possible, which could involve linking into higher land at Canon Winder and Raven Winder. Baseline mapping © Crown copyright and database rights, 2019. Ordnance Survey licence number: 1000019596.

Summary

The table below provides a summary of the Managed realignments outlined above. The concepts are based on a high level desk study and should only be considered as indicative – there are several variations possible to achieve the same aims.

Further studies would be required before a preferred option could be developed. Due to naturally higher ground in some of the area the need for flood embankments along some of the frontage depends on the extent of sea level rise that is realised in the longer term. The limited numbers of properties that are at tidal flood risk means that it may be difficult to justify the cost of maintaining defences along this frontage in the long term.

Table 6 Summary of issues and opportunities presented by each realignment concept

Concept	Length of new embankments	Existing defence length (natural + man-made)	Total length of new defences	Current length of defence (natural + man-made)	Opportunities	Issues
1 (retreat to natural shoreline position)	none	none	none	10500 m	No FCERM cost involved (although costs involved in relocating services etc.) Increase in intertidal habitat	Would result in the loss of Lakeland Leisure, a significant local business Loss of Cark Airfield and memorial Flood risk to section of railway and properties at Flookburgh Access to isolated properties restricted
2 (new set back embankment along whole frontage)	3600 m	4700 m	8300 m	10500 m	Maintains existing main drain Minimal loss of existing property and business Continues to manage flood risk to hinterland area Increase in intertidal habitat Set back defences less exposed to erosion so cheaper to maintain	Would result in the loss of Lakeland Leisure, a significant local business Loss of Cark Airfield and memorial High capital cost as requires construction of new set back embankments along significant length. Limited assets at risk may not justify this intervention.
3 (limited realignment)	2500 m	8100 m	10600 m	10500 m	Would result in the lower losses of business and property including the continued flood protection of Flookburgh and Cark Airfield and memorial Would continue to use large elements of the existing defence, with potential reduction in maintenance costs associated with new set back defences. Possible partnership with Lakeland Leisure for creation and ongoing maintenance Some additional intertidal habitat created	Least natural of options and would require maintenance of significant lengths of defence to maintain line. Maintenance costs high to manage erosion risk to defences. Reliant on funding from Lakeland Leisure. Has the greatest commitment to holding the line.