Royal HaskoningDHV
Enhancing Society Together

Cell 1 Regional Coastal Monitoring Programme
Aerial Photography and LiDAR Surveys 2019-20

North East Coastal Observatory

March 2021

North East Coastal Observatory

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[1] Scarborough Borough Council is acting as client on behalf of all Local Authorities within 'Coastal Cell 1'.

Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the northeast coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. This coastline is often referred to as 'Coastal Sediment Cell 1' in England and Wales (Figure 0-1). Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with fringing salt marshes, hard rock cliffs that are mantled with glacial till to varying thicknesses, softer rock cliffs, and extensive landslide complexes.

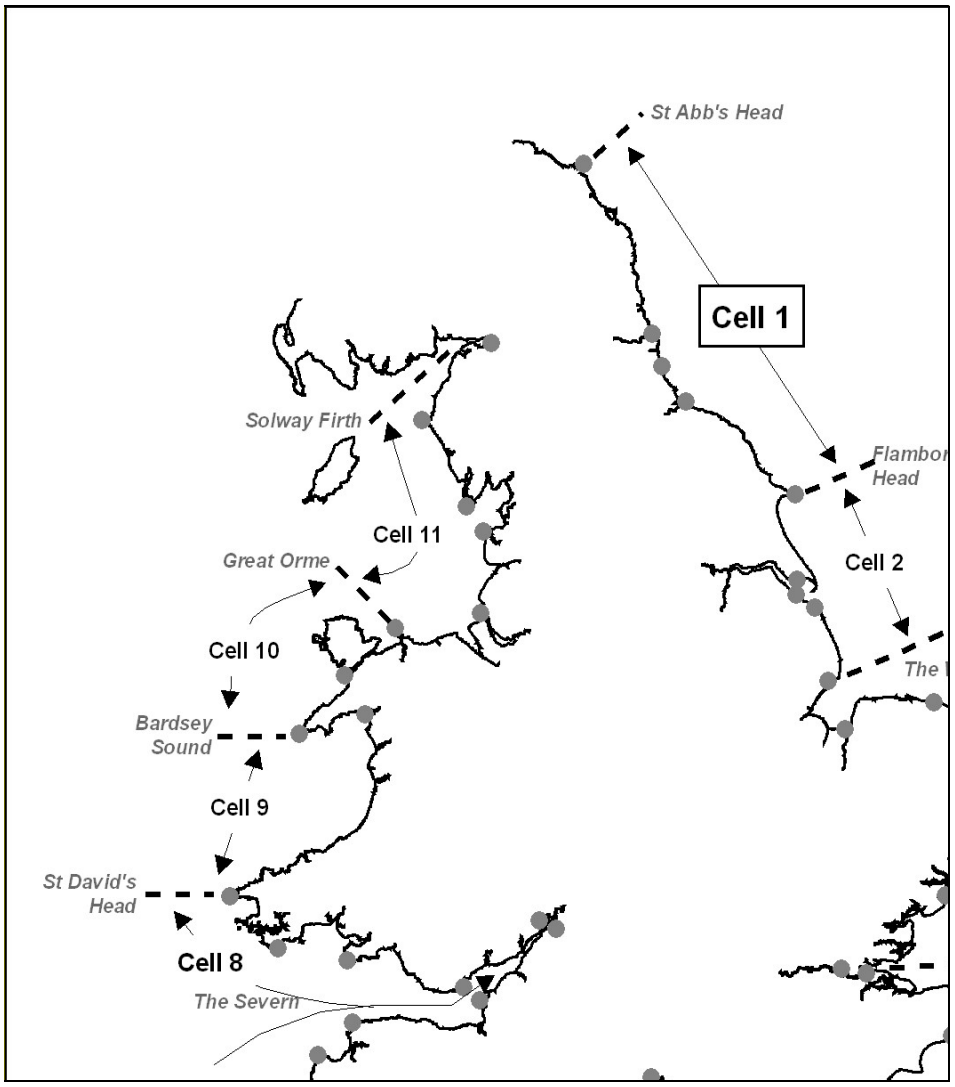

Figure 0-1 - Sediment Cells in England and Wales

The programme commenced in its present guise in September 2008 and is managed by Scarborough Borough Council on behalf of the North East Coastal Group. It is funded by the Environment Agency, working in partnership with the following organisations

The main elements of the Cell 1 Regional Coastal Monitoring Programme involve:

- beach profile surveys
- topographic surveys
- cliff top recession surveys
- real-time wave data collection
- bathymetric and sea bed characterisation surveys
- aerial photography
- LiDAR surveys
- walk-over inspection surveys

Royal HaskoningDHV has been appointed to provide Analytical Services in relation to the Cell 1 Regional Coastal Monitoring Programme 2016 - 2021.

The present report covers the **Aerial Photography and LiDAR Surveys 2019-20** and provides details of these surveys and a comparison with past aerial surveys.

In addition, separate reports are produced for other elements of the programme as and when specific components are undertaken, such as beach profile, topographic and cliff top surveys, wave data collection, bathymetric and sea bed characterisation surveys, and walk-over inspection surveys.

1. Introduction

1.1 Scope of work

Coastal Sediment Cell 1 extends from St. Abb's Head, north of the Scottish Border, to Flamborough Head in East Yorkshire. The purpose of this report is to review aerial photography and LiDAR (Light Detection and Ranging) survey data collected in 2019 and 2020 for Cell 1, and to document notable changes based on a visual comparison with selected orthorectified aerial photographs collected in the past

1.2 Previous Surveys

The coastline of Cell 1 has been the subject of a number of aerial photography surveys in recent decades, as summarised below:

- St. Abb's Head to Flamborough Head, 1999
- Staithes to Speeton (Scarborough Borough Council's frontage), 2003
- St. Abb's Head to River Tyne, 2008
- St. Abb's Head to Flamborough Head, 2010
- St. Abb's Head to Flamborough Head, autumn 2012 to spring 2013
- St. Abb's Head to Flamborough Head, 2015
- St. Abb's Head to Flamborough Head, 2017

Note: Those surveys prior to 2010 were taken as part of forerunner programmes to the present Cell 1 Regional Coastal Monitoring, and those since 2010 have been undertaken as part of the ongoing Cell 1 Regional Coastal Monitoring programme. Prior to 2010, the photographs are of varying format (e.g. some were scanned from prints) and accuracy (e.g. manual geo-referencing rather than ortho-rectification) whilst from 2010 onwards the Cell 1 Regional Coastal Monitoring programme has ensured a greater consistency of format and accuracy in the outputs.

Note: LiDAR surveys of the Cell 1 frontage accompany the aerial photography surveys since 2010, but not prior to this date.

1.3 Previous Analyses

Changes in the Cell 1 coastline between the available baseline surveys and the 2010 survey were documented in the Cell 1 report *Aerial Photographic Survey 2010: Areas of Change* (dated August 2010). The 2010 aerial photography was also used to inform the *Northumberland and North Tyneside Rocky Foreshore Coastal Squeeze Study* (dated 2010).

Changes observed in the Cell 1 coastline were then updated to 2012/13 in the Cell 1 report *2012/13 Aerial Survey Analysis* (dated December 2013). The 2012/13 aerial photography was also used to inform two bespoke Cell-wide analyses:

1. highlighting the presence of possible archaeological features (see *2012/13 Aerial Survey Archaeological Assessment Report*, dated January 2014); and

2. mapping the presence of BAP habitats (see *Mapping of BAP Habitats from Aerial Imagery*, dated December 2015).

For the 2015 survey a somewhat different approach was adopted to the analysis and reporting of coastal changes. Scarborough Borough Council commissioned an extensive trawl through available archives of historic aerial photography, enabling images from various years in the 1940s and covering the whole Cell 1 frontage to be purchased.

These were then digitized and geo-referenced and used as a baseline for comparing against the 2015 survey. The Cell 1 report *Analysis of 1940s and 2015 Aerial Photography & Detailed Assessment of Filey Bay to Cayton Bay* (dated March 2016) provides the results of this detailed analysis. As the report title suggests, a more detailed examination of changes within both Cayton Bay and Filey Bay was also undertaken, specifically to inform an ongoing Coastal Strategy in these areas, additionally using historic aerial photography data from both 1968 and 1996 for that frontage.

For 2017, changes in the Cell 1 coastline between the 2015 survey and the 2017 survey were documented in the *Cell 1 Regional Coastal Monitoring Programme Aerial Photography and LiDAR Surveys 2017* report.

The present report updates the 2017 analysis with changes in the Cell 1 coastline between the 2017 survey and the 2019-20 survey.

1.4 Aerial Photography and LiDAR Survey 2019-20

It was originally intended that the aerial photography and LiDAR surveys would be undertaken in 2019. Whilst much of the frontage was covered at that time, a period of poor weather and adverse cloud conditions delayed completion of the surveys. These were then intended to be undertaken in the first suitable available tidal and weather windows in 2020, but these re-scheduled surveys were further delayed by the onset of the Coronavirus (COVID-19) pandemic. Surveys could not be completed in 2020 until both national lockdown arrangements were lifted and suitable tidal and weather conditions were encountered. These surveys of different areas were undertaken on the days listed in Table 1 (aerial) and Table 2 (LiDAR).

The survey undertaken in 2019-20 delivered the following datasets:

- Orthorectified digital vertical aerial at 10cm pixel resolution and an accuracy of at least ±10cm;
- Oblique imagery of the coastal frontage; and
- LiDAR elevation model at 1m resolution. Data were supplied as both ‘first return’ (with vegetation and buildings) and ‘bare earth’ elevation models.

All data were delivered in 1 km^2 tiles in GIS-ready format. The specification of the survey dictated that all data were to be captured at mean low water of spring tides to maximise coverage of the intertidal zone. The surveys were also to be undertaken on cloud free days to ensure clarity of imagery. For operational flexibility, the aerial photography and LiDAR surveys were not synchronous, but were instead captured as close together as possible. The aerial photography was undertaken by Cyient and the LiDAR data was collected by the Environment Agency.

Table 1 – Aerial Photography Survey Dates 2019-20

AERIAL PHOTOGRAPHY COVERAGE 2019/2020	
VERTICLE PHOTOS	
ANE01_03 - Cockburnspath to Amble	
Cockburnspath to Scremerston	30th August 2019 – 28th October 2019
Scremerston to Amble	19 August 2020 – 18 September 2020
ANE01_02 - Amble to Boulby	
Hendon to River Tees, and Saltburn-by-the-Sea to Boulby	30th August 2019 – 28th October 2019
Amble to Hendon, and River Tees to Saltburn-by-the-Sea	19 August 2020 – 18 September 2020
ANE01_01 - Boulby to Flamborough Head	
Boulby to Flamborough Head	30th August 2019, and 27-28th October 2019
OBLIQUE PHOTOS [only partial coverage by agreement]	
Torness Point to Cheswick	20th August 2020
Berwick upon Tweed to Alnmouth	20th May 2019

Table 2 –LiDAR Survey Dates 2019-20

LiDAR COVERAGE 2019/2020	
ANE01_03 - Cockburnspath to Amble	
Cockburnspath to Beadnell	2nd - 28th October 2019
Beadnell to Amble	20th August 2020
ANE01_02 - Amble to Boulby	
Amble to Blyth, and South Shields to Sandsend	1st September - 31st October 2019
Blyth to South Shields	20th August 2020
ANE01_01 - Boulby to Flamborough Head	
Sandsend to Flamborough Head	1st September - 29th October 2019

In general, the quality of the aerial imagery appears similar to that recorded in 2017, as shown in Figure 1-1, which was better than that captured in 2015.

Figure 1-1 – Comparison of image quality from 2017 (left) and 2019-20 (right)

The newly-acquired 2019-20 aerial photography was compared directly against the previous survey from 2017 in ArcReader GIS to identify areas ('hotspots') of coastal change over the short term. This was achieved by viewing the 2017 and 2019-20 photography side-by-side in corresponding 'zoomable' screen panels and by viewing the 2017 and 2019-20 photography in a 'swipe' mode where a cursor movement could drag one image across to reveal the other underneath.

In particular, changes in cliff top and dune crest position between surveys were identified and, where measurable change has occurred, quantified. Where notable change occurred, aerial photography was 'draped' over a DGM created using the LiDAR data from 2017 and 2019-20 within ArcGIS to calculate locations and rates of change between successive surveys. This was performed at four locations, namely (i) Hawks Cliff (Northumberland); (ii) Lynemouth Bay (Northumberland); (iii) Horden (County Durham) and (iv) Filey (southern end of seawall, Scarborough borough.

Although the aerial photography covers the entirety of Coastal Sediment Cell 1, namely from St. Abb's Head to Flamborough Head, the analysis focuses on the coastline between the Scottish Border and Speeton, covering the responsibilities of Northumberland County Council, North Tyneside Council, South Tyneside Council, Sunderland City Council, Durham County Council, Hartlepool Borough Council, Redcar & Cleveland Borough Council and Scarborough Borough Council.

This analysis of short term 'hotspots' of coastal change between 2017 and 2019-20 updates the earlier 2015 to 2017 analysis and complements the analysis of longer term (1940s to 2015) coastal change that was previously undertaken with the 2015 dataset.

1.5 Regional overview

Coastal Sediment Cell 1 has a coastline of approximately 300km on the northeast coast of England. Its aspect is generally northeast facing, but there is considerable local variation due to the underlying solid and drift geology which play a significant control on the coastal geomorphology. The bedrock that crops out along the coast forms an almost complete sequence of Carboniferous to Upper Cretaceous rocks. The presence and thickness of glacial sediments varies, but they are generally thicker towards the south.

The north of Northumberland, from Berwick northwards, extending across the border to St Abb's Head, is characterised by hard shales of Silurian age which form simple cliffs of moderate height and sections of glacial sediments which form simple landslides. The central and southern Northumberland coast from Berwick-upon-Tweed to Hartley and the North Tyneside coast from Hartley to Tynemouth are characterised by a low elevation coastline dominated by sand dunes with occasional low elevation simple cliffs of Carboniferous limestone or gritstone, or higher cliffs formed of intrusive volcanic rocks associated the Whin Sill.

South of the River Tyne to Saltburn, the coastline is well-developed and has extensive defences and harbour structures with some unprotected low cliffs cut in glacial sediments which form small simple landslides, outcrops of hard Magnesian limestone which form simple cliffs, and occasional dune frontages. This coast, together with much of the southern Northumberland coast, was formerly characterised by extensive coal mining activity with spoil being tipped directly onto the beach, contributing to the coastal sediment system. In recent years, following the decline in this industry, considerable effort has been made to remediate beaches, and today only localised evidence of colliery spoil remains, e.g. at Blast Beach and Horden, where extensive spoil protects a relict cliff. This has resulted in a net loss of sediment from the coastal system and is thought to have triggered localised increases in erosion rates. Furthermore, monitoring has shown very high initial rates of erosion of the residual spoil, but with rates decreasing as the shore profile is more strongly influenced by the natural geomorphology. As spoil is removed so the dormant cliffs will be exposed. There is little historical evidence upon which to base prediction of future recession rates. This ongoing aerial surveying as part of the Cell 1 Regional Coastal Monitoring programme will be essential in providing this future understanding.

From Saltburn to Flamborough, the coastline is dominated by high, often near vertical, cliffs cut in Jurassic limestones and mudstones and Cretaceous chalk, with a variable thickness cover of glacial sediments, forming simple or composite cliffs. As a result of faulting in bedrock, and the pattern of glaciation, at many locations along this section of coast glacial sediment crops out at or near sea-level. This results in many simple landslides, such as those seen in Robin Hood's Bay, Sandsend, around Scarborough (e.g. the well-documented landslides at Holbeck Hall and Cayton Bay) and in Filey Bay.

2. Changes Detected

2.1 Background

This section documents the results of the comparison between the newly-collected 2019-20 aerial photography and the previous 2017 survey to identify short term 'hotspots' of coastal change.

The assessment runs from north to south, and the SMP2 Policy Unit (PU) or SMP2 Management Area (MA) references have been specified to help locate areas of change given below. Geographical locations mentioned in the text are based on 1:25,000 Ordnance Survey maps.

2.2 Areas of Change – Cell 1a Scottish Border to River Tyne (2017 to 2019-20)

- **Marshall Meadows Bay**, Berwick-upon-Tweed (PU1.1): An area of cliff which appeared bare of vegetation in 2015, indicating either a small slippage or provision of a local access ramp to the beach, appears to have become partially remediated by 2017 and fully remediated by 2019-20.
- **Sharpers' Head**, Berwick-upon-Tweed (PU1.2): The coastal slopes fronting the caravan park just to the west of the headland suffered small slippages in a number of locations from 2015-2017, but these areas have become vegetated by 2019-20. Whilst warning signs are erected, the failures are not currently affecting the siting of the caravans on the cliff top. A similar situation exists at one location just to the east of the headland, south of Fisherman's Haven breakwater.
- **Meadow Haven**, Berwick-upon-Tweed (PU1.3): The dunes along Little Beach, to the immediate north of the Berwick Breakwater have prograded seaward, with sediment accumulation and dune vegetation growth since 2017.
- **Sandstell Point**, Berwick-upon-Tweed (PU2.4): The sand spit at the mouth of the Tweed estuary has long been known to be dynamic, and changes continue between 2017 and 2019-20. In the recent survey, the spit appears more like its alignment in 2015, with a build-up of sediment constraining the river channel towards the Berwick Breakwater near the structure's landward end (Figure 2-1).

Figure 2-1 – Changes at Sandstell Spit 2017 (left) and 2019-20 (right)

- **Spittal**, Berwick-upon-Tweed (PU2.5): There has been a build-up of sand on the upper beach, covering the rock revetment along the northern end of the promenade which was covered at the time of the aerial survey in 2017. The sand accumulation appears to continue along the whole Spittal length, partially covering the rock outcrops at Bear's Head.
- **Goswick Sands** (PU4.1): In 2017 there was noted to have been accretion from 2015 which had partially buried the concrete anti-tank blocks that are now used as coast protection measures in front of a 'scalloped' section of the dunes, and there appears to have been continued sand accretion in some areas of the dunes to 2019-20, advancing the front face seawards.
- **Beal** (PU4.1 & PU4.2): Perhaps due to the different time of year that the surveys were carried out, there is more algae / pioneer saltmarsh vegetation across the mudlflats north of the South Low channel at Beal and also north of the causeway at Beal Point in 2019-20 than was observed in 2017.
- **Holy Island** (PU4.8 & PU5.1): Restoration works at Lindisfarne Castle have been completed and the temporary scaffolding around the historic building removed by 2019-20. Some small areas of slippage appear to be present east of the Castle in the cliffs. The western face of the gravel ness at Castle Point has experienced some change since 2017, with sections of erosion and adjacent sections of deposition of sediment, suggesting local re-adjustment due to storm conditions. The eastern face experienced minor accretion (progradation) of the gravel berm. On the eastern side of the island, two areas of sandy cliff face (one due east of The Lough and another northeast from The Lough along the existing field fence line) had some notable erosion in 2017 and this has worsened in both locations to 2019-20. However, with no assets at risk there is suitable signage in place regarding safety of footpath walkers. Around the northern side of the island, there appears to be continuation of the previous trend of plentiful embryonic dune vegetation growth and sand accumulation within the sandy bays that stretch between rocky headlands.
- **Ross Back Sands** (PU4.4): There is a continued (progradation) growth of sand to the seaward face of the dunes along Ross Back Sands, including to the Old Law dune ridge that extends from the western end of the beach. There is also pronounced growth of a sand spit at the southern end (seaward face) of Old Law Dunes, extending into Wide Open (Figure 2-2).

Figure 2-2 – Changes at Old Law Dunes (Ross Back Sands) 2017 (left) and 2019-20 (right)

- **Budle Point** (PU4.5): The spit at Budle Point has experienced some embryonic dune vegetation growth on its seaward face, but the spit further southwest, near Heather Cottages (southwest of the jetty) has diminished in size since 2017.

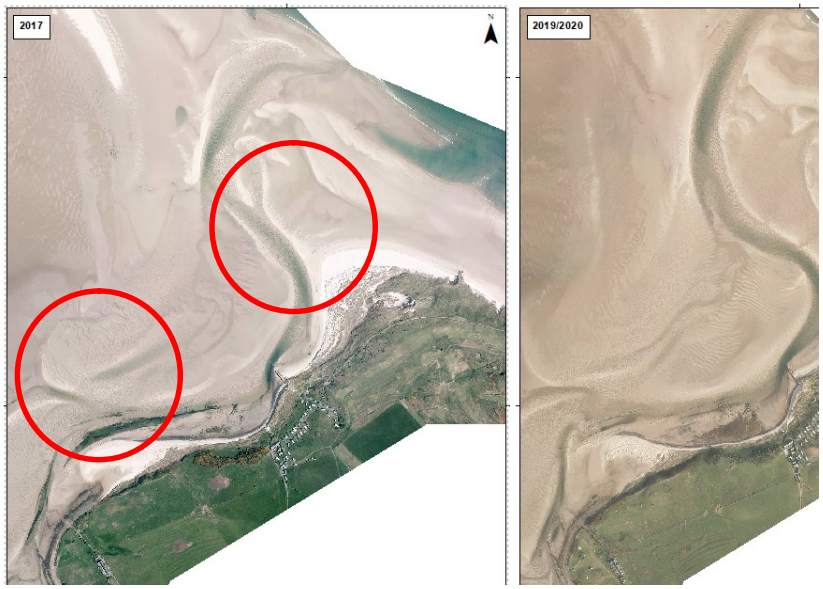

Figure 2-3 – Spit changes at Budle Point, 2017 (left) and 2019-20 (right)

- **Annstead** (PU7.1 & PU7.2): There has been sand accumulation and embryo dune growth along much of the Annstead Links since 2017.
- **Beadnell North** (PU8.1): The failing Reno mattresses used to form a revetment where the road is less than 10 m from the coastal margin remain clearly visible in the 2017 aerial photography.
- **Beadnell Bay** (PU8.4): There appears to have been accretion of the dune front throughout much of the northern part of the bay, until approaching the channel of Brunton Burn. This adopts a more northerly alignment across the foreshore than was observed in 2017 and as a consequence some of the previous dune growth has been washed away, whilst the spit to the south of the channel has grown.

Figure 2-4 – Channel changes at Beadnell Bay, 2017 (left) and 2019-20 (right)

- **Low Newton** (PU9.2): The very small slippages noted in the cliffs running from Low Newton towards Newton Point in 2017 were not observable in the 2019-20 photography.
- **Embleton Bay** (PU9.2): There has been modest accretion of the dune face in the north of Embleton Bay since 2017, but changes are more pronounced at Embletonburn Mouth. The channel of the burn has adopted a more southerly alignment than was present in 2017, causing erosion of the dune face to the immediately south over a length of around 150m. Further south the dunes have remained relatively stable.

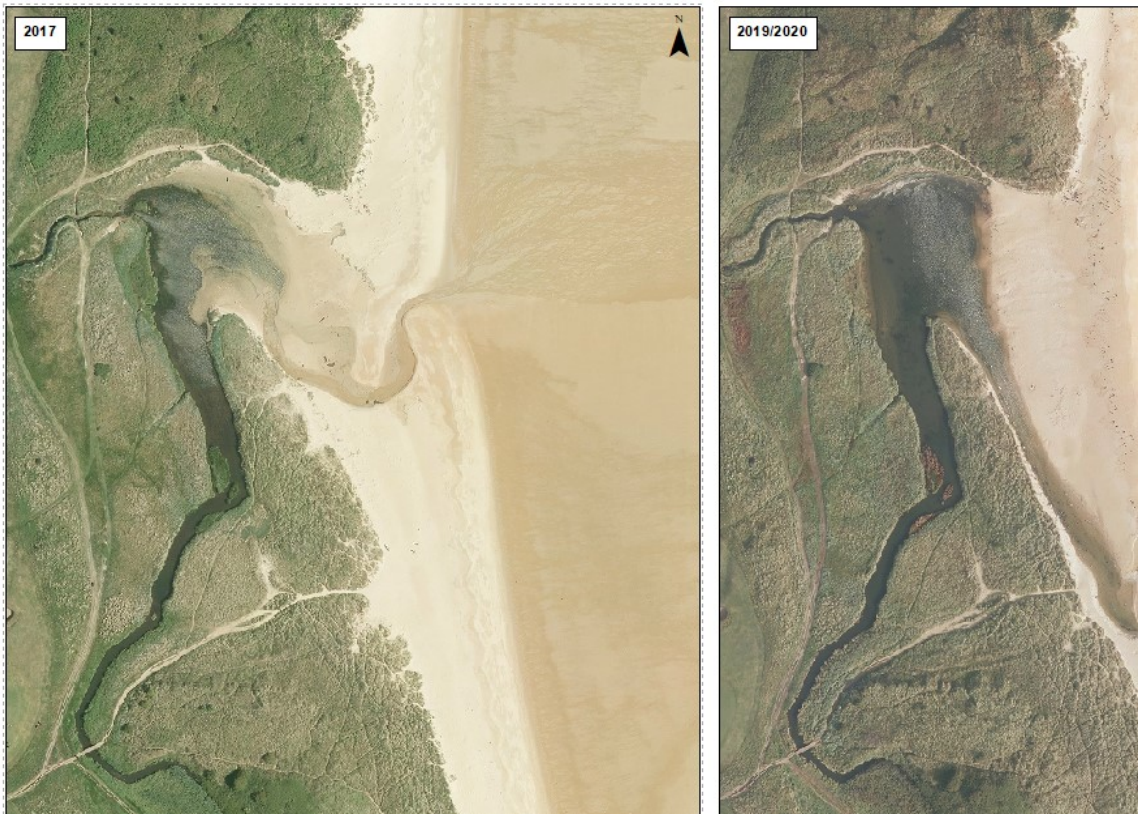

Figure 2-5 – Channel changes at Embleton Bay, 2017 (left) and 2019-20 (right)

- **Alnmouth Bay** (PU13.1): The channel of the River Aln was in a broadly similar position in 2019-20 to 2017 and therefore there were no major changes to the dunes either side of the channel.
- **Church Hill** (PU13.8): The short length of retaining wall shown to be collapsed in 2015, remained in this condition in 2019-20.
- **Birling Links** (PU14.1): The dunes in the north of Birling Links experienced some sand build up and vegetation growth since the 2017 survey. This was also observed south of Birling Carrs, but to a lesser extent. Until reaching the root of the North Pier of Warkwarth Harbour, where the accumulation was again more pronounced.
- **Warkworth Harbour** (PU15.2): The sand build-up seaward of the dilapidated timber jetty has continued, keeping the main channel flowing flush against the quays at Amble.
- **Druridge Bay** (PU17.4): There was minor accretion through most of Druridge Bay, although no notable change at the southern end.

- **Cresswell** (PU17.5): The landslip in the cliffs just to the north of Cresswell that occurred prior to the 2015 survey had not worsened to 2017 or 2019-20, but remains impacting the carriageway.

Figure 2-6 – Landslip at Cresswell, 2017 (left) and 2019-20 (right)

- **Lynemouth** (PU19.1 & PU19.3): In Lynemouth Bay there has been continued erosion of the colliery spoil beach where it is present in the north of the bay (i.e. around the Headagee rock outcrops) and erosion of the colliery spoil cliffs elsewhere, where not protected by fronting spoil beach.

Figure 2-7 – Erosion of colliery spoil beach in Lynemouth Bay, 2017 (left) and 2019-20 (right)

Figure 2-8 – Erosion of colliery spoil cliffs in Lynemouth Bay, 2017 (left) and 2019-20 (right)

Figure 2-9 – Erosion of colliery spoil cliffs in Lynemouth Bay, 2017 (left) and 2019-20 (right)

Figure 2-10 – Erosion of colliery spoil cliffs south of Lynemouth Power Station revetment, 2017 (left) and 2019-20 (right)

- **Newbiggin Moor** (PU20.1): Three of the caravans at the caravan park which were closest to the edge of the cliff top were removed between 2015 and 2017, but have since been replaced by the time of the 2019-20 survey. Elsewhere along this frontage, erosion has cut the cliff top right back to the footpath on the northern face of Newbiggin Point.

Figure 2-11 – Caravans previously removed from eroding cliff edge before 2017 now replaced, 2017 (left) and 2019-20 (right)

- **Newbiggin Bay** (PU20.3): Beach levels in 2017 and 2019-20 were higher than at the time of the 2015 survey, resulting in sand being blown across the promenade and much of the rock placed at the toe of the seawall at the southern end of Newbiggin bay being buried or partially buried by beach sand. The tombolo in the lee of the offshore breakwater in the centre of Newbiggin Bay continues to be substantial in volume.
- **Hawks Cliff / Sandy Bay** (PU21.3): The cliffs along Hawks Bay have continued to slowly erode, with further exacerbation of pre-existing rock falls at two distinct areas. At one location just to the north of Sandy Bay Caravan Park, a larger slip has occurred, requiring the footpath to be diverted inland and warning signs to be erected. At the southern end of the caravan park there continues to be active and show ongoing signs of small scale, but persistent, erosion.

Figure 2-12 – Cliff collapse at Hawks Cliff, 2017 (left) and 2019-20 (right)

Figure 2-13 – Cliff erosion at Sandy Bay Caravan park, 2017 (left) and 2019-20 (right)

- **Cambois** (PU21.5): Some of the rock armour at the toe of the slipway has been repositioned to prevent outflanking at its northern end. There has been notable erosion in some places along the North Blyth dunes, especially in the vicinity of The Rockers.
- **Meggies Burn** (PU23.2): The channel of the burn had adopted a southerly alignment across the foreshore in 2015, prompting erosion counter-measures to the toe of the dunes to the south. However, by the time of the 2017 survey, the burn was flowing more directly easterly to discharge at sea. In the 2019-20 survey, it can be seen that the burn is aligned northerly along the dunes, causing their erosion and resulting in undermining of the timber groyne present on the foreshore. The has caused adverse amenity and safety issues.

Figure 2-14 – Channel changes at Meggies Burn, 2017 (left) and 2019-20 (right)

- **Whitley Bay Miniature Golf Course** (PU25.2): Whilst it is known that the undefended cliffs fronting the golf course continued to experience small slumping between 2017 and 2019-20, the changes were so localised as to be not distinguishable on the aerial photography.
- **Whitley Bay** (PU25.3): Construction works were underway at the time of the 2017 aerial survey, associated with promenade and seawall works as part of the Whitley Bay Coastal Masterplan. These works were complete by the time of the 2019-20 survey.

Figure 2-15 – Whitley Bay promenade and seawall works, 2017 (left) and 2019-20 (right)

- **Tynemouth Longsands** (PU26.4): In many parts of the dunes, there is increased embryo dune vegetation in the present survey compared to 2017.

2.3 Areas of Change – Cell 1b River Tyne to Chourdon Point, Seaham (2017 to 2019-20)

- **Man Haven** (MA04): A sink hole that had opened in the cliff top and which was partially infilled and fenced-off for reasons of public safety between 2015 and 2017 has not increased in size to 2019-20.

Figure 2-16 – Sink hole at Man Haven, 2017 (left) and 2019-20 (right)

- **Marsden Bay** (MA04): In the area south of the Grotto, the fence line and footpath have been diverted inland away from areas of cliff which have been identified to be undercut by caves.

Figure 2-17 – Landward re-alignment of footpath and fence line, 2017 (left) and 2019-20 (right)

- **Old Harbour Quarry** (MA05): A new sink hole has opened up between 2017 and 2019-20 along the north part of Whitburn Coastal Park. The existing sink hole at Whitburn Coastal Park (Old Harbour Quarry) has further increased in size between 2015 and 2017, now measuring 23 m across at its widest point.

Figure 2-18 – New sink hole at Whitburn Coastal Park, 2017 (left) and 2019-20 (right)

Figure 2-19 – Increase in size of existing sink hole at Whitburn Coastal Park (Old Harbour Quarry), 2017 (left) and 2019-20 (right)

- **Roker Pier** (MA07): Construction works that were reported to have been underway at the time of the 2017 aerial survey on the Rocker Pier were completed by the 2019-20 survey.

- **Hendon** (MA08): Some of the utility facilities behind the southern end of the Hendon seawall had been demolished by the 2019-20 surveys.

Figure 2-19 – Land use changes at Hendon Seawall, 2017 (left) and 2019-20 (right)

- **Pincushion** (MA09): The cliffs between Pincushion Rocks and Ryhope Dene have become more deeply 'scalloped' in one area, but this is not significant in magnitude.

- **Dawdon** (MA09): The cliffs at the southern end of the rock revetment south of Seaham Harbour have had a small, local slippage in one area, but this is not significant in magnitude.

- **Blast Beach** (MA09): There has been modest further erosion of the colliery spoil beach just south of Nose's Point, continuing the long term trend since cessation of colliery spoil tipping.

2.4 Areas of Change – Cell 1c Chourdon Point, Seaham to Saltburn (2017 to 2019-20)

- **Hawthorne Hive** (MA10): There has been a small extent of further erosion of the colliery spoil beach at Hawthorne Hive, continuing the long term trend since cessation of colliery spoil tipping.

- **Shippersea Bay** (MA10): There has been further erosion of the colliery spoil beach at Shippersea Bay, continuing the long term trend since cessation of colliery spoil tipping.

- **Horden** (MA10): There has been a small landward erosion of the edge of the colliery spoil beach, but along the full length of Horden, continuing the long term trend since cessation of colliery spoil tipping.

- **Castle Eden Dene** (MA10): The channel of Castle Eden Burn runs a further 30m south directly at the toe of the cliffs in 2019-20 compared to 2017, although this does not appear to have triggered any erosion in the cliffs.

- **Seaton Snook** (MA13): There has been some modest dune growth at Seaton Snook since the 2017 surveys.

- **Coatham Sands** (MA13): There have been past reports that the December 2013 and January 2017 storms caused severe erosion of the dunes at Coatham Sands, especially in the vicinity of Majuba area near the public car park. In the immediate lee of the South Gare breakwater, the trend remains one of accretion in the shelter of the structure, with a modest increase in the extent of dune vegetation since 2017. Elsewhere, the frontage remains relatively unchanged and although the dunes become narrower and less continuous features towards the east, new holiday units had been placed since 2017 in the former car park in this area. This area was previously described by the holiday park owners as 'breaching' or 'severely eroding' during the January 2017 storms in this area, and yet despite this new facilities are being installed.

Figure 2-20 – Land use changes at Majuba, 2017 (left) and 2019-20 (right)

2.5 Areas of Change – Cell 1d Saltburn to Staithes (2017 to 2019-20)

- **Cowbar** (MA19): A further section of the public footpath approaching Cowbar has been relocated inland.

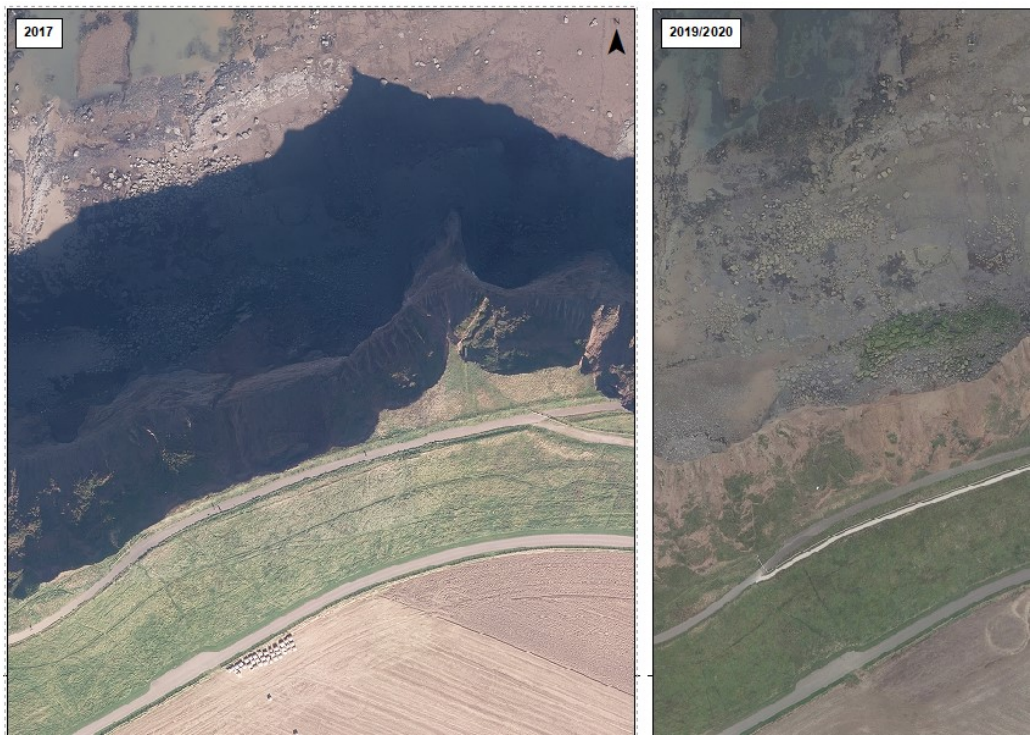

Figure 2-21 – Footpath realignment at Cowbar Lane, 2017 (left) and 2019-20 (right)

2.6 Areas of Change – Cell 1e Staithes to Speeton (2017 to 2019-20)

- **Port Mulgrave** (MA20): The two areas within Port Mulgrave that suffered fairly largescale slippages between 2015 and 2017 have been partially covered by new vegetation growth by the time of the 2019-20 survey.

- **Whitby West Cliff** (MA23): A series of shallow slips remain evident near the base of the cliffs, in the area where there is a gap in the rock revetment which fronts the seawall. However, these have not worsened between 2015 and 2019-20.

- **Whitby Harbour** (MA23): Construction of the refurbishment works to the Whitby Piers was captured during the 2019-20 survey.

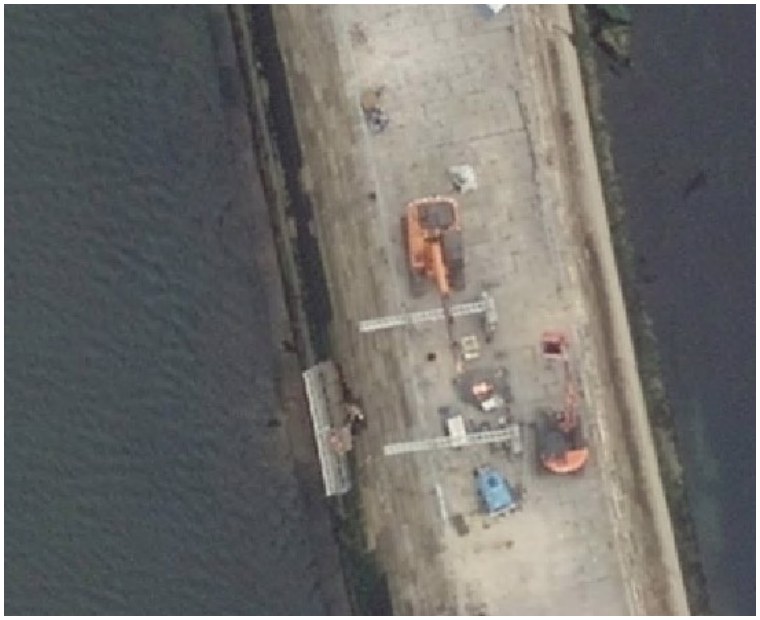

Figure 2-22 – Refurbishment works to Whitby East Pier during 2019-20 survey

- **Scarborough South Bay** (MA28): Demolition of the Futurist Theatre had been completed by the time of the 2019-20 survey and works were just commencing on the cliff stabilisation behind Scarborough Spa. A local landslip in the vicinity of the Clock Tower Café caused destruction of some of the beach huts.

Figure 2-23 – Demolition of the Futurist Theatre by the 2019-20 survey

Figure 2-24 – Stabilisation works to cliffs behind Scarborough Spa during 2019-20 survey

Figure 2-24 – Damaged beach huts by Clock Tower Café captured during the 2019-20 survey

- **Cornelian Bay and Cayton Bay** (MA29): Whilst these areas are known to be potentially active, there is no significant apparent movement between the 2017 and 2019-20 surveys.

- **Filey Brigg** (MA30) and **north of Filey Town** (MA31): The apparently active or unstable sections of cliff do not appear to have altered since the 2017 survey. Remnants of past slippages and past rock falls remain evident in the slope face or cliff toe. The only exception is immediately south of Filey Town, where the seawall ends. At this location the outflanking of the rock armour placed at the end of the seawall continues.

Figure 2-25 – Outflanking at end of Filey Seawall

- **Filey Bay** (MA32): A small number of isolated sections of Filey Bay, south of the town, appear to remain active, with occasional shallow slips in the cliffs. However, the most notable past slippages (medium scale and larger) do not appear to have worsened since the 2015 survey. At Flat Cliffs, however, there are measurable changes in cliff top position to the north of the access road into the hamlet from the Primrose Valley Holiday Park (Figure 2-22). This area is soon to benefit from urgent works to reduce the risk of future failures.

- **General**: There are a small number of areas where occasional rock falls or small slippages near the cliff top have occurred. Other than the Cleveland Way footpath, which can be diverted inland when necessary, no assets are at risk from these occasional events.

3. LiDAR Analysis

3.1 Background

In four areas of notable observed change between the 2017 and 2019-20 surveys, LiDAR survey data has been used to create a Digital Ground Model to further visualise or analyse the changes. These four areas are:

- Hawks Cliff, Northumberland – cliff landslip;
- Lynemouth Bay, Northumberland – erosion of historically tipped colliery spoil;
- Horden, County Durham - erosion of historically tipped colliery spoil; and
- Filey, Scarborough Borough – outflanking at southern end of seawall.

3.2 Areas of Change – Hawks Cliff (Northumberland) (2017 to 2019-20)

The aerial photography analysis (together with the 2020 walkover inspections) has identified that the cliffs along Hawks Cliffs have generally continued to slowly erode, but notably with further exacerbation of pre-existing rock falls at two distinct areas through a larger-scale cliff failure in the area in between.

Figure 3-1 (overleaf) shows aerial photography imagery draped over a LiDAR-based DGM from 2017 (top plot) and 2019 (bottom plot). In 2017, one small and one medium sized rockfall are evident from previous cliff failures. By 2019, it can be seen that the area in between these two failures has been subject to a larger-scale collapse. This has necessitated inland relocation of the cliff top public footpath and the erection of warning signs to path users. Sections of the affected cliff top have also been fenced off.

GIS analysis of the difference between 2017 and 2019 in topographic elevation and surface slope (Figure 3-2). This shows how material lost from the cliff crest and cliff face has been deposited at the toe as talus debris. It is envisaged that the talus will be slowly eroded away over time and future surveys should capture the morphological effects of such processes.

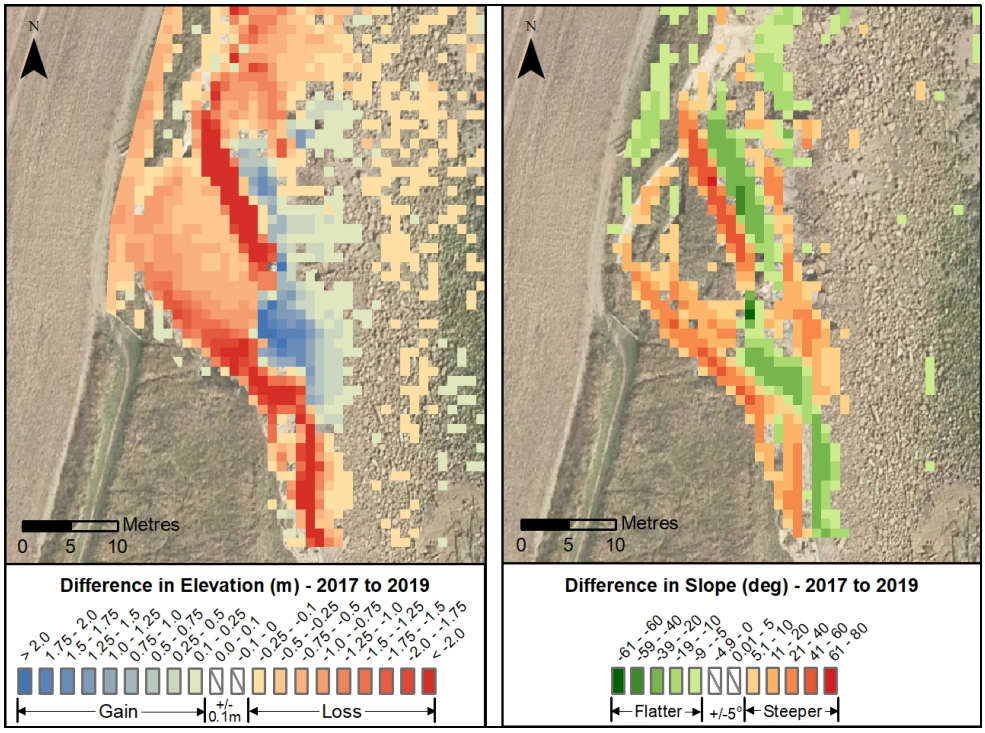

Figure 3-2 Difference in elevation (left plot) and surface slope (right plot) at Hawks Cliff, 2017 – 2019

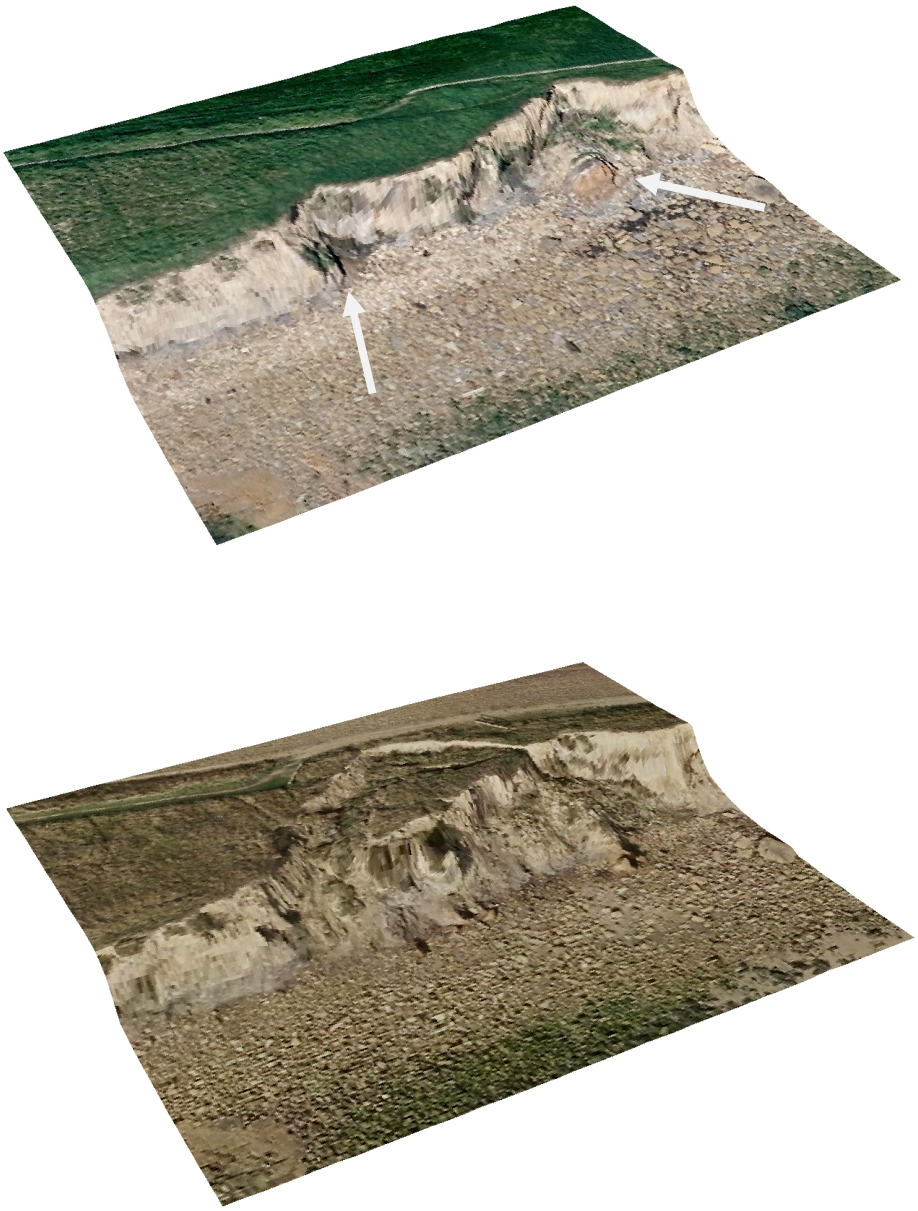

Figure 3-1 - Aerial photography over a LiDAR DGM showing pre-existing failures from 2017 (top plot) and a new larger-scale collapse by 2019 (bottom plot) at Hawks Cliff

3.3 Areas of Change – Lynemouth Bay (Northumberland) (2017 to 2019-20)

Lynemouth Bay, like Horden, has a long history of colliery spoil tipping which has resulted in the formation of spoil cliffs and beaches which has prograded the shore seawards. Upon cessation of tipping in 2005, natural processes have resumed and the tipped spoil is now being actively eroded at quite a rate. The effect of this can be seen in Figures 3-3 & 3-4 which show the change in elevation and change in surface slope, respectively, between 2017 and 2019.

In Figure 3-3 it can be seen that between 2017 and 2019, nearly 30,000m^3 of material has been eroded from the colliery spoil cliff within the three areas considered, with nearly a further 55,000m^3 of material eroded from the fronting spoil beach. Whilst some of this material has remained on the foreshore within Lynemouth Bay (note the yellow / green blue areas in Areas 2 and 3 in particular) most will have been washed offshore.

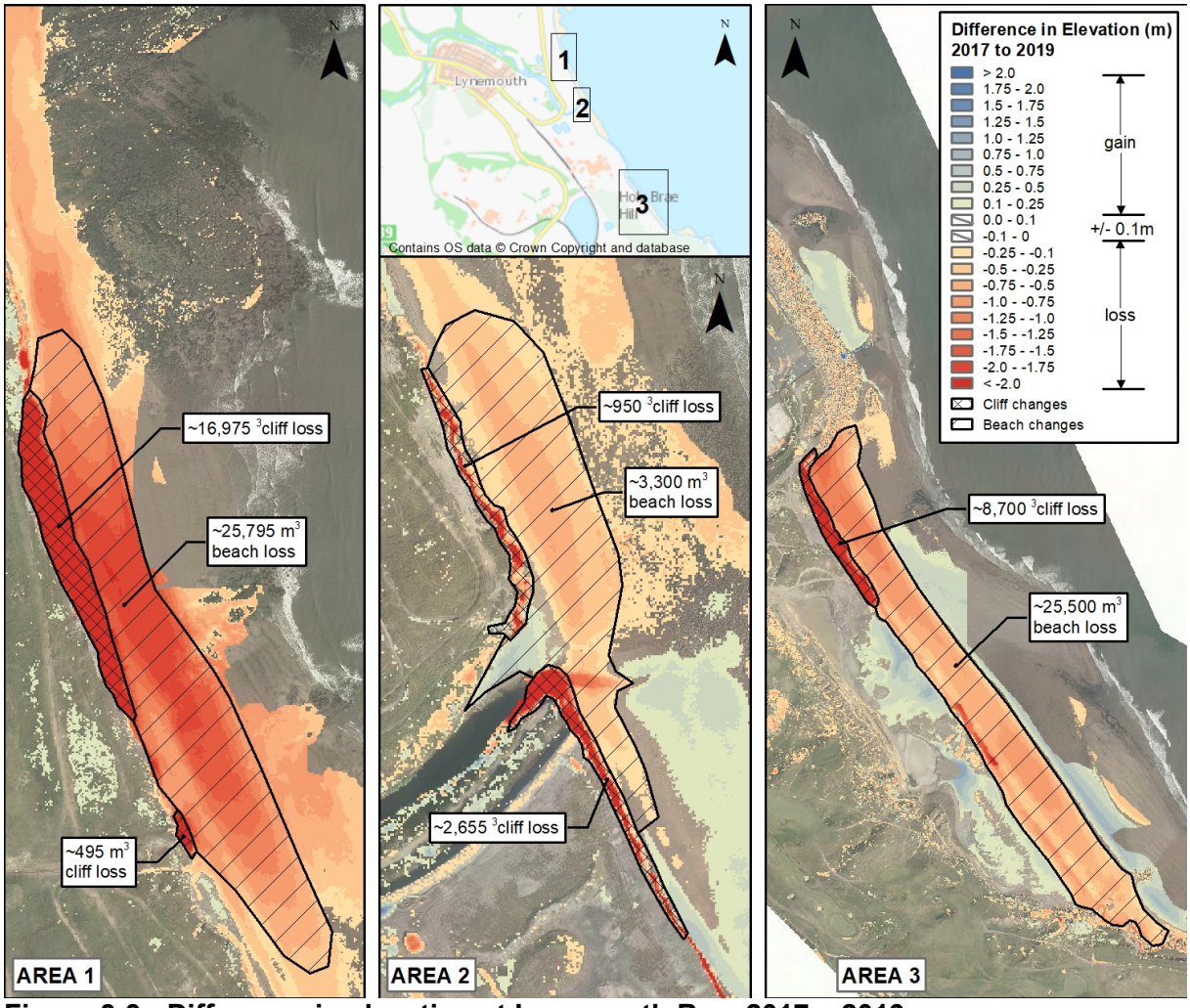

Figure 3-3 - Difference in elevation at Lynemouth Bay, 2017 – 2019

The spoil cliff erosion is also depicted in Figure 3-4, where red areas in the plot are areas of colliery spoil cliff which have become eroded and have changed from near horizontal cliff top to sloping cliff face as the erosion occurs. Green areas in the plot are areas of colliery spoil cliff face that have been eroded, forming a near horizontal beach surface. The total erosion over a 2 year period is a notable change, varying between 3m and 14m depending on location.

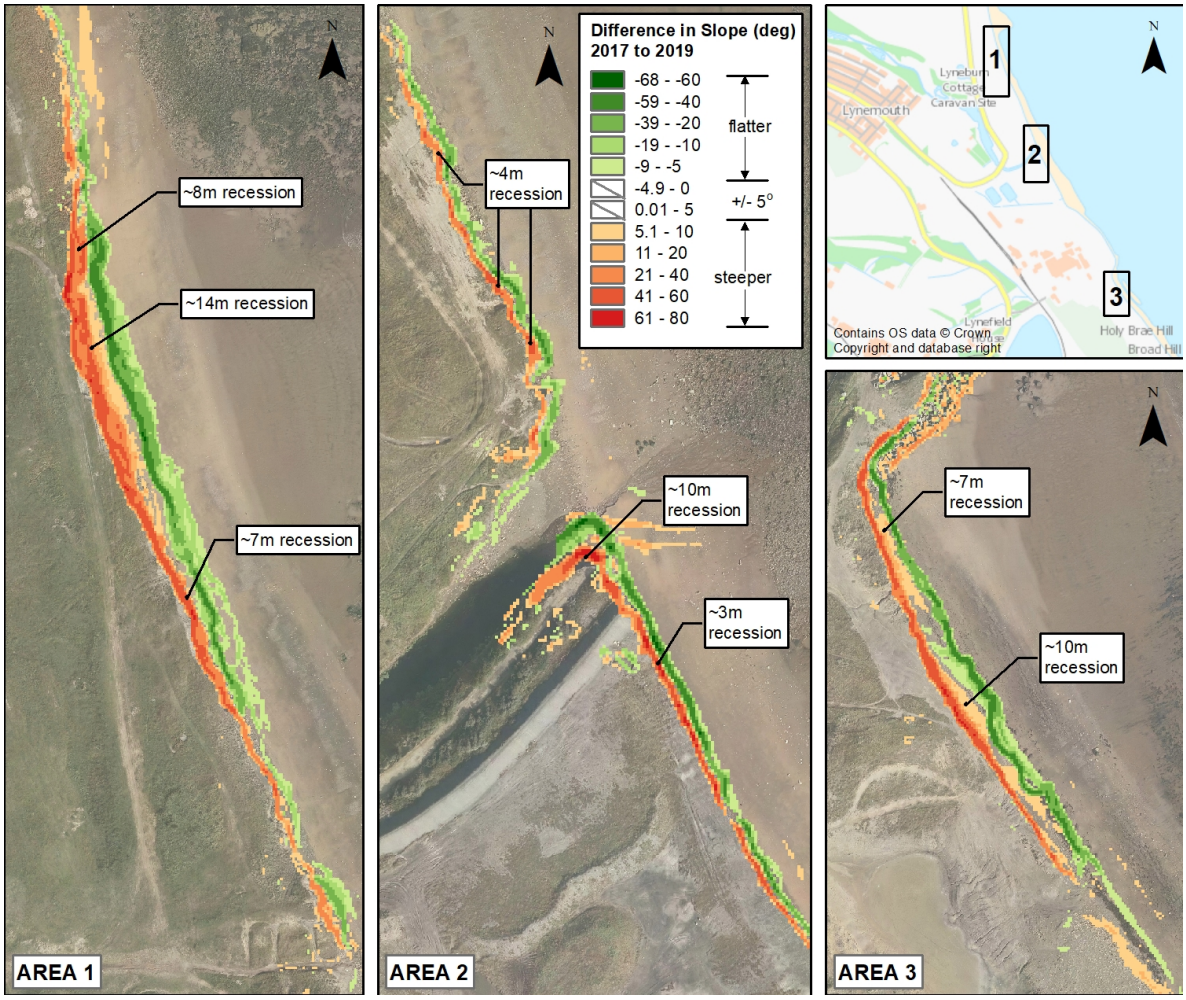

Figure 3-4 - Difference in surface slope at Lynemouth Bay, 2017 – 2019

3.4 Areas of Change – Horden (County Durham) (2017 to 2019-20)

Horden, like Lynemouth Bay, has a long history of colliery spoil tipping which has resulted in the formation of spoil beaches which has prograded the shore seawards and protected the natural backing cliffs and slopes. Upon cessation of tipping, natural processes have resumed and the tipped spoil is now being actively eroded.

In Figure 3-5 it can be seen that between 2017 and 2019, there was a gross loss of 131,100m^3 of material due to ongoing erosion of the colliery spoil beach. Whilst 45,800m^3 of this material has remained on the foreshore, some 85,300m^3 has been washed offshore over this relatively short time period.

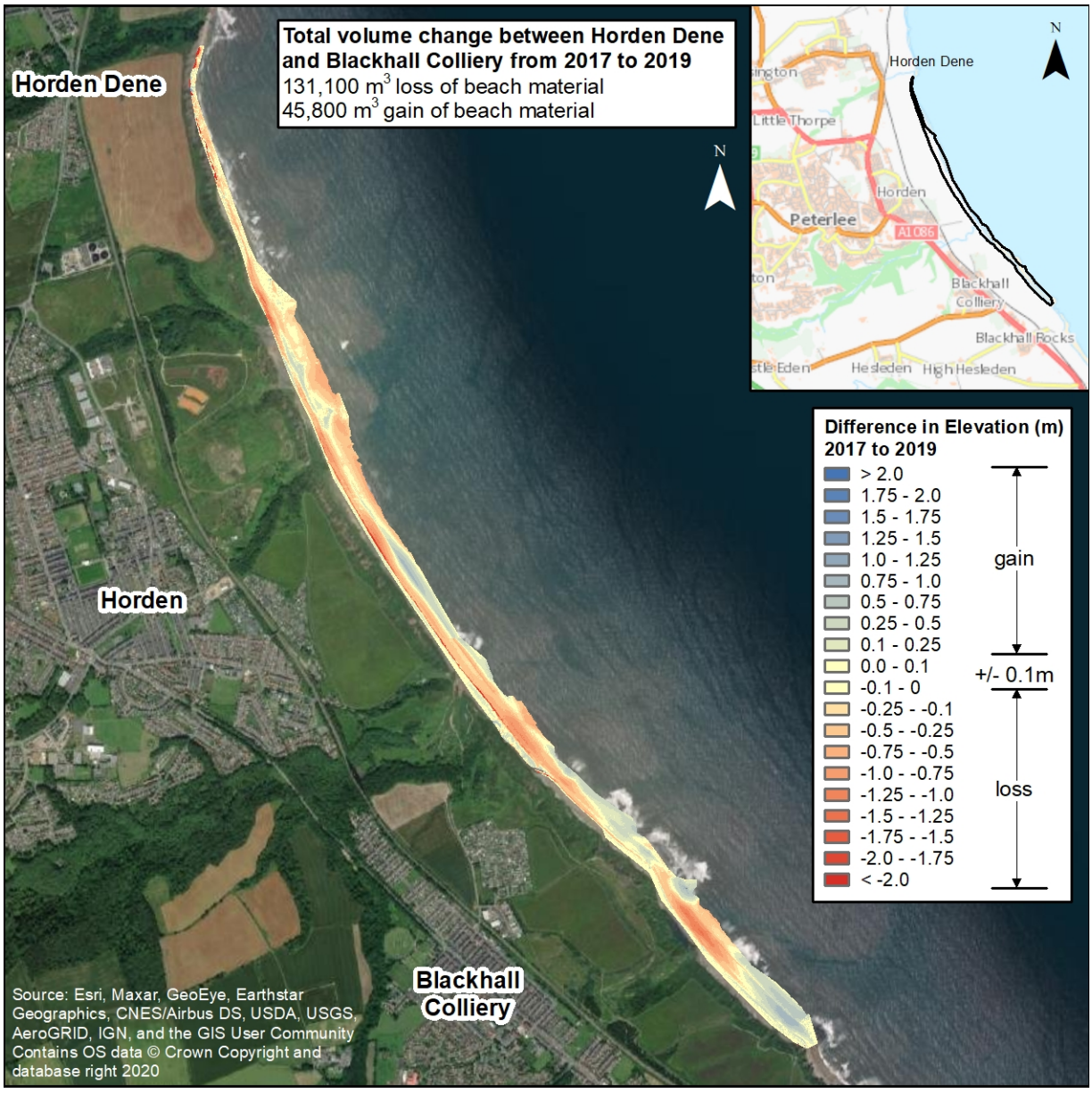

Figure 3-5 - Difference in elevation at Horden, 2017 – 2019

The spoil beach erosion is also depicted at a more local scale from three locations along the Horden frontage in Figure 3-6. In the left hand plot, two slippages are noted in the natural cliffs towards the northern end of Horden where the spoil beach is absent, cutting the cliff top back by up to 12m and depositing material at the cliff toe. In the central plot, the long length of colliery spoil beach throughout the Horden frontage has experienced erosion of 3 – 7m between 2017 and 2019. In the right hand plot, the colliery spoil beach has been eroded not only at its coastal margin, but also by a southern extension of the route of the channel of the beck before it discharges to sea.

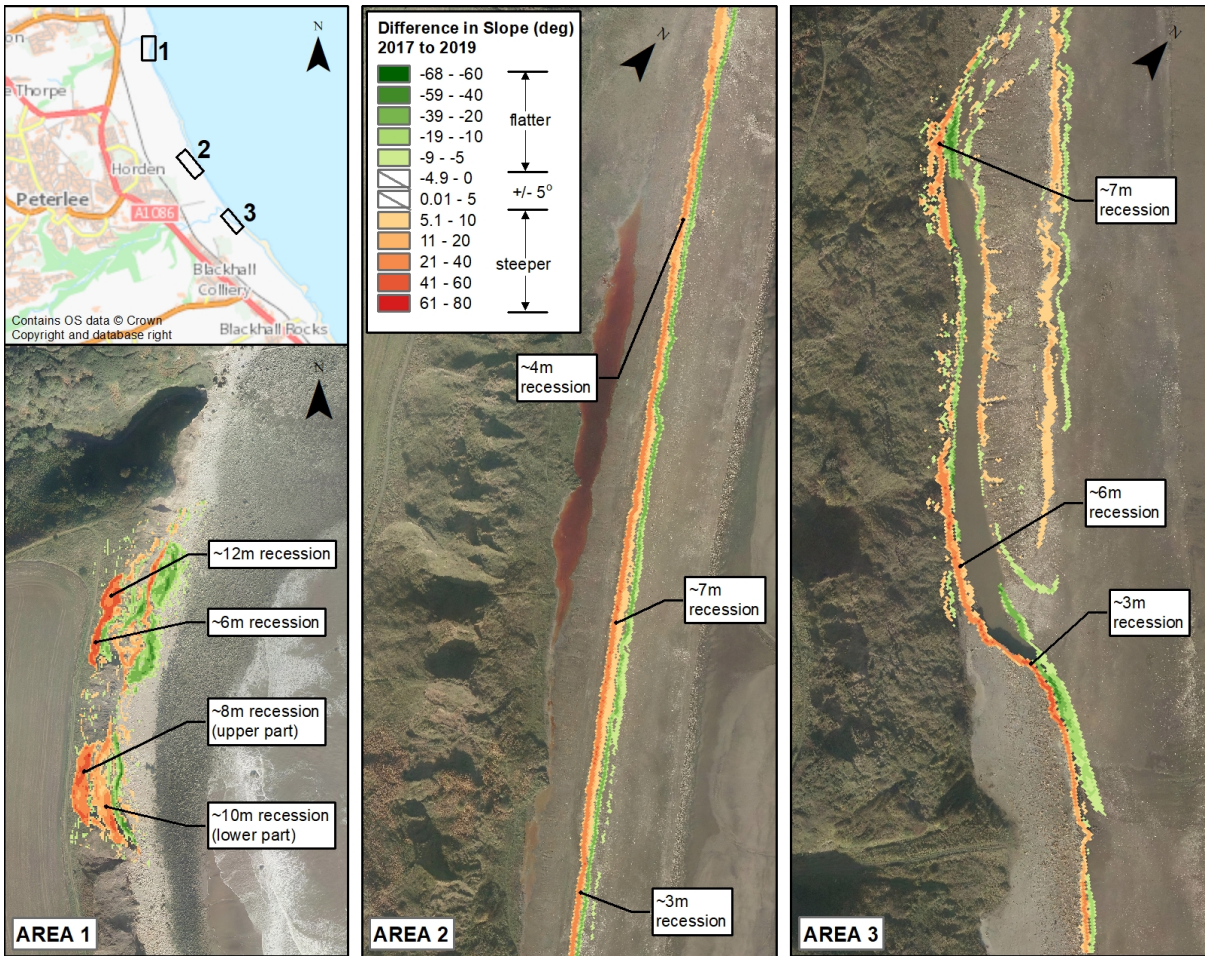

Figure 3-6 - Difference in surface slope at Horden, 2017 – 2019

3.5 Areas of Change – Southern End of Filey Seawall (Scarborough) (2017 to 2019-20)

The coastal slopes at the southern end of Filey seawall have been an area of long-standing concern regarding instability at this location potentially leading to outflanking of the seawall. In respect of this, a rock armour toe has been placed to the immediate south of the slipway for a short distance south of the concrete slipway (approximately 30m in length), but the concern remains ongoing.

The aerial photography analysis (together with the 2020 walkover inspections) has identified that the coastal slopes now protected by the rock armour toe are exhibiting lower activity (although it must be stated they are not necessarily deemed 'stable'), but the coastal slopes immediately south of the rock armour remain more active.

Figure 3-7 (overleaf) shows aerial photography imagery draped over a LiDAR-based DGM from 2017 (top plot) and 2019 (bottom plot). There is not a significant amount of visual difference between the successive surveys, indicating that the issue is not a hugely worsening one, but GIS analysis of the difference between 2017 and 2019 in topographic elevation and surface slope (Figure 3-8) does confirm some activity occurred over this timescale in the headscarp and at the toe of the coastal slopes south of the rock armour. It is intended that a scheme is developed to better protect the southern end of the seawall against outflanking due to this ongoing process.

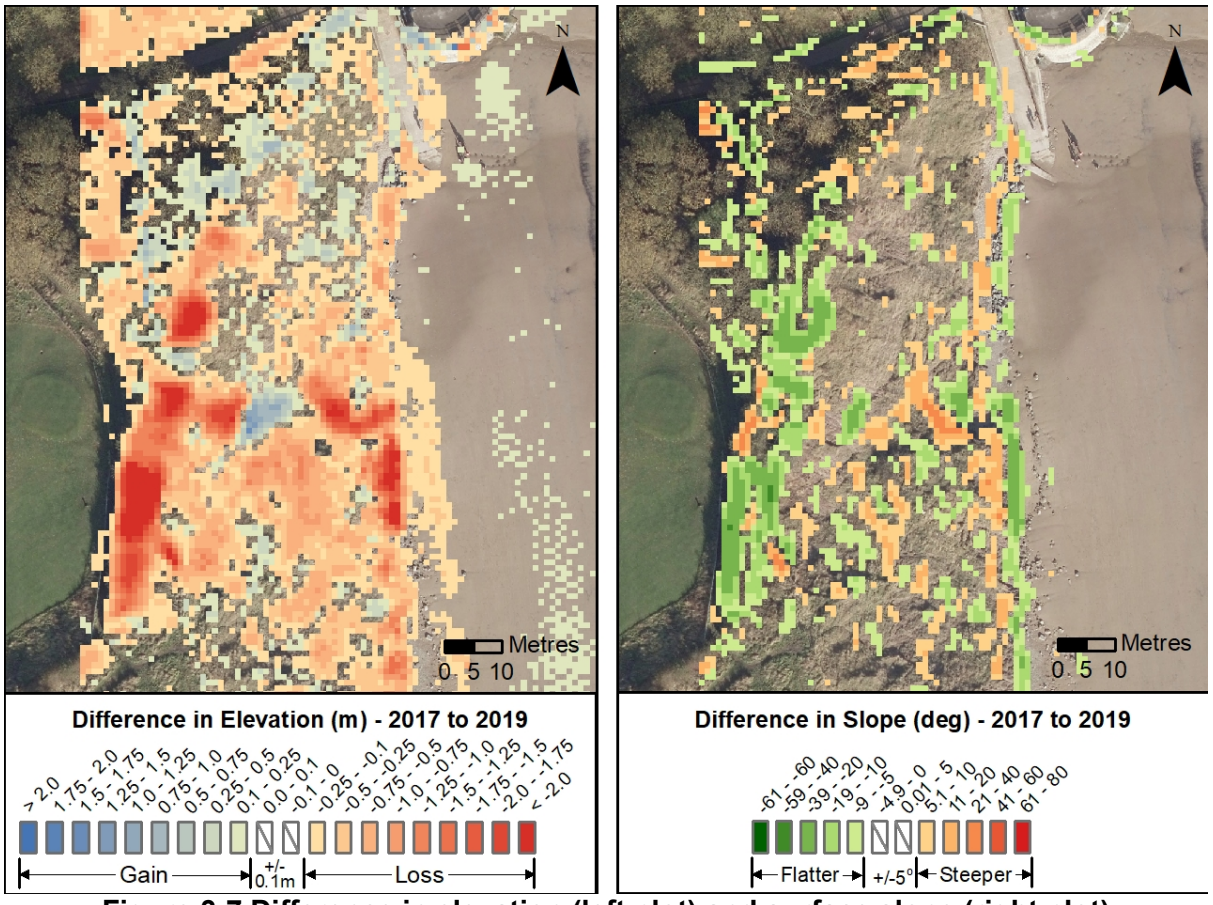

Figure 3-7 Difference in elevation (left plot) and surface slope (right plot) at the southern end of Filey seawall, 2017 – 2019

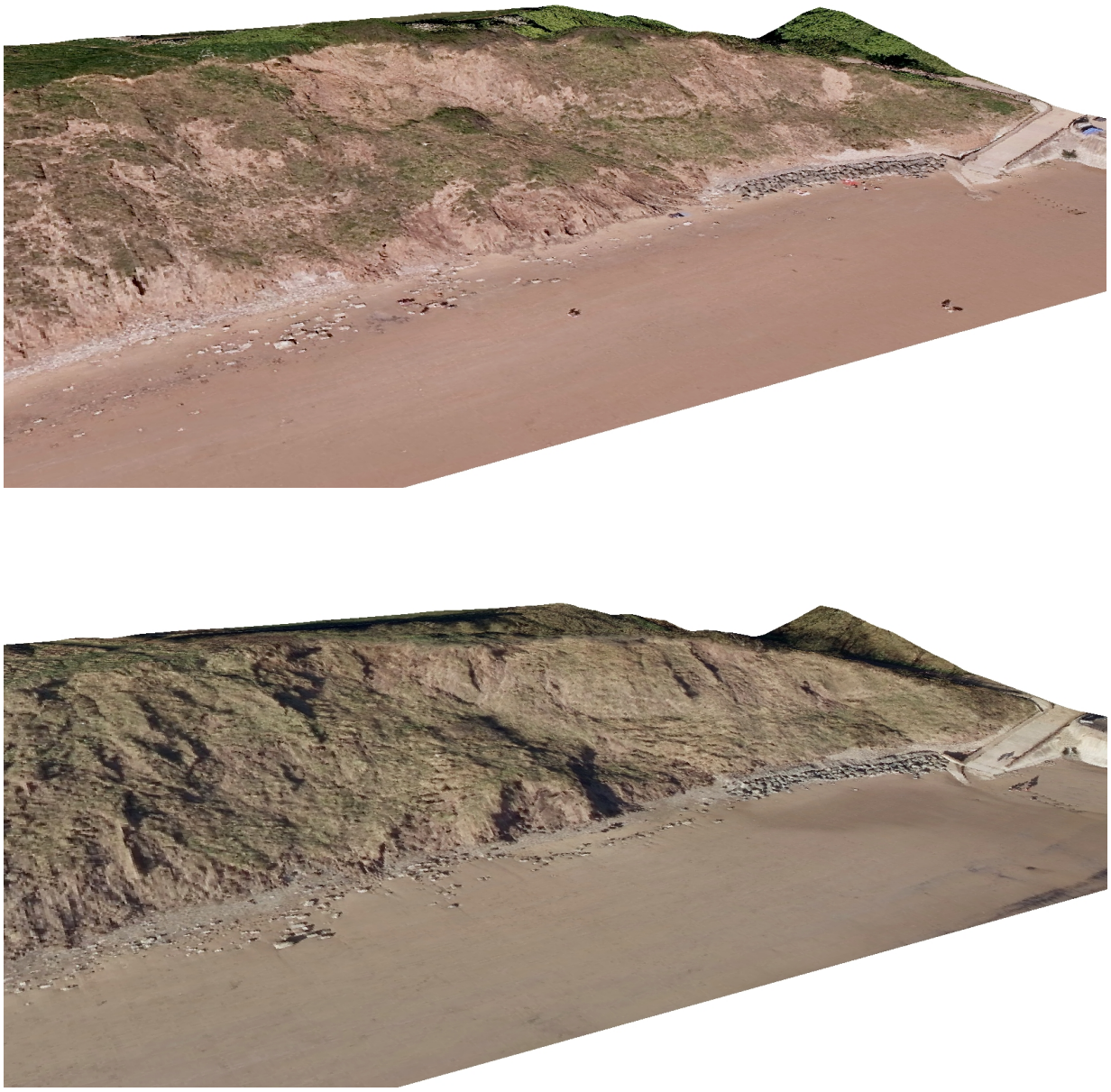

Figure 3-8 - Aerial photography over a LiDAR DGM showing coastal slopes at the southern end of Filey seawall from 2017 (top plot) and 2019 (bottom plot)

4. Summary

The review of the high quality orthorectified imagery acquired in 2019-20 has shown the data is of excellent quality and reveals a large amount of information on the form of the coast and the nature and location of activity in the present day.

Visual comparison with the 2017 survey highlights the following key findings:

- Several sections of cliff throughout the Cell 1 frontage remain active, with occasional, usually localised, rock falls or slumps occurring. Generally, these areas of local cliff instability present no risks to assets, which are either absent, set well back or adaptable to ongoing change (e.g. footpaths). However, they can represent public safety concerns in some areas and usually the local authorities have warning signs in place (e.g. Hawks Cliff (Northumberland), Whitley Bay (North Tyneside), Marsden Bay (South Tyneside), Staithes (Scarborough borough).
- In some areas of local cliff activity, such as: (i) Sandy Bay Caravan Park (Cambois, Northumberland); (ii) Marsden Bay, south of the Grotto (South Tyneside); and (iii) the approach to Cowbar (Redcar & Cleveland), the local authorities / landowners have adapted to the ongoing coastal changes by locally relocating fence lines and cliff top footpaths inland.
- The two most notable areas of cliff landslips between the 2017 aerial photographs and those from 2019/20 are at Hawks Cliff (Northumberland) and near the Clock Tower Café (Scarborough South Beach). At the latter site, the landslip caused destruction of some of the adjacent beach huts and has prompted remedial stabilisation works locally. In addition, persistent outflanking erosion continues to be observed at the southern end of Filey Seawall (Scarborough borough), where the rock revetment ends.
- In some areas of coast that have previously been subject to cliff collapses or landslips, caravans have been newly placed in (or returned to) areas known to be potentially active and vulnerable to further recession. This is most noticeable at Newbiggin Point Caravan Park (Northumberland) and Majuba (Redcar & Cleveland).
- In other areas of coast that have previously been subject to cliff collapses or landslips (see 2017 report for recent examples), there appear to have been no further slippages by the time of the 2019-20 survey and affected areas have since become partially or fully covered with vegetation. [Such areas include Marsden Bay (South Tyneside), Port Mulgrave and Runswick Bay (Scarborough borough), where further slippages are known to have occurred since the 2019-20 survey (see **Appendix A**) and should be apparent in the aerial photography from the next scheduled survey in 2021].
- A new sink hole has opened up in the cliff top at Whitburn Coastal Park (South Tyneside) and an existing sink hole has become further enlarged.
- A number of new construction works have now been completed since the 2017 survey, most notably:
    - **Seahouses Main Pier** – delivered by Northumberland County Council;
    - **Whitley Bay Coastal Masterplan** – some phases complete with some remaining ongoing, being delivered by North Tyneside Council;
    - **Whitby Piers Coast Protection Scheme** – delivered by Scarborough Borough Council;
    - **Scarborough Spa Coastal Slope Stabilisation Scheme** – delivered by Scarborough Borough Council; and

- **Clock Tower Café Coastal Slope Stabilisation Scheme** – delivered by Scarborough Borough Council.

- It is also apparent that some new land use developments have occurred, including demolition of infrastructure behind the seawall at Hendon (Sunderland) and demolition of the Futurist Theatre (Scarborough).
- Some areas of the coastline remain dynamic, in particular at the mouths of estuaries or small burns such as the Tweed estuary, Brunton Burn, Embletonburn Mouth, Aln estuary, Warkworth Harbour and Meggies Burn (all Northumberland) and Castle Eden Dene (County Durham). In these locations, changes in the channel of the watercourses can have effects on the erosion or accretion of the adjacent coastlines or can cause increased or relieved loading pressure on structures such as quay walls.
- Elsewhere, spits and barrier beaches such as at Goswick Sands, Ross Back Sands and Budle Point (all Northumberland) have continued to grow.
- Erosion of colliery spoil beaches or cliffs has continued at a measurable rate in Lynemouth Bay (Northumberland) and at Blast Beach, Hawthorn Hive, Shippersea Bay and Horden (all County Durham).
- Several dune areas appeared to show embryonic dune vegetation growth in front of the toe of the main dune with no areas of notable blow-outs or erosion identified. Also, in areas of tidal flats, such as Lindisfarne National Nature Reserve, there appears to be some saltmarsh growth. However, these changes may be due to the timing of the photography with respect to seasonal changes in dune and marsh vegetation.

LiDAR data was collected in 2019-20 to compliment the aerial photography. GIS-based comparison between the 2017 and 2019/20 LiDAR surveys highlights the following key findings in the four areas of targeted analysis:

- **Hawks Cliff** - Pre-existing rock falls at two distinct areas have become exacerbated through a larger-scale cliff failure in the area in between. Material lost from the cliff crest and cliff face has been deposited at the toe as talus debris. It is envisaged that this will slowly be eroded away over time and future surveys should capture the morphological effects of such processes. The cliff top path has been relocated inland away from the affected section of cliff top.
- **Lynemouth Bay** - Since cessation of colliery spoil tipping in 2005, the historically tipped spoil has actively been eroded. Over the 2 year period from 2017 to 2019, recession varied between 3m to 14m, depending on location.
- **Horden** – Like Lynemouth Bay, Horden historically received tipped colliery spoil and since cessation has been experiencing erosion of the spoil beaches. Over the 2 year period from 2017 to 2019, recession varied between 3m to 7m, depending on location.
- **Filey** – The coastal slopes immediately south of the Filey seawall are (quasi) protected at their toe by rock armour and showed little change from 2017 to 2019, but the coastal slopes to the immediate south of the rock armour are showing ongoing slippage at the headscarp and erosion at the toe.

Appendix A – Recent Cliff Landslips and Rock Falls

Some slippages or rock falls are known to have occurred in the cliffs since the 2019-20 aerial photography surveys were undertaken. These include:

- **Marsden Bay** (rock fall) - In late January 2021, following a period of heavy rainfall and freezing temperatures. The collapse was captured in a video clip by a member of the public and posted on social media.
- **Huntcliff**, near Saltburn (landslip, shown below) – In late January 2021, following a period of heavy rainfall and freezing temperatures. Redcar & Cleveland Council closed a section of the Cleveland Way cliff top footpath while the site was being inspected.

- **Runswick Bay** (landslip, shown below) - In late January 2021, following a period of heavy rainfall and freezing temperatures. The HM Coastguard estimated 200 tonnes of cliff material fell onto the beach.

(Image: Staithes Coastguard)

- **Port Mulgrave** (landslip) - In late January 2021, following a period of heavy rainfall and freezing temperatures. Reactivation of part of an earlier, October 2018, landslip that left recently installed metal access steps to the beach dangling precariously.
- **Whitby** (landslip) - In early January 2021 following a period of heavy rainfall. The North York Moors Park Authority closed a 1.4 km section of the Cleveland Way between Whitby Abbey Farm and Saltwick Bay, diverting the National Trail to an alternative route. The intention is to set-back the path once it is know if any subsequent slippages occur along this section.
- **Easington Colliery** (erosion near footpath) - In late November 2019, with the National Trust issuing a public warning statement on social media alerting the public to the dangers in this location.