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Cell 1 Regional Coastal Monitoring Programme Overview Report (2008 - 2011)

Northumberland County Council · North Tyneside Council · South Tyneside Council · Sunderland City Council · Durham County Council · Hartlepool Borough Council · Redcar & Cleveland · East Riding

Final Report

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Abbreviations and Acronyms

Acronym / Abbreviation	Definition
AONB	Area of Outstanding Natural Beauty
CAM	Condition Assessment Manual
CBU	Cliff Behaviour Unit
DGM	Digital Ground Model
GIS	Geographical Information System
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
Lidar	Light Detection and Range
m	metres
MHWN	Mean High Water Neap
MHWS	Mean High Water Spring
MLWN	Mean Low Water Neap
MLWS	Mean Low Water Spring
MSL	Mean Sea Level
NCAG	Northumbrian Coastal Authorities Group (part of wider NECG since 2009)
NECAG	North East Coastal Authorities Group (part of wider NECG since 2009)
NECG	North East Coastal Group (formed in 2009)
NFCDD	National Flood and Coastal Defence Database
ODN	Ordnance Datum Newlyn
SMP	Shoreline Management Plan

Glossary of Terms

Term	Definition
Beach nourishment	Artificial process of replenishing a beach with material from another source.
Berm crest	Ridge of sand or gravel deposited by wave action on the shore just above the normal high water mark.
Breaker zone	Area in the sea where the waves break.
Coastal squeeze	The reduction in habitat area which can arise if the natural landward migration of a habitat under sea level rise is prevented by the fixing of the high water mark, e.g. a sea wall.
Downdrift	Direction of alongshore movement of beach materials.
Ebb-tide	The falling tide, part of the tidal cycle between high water and the next low water.
Fetch	Length of water over which a given wind has blown that determines the size of the waves produced.
Flood-tide	Rising tide, part of the tidal cycle between low water and the next high water.
Foreshore	Zone between the high water and low water marks, also known as the intertidal zone.
Geomorphology	The branch of physical geography/geology which deals with the form of the Earth, the general configuration of its surface, the distribution of the land, water, etc.
Groyne	Shore protection structure built perpendicular to the shore; designed to trap sediment.
Mean High Water (MHW)	The average of all high waters observed over a sufficiently long period.
Mean Low Water (MLW)	The average of all low waters observed over a sufficiently long period.
Mean Sea Level (MSL)	Average height of the sea surface over a 19-year period.
Offshore zone	Extends from the low water mark to a water depth of about 15 m and is permanently covered with water.
Storm surge	A rise in the sea surface on an open coast, resulting from a storm.
Swell	Waves that have travelled out of the area in which they were generated.
Tidal prism	The volume of water within the estuary between the level of high and low tide, typically taken for mean spring tides.
Tide	Periodic rising and falling of large bodies of water resulting from the gravitational attraction of the moon and sun acting on the rotating earth.
Topography	Configuration of a surface including its relief and the position of its natural and man-made features.
Transgression	The landward movement of the shoreline in response to a rise in relative sea level.
Updrift	Direction opposite to the predominant movement of longshore transport.
Wave direction	Direction from which a wave approaches.
Wave refraction	Process by which the direction of approach of a wave changes as it moves into shallow water.

Preamble

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the north east coastline, from the Scottish Border (just south of St. Abb's Head) to Flamborough Head in East Yorkshire. 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 data collection, analysis and reporting is undertaken as a partnership between the following organisations:

1. Introduction

1.1 Study Area

The Cell 1 Regional Coastal Monitoring Programme covers approximately 300km of the north east 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' (or 'Cell 1' for short) in England and Wales (Figure 1).

Within this frontage the coastal landforms vary considerably, comprising low-lying tidal flats with occasional fringing salt marshes, hard rock cliffs that are mantled with glacial till to varying thicknesses, softer rock cliffs, expansive sandy beaches backed by dunes, and extensive landslide complexes.

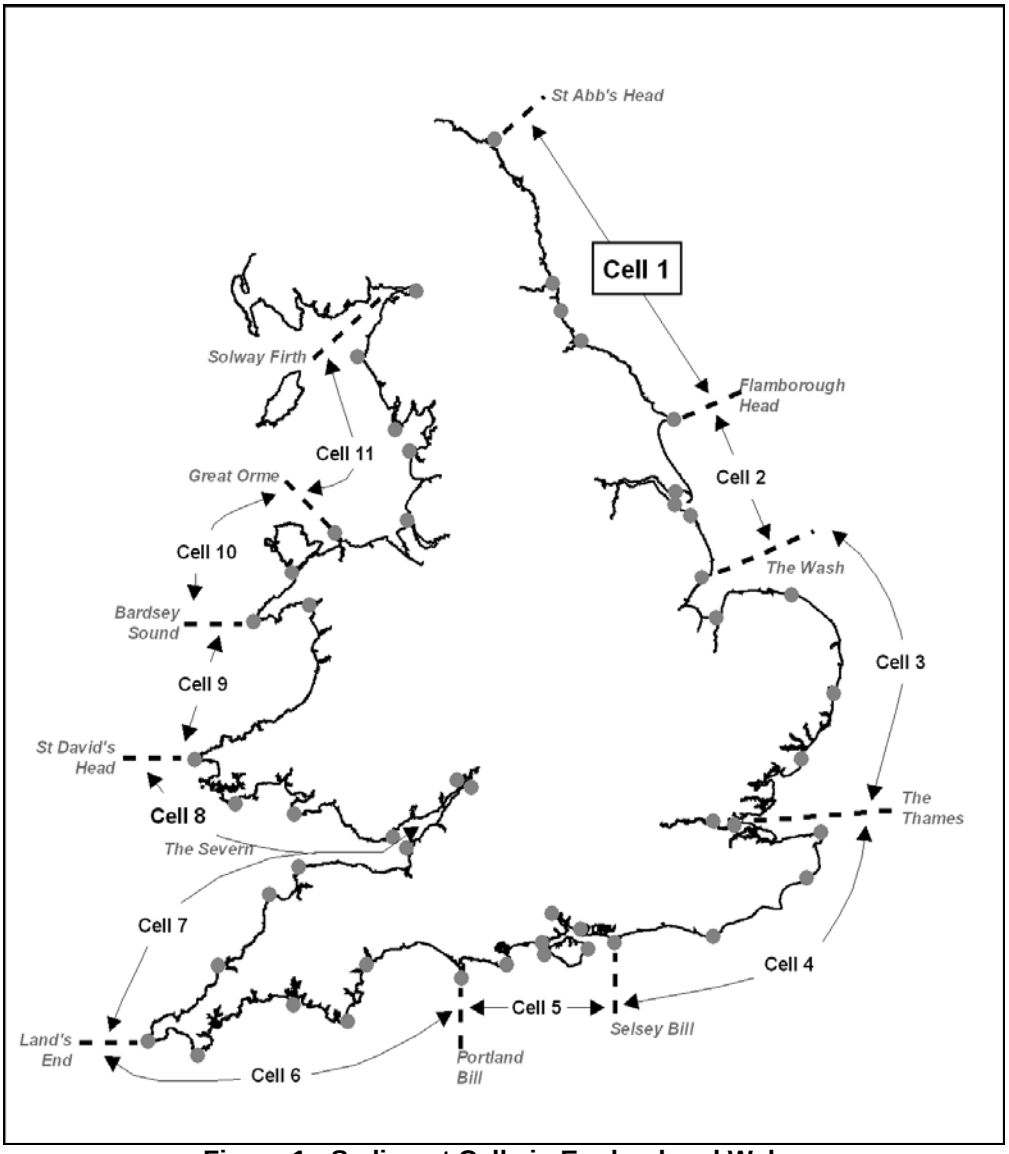

Figure 1 - Sediment Cells in England and Wales

For purposes of analysis, the Cell 1 frontage has been split into the sub-sections listed in the Table 1.

Table 1 Sub-division of the Cell 1 Coastline

Authority	Zone
Northumberland County Council	Spittal A
	Spittal B
	Goswick Sands
	Holy Island
	Bamburgh
	Beadnell Village
	Beadnell Bay
	Embelton Bay
	Boulmer
	Alnmouth Bay
	High Hauxley and Druridge Bay
	Lynemouth Bay
	Newbiggin Bay
	Cambois Bay
	Blyth South Beach
North Tyneside Council	Whitley Sands
	Cullercoats Bay
	Tynemouth Long Sands
	King Edward's Bay
South Tyneside Council	Littehaven Beach
	Herd Sands
	Trow Quarry
	Marsden Bay
Sunderland City Council	Whitburn Bay
	Harbour and Docks
	Hendon to Ryhope
Durham County Council	Featherbed Rocks
	Seaham
	Blast Beach
	Hawthorn Hive
	Blackhall Colliery
Hartlepool Borough Council	North Sands
	Headland
	Middleton
	Hartlepool Bay
Redcar & Cleveland Borough Council	Coatham Sands
	Redcar Sands
	Marske Sands
	Saltburn Sands
	Cattersty Sands (Skinningrove)
Scarborough Borough Council	Staithes
	Runswick Bay
	Sandsend Beach, Upgang Beach and Whitby Sands
	Robin Hood's Bay
	Scarborough North Bay
	Scarborough South Bay
	Cayton Bay
	Filey Bay

1.2 Coastal Monitoring, Pre-2008

Prior to 2008, coastal monitoring differed north and south of the River Tyne, with each of these frontages being managed by different Coastal Groups, namely Northumbrian Coastal Authority Group (NCAG) in the north and North East Coastal Authority Group (NECAG) in the south.

1.2.1 Northumbrian Coastal Authority Group

Following development of the first Shoreline Management Plan (SMP) within NCAG between St. Abb's Head and the River Tyne (coastal sub-cell 1a) in the late 1990s (Posford Duvivier, 1998), a Strategic Coastal Monitoring Programme was designed across this frontage in 2001 to specifically address known data gaps or areas particularly susceptible to coastal change. This was intended as a means of better understanding trends in coastal evolution so as to inform future management decisions. The programme included a suite of beach profile surveys in autumn of each year as a Full Measures survey, with a repeat of a selection of these every spring as a Partial Measures survey. In addition, walk-over inspections of the coastline were undertaken every two years, and aerial photography was undertaken once in 2003 to complement an earlier data set from 1999 (see Section 1.2.2). The first beach surveys were initiated in April 2002 and have subsequently been undertaken at six-monthly intervals as Full Measures or Partial Measures to April 2011. From Full Measures 2008 onwards, the NCAG programme became subsumed within the wider Cell1 Regional Coastal Monitoring Programme.

Over the years, aspects of the NCAG Strategic Coastal Monitoring Programme were refined or enhanced, with surveys being added to better capture the geographical extent or seasonal patterns of change as understanding of key physical processes began to increase based on analysis of early datasets. Additionally, a MS Access database was used to record findings from the walk-over inspections, allowing signs of deterioration over time to be recorded in a consistent form every 2 years; and using software that was usable on an operational basis to the maritime Local Authorities.

Some specific enhancements included addition of a topographic survey at Holy Island causeway to investigate rates of sand deposition following raising of the causeway road levels, addition of cliff top surveys at two caravan parks to monitor cliff recession rates, and topographic surveys at the mouths of the River Tweed and River Aln estuaries to capture the three-dimensional nature of the complex relationships between the beaches and the dynamic behaviour of the river channels.

Much of the data and, importantly, much of the understanding of physical change along this coast has fed into both high level or strategic management decisions and individual scheme appraisals and design. Indeed, the Northumberland and North Tyneside SMP2, which was produced between late 2007 and early 2009 (Royal Haskoning, 2009), benefited greatly from the datasets that were available since April 2002 along this frontage. Also, both Northumberland County Council and North Tyneside Council structure their coastal defence maintenance activities around the findings from the coastal walk-over inspections.

1.2.2 North East Coastal Authority Group NECAG

Several authorities within NECAG undertook their own local monitoring programmes following completion of the first Shoreline Management Plans in coastal sub-cells 1b (River Tyne to Seaham Harbour) and 1c (Seaham Harbour to Huntcliffe, Saltburn). Most notably, this included a suite of beach and bathymetric surveys along Sunderland City Council's frontage and quarterly asset inspections by in-house engineers along Hartlepool Borough Council's frontage.

In addition to this, the Huntcliffe (Saltburn) to Flamborough Head Shoreline Management Plan (coastal sub-cell 1d), adopted in January 1998, recommended a schedule of coastal monitoring activities which included beach and aerial photographic surveys.

In accordance with these recommendations, Scarborough Borough Council commissioned the first aerial photographic survey, covering the entire NECAG coastline, in 1999. This was extended to also cover the coastline northwards to St. Abb's Head on behalf of NCAG.

Then, in November 2001, Scarborough Borough Council approved a five year Coastal Monitoring Programme, primarily covering the North Yorkshire coast from Staithes to Speeton but also including some strategic coastal monitoring for the whole of NECAG.

This 5-year Coastal Monitoring Programme included the following elements:

- aerial surveys in 2003 and interpretative analysis (covering the whole of Cell 1)
- bathymetric and sediment budget scoping study (covering the Tees Estuary to Flamborough Head)
- wave and tide data collection and interpretative report (Scarborough)
- 6-monthly beach surveys and interpretative report (Staithes to Speeton)
- cliff condition surveys and interpretative report (Staithes to Speeton)
- coastal defence condition surveys and interpretative reports (Staithes to Speeton)

Following completion of this 5-year programme in 2006/07, proposals to undertake further monitoring were discussed by officers with Defra and the Environment Agency as part of a national review of coastal monitoring programmes. In addition to this national review, which recommended coastal monitoring on a more regional basis, the River Tyne to Flamborough Head SMP2 was published in 2007, re-stating the need for monitoring to be implemented in a co-ordinated manner. In 2007, it was therefore proposed to develop a regional coastal monitoring programme for the whole of Cell 1 commencing in autumn 2008.

In the transition period, a walk-over inspection of the entire NECAG coastline was undertaken in 2008, extending between the River Tyne and Flamborough Head. This was the first large-scale walk-over undertaken across the frontage and the methodology was designed to complement the similar assessments being undertaken across the NCAG frontage, also in 2008, as part of their Strategic Coastal Monitoring Programme. In effect, these surveys combined became the first walk-over inspections undertaken in a consistent manner across the whole coastal Cell 1, with findings being fed into the National Flood and Coastal Defence Database.

1.3 Cell 1 Regional Coastal Monitoring Programme, 2008 – 2011

In 2008, the Cell 1 Regional Coastal Monitoring Programme was initiated. This subsumed and continued both the NCAG Strategic Coastal Monitoring Programme and the previous 5-year NECAG Coastal Monitoring Programme, which became expanded to address specific issues or uncertainties identified during the preparation of the River Tyne to Flamborough Head SMP2 (Royal Haskoning, 2007).

The main elements of the Cell 1 Regional Coastal Monitoring Programme during its first three years involved (see Appendices A, B and C for locations):

- beach profile surveys
- beach topographic surveys
- cliff top recession surveys
- real-time wave data collection
- bathymetric and sea bed characterisation surveys
- aerial photography and Lidar surveys to generate orthophotos
- walk-over surveys
- development and maintenance of a website called the North East Coastal Observatory (NECO)

The beach profile surveys, topographic surveys and cliff top recession surveys are undertaken as a 'Full Measures' survey in autumn every year. Some of these surveys are then repeated the following spring as a 'Partial Measures' survey.

Each year, an Analytical Report is produced for each individual authority, providing a detailed analysis and interpretation of the 'Full Measures' surveys.

This is followed by a brief Update Report for each individual authority, providing ongoing findings from the 'Partial Measures' surveys.

In addition, separate reports are produced for other elements of the programme as and when specific components are undertaken, such as wave data collection, bathymetric and sea bed sediment data collection, aerial photography, and walk-over visual inspections.

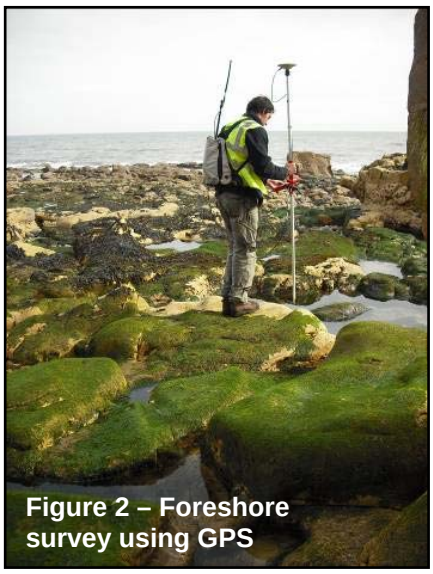

Figure 2 – Foreshore survey using GPS

This 'Cell 1 Overview Report' is intended to draw together key findings from each of the aforementioned reports, covering the three-year period 2008 to 2011, now that the initial contracted phase of the programme is completed. The report provides an overview of key findings of relevance to each maritime Local Authority, provides some case studies of where specific data types have been particularly useful, assesses the website and data usage, produces commentary of the future five year phase of the programme, and provides some concluding discussion about the programme.

2. Overview of Programme Findings

2.1 Northumberland

2.1.1 Monitoring Activities

Northumberland County Council's frontage extends from the Scottish border in the north to Hartley in the south. For the purposes of data analysis, it has been sub-divided into fifteen areas, namely:

- Sandstell Point
- Spittal
- Goswick Sands
- Holy Island
- Bamburgh
- Beadnell Village / Beadnell Bay
- Embleton Bay
- Boulmer
- Alnmouth Bay
- Hauxley & Druridge Bay
- Lynemouth Bay
- Newbiggin-by-the-Sea
- Cambois
- Blyth South Beach

Along Northumberland County Council's frontage, the following coastal monitoring has been undertaken between 2008 and 2011:

- Full Measures survey annually each autumn/early winter comprising:
  - Beach profile surveys along 88 no. transect lines
  - Topographic survey along Holy Island
  - Topographic survey along Alnmouth Bay
  - Topographic survey along Sandstell Point (since Full Measures 2009)
  - Topographic survey along Newbiggin Bay (since Full Measures 2010)

- Partial Measures survey annually each spring comprising:
  - Beach profile surveys along 39 no. transect lines
  - Topographic survey along Alnmouth Bay
  - Topographic survey along Sandstell Point (since Full Measures 2009)
  - Topographic survey along Newbiggin Bay (since Full Measures 2010)

- Cliff top survey (bi-annually) at:
  - Cliff top survey at Newbiggin Caravan Park
  - Cliff top survey at Sandy Bay Caravan Park
  - Cliff top survey at Cambois (since Partial Measures 2009)

- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010

- Wave data collection offshore from Newbiggin Ness from May 2010 to May 2011

- Walk-over inspections of coastal defences and natural assets in summer 2008 and summer 2010

2.1.2 Rationale

The monitoring programme along the Northumberland coast was initially designed in 2001 to incorporate beach profiles along seventy-eight transect lines, aerial photography and walk-over inspections in order to better understand changes in key areas highlighted by the St. Abb's Head to River Tyne Shoreline Management Plan, which was published in September 1998.

The design of the programme adopted a risk-based approach, meaning that large sections of stable coastline (typically hard rock geology) or areas with few assets at risk of erosion were not surveyed using beach profiles, but instead changes were recorded by the aerial photography and walk-over inspections. Beach profiling then focused on areas where change

was anticipated to be more dynamic or where assets were perceived to have been at some potential risk from erosion or overtopping.

The beach profiles were first surveyed in April 2002 along seventy-eight transect lines. These were repeated in autumn 2002 and annually thereafter during what became know as the Full Measures surveys. From spring 2003, repeat beach profile surveys were undertaken along a represented sample of twenty-nine of the transect lines in what became known as the Partial Measures surveys in order that seasonal cycles of behaviour could be captured.

In the Full Measures survey of 2007, a further ten profile lines were added in order to better understand beach changes that were being observed along some bays. These have been repeated in each Full and Partial Measures survey since that time.

Topographic surveys were added to the monitoring programme at Holy Island (2004) to investigate the impacts of raising the road causeway upon the adjacent sand flats in terms of increased siltation. Similar surveys have since been added at Alnmouth (2005) and Sandstell Point (2009) to capture the three-dimensional nature of changes along the foreshore associated with complex behaviour patterns between the foreshore and the adjacent river channels. A topographic survey was also introduced at Newbiggin Bay (2010) to continue the post-project monitoring that was being undertaken to evaluate the performance of a large capital recharge and offshore breakwater scheme that was constructed in 2007.

Having identified quite rapid rates of cliff retreat from aerial photography analysis and the 2-yearly walk-over inspections, cliff top surveys were introduced at Newbiggin Bay Caravan park (2007), Sandy Bay Caravan Park (2007) and Cambois Bay (2009). These are specifically to capture better data on locations and rates of cliff top recession.

Walk-over inspections of the coastal defences and natural assets, such as beaches, dunes and cliffs, commenced in 2002 and have been repeated at 2-yearly intervals since. These have informed the development of maintenance strategies and applications for funding for capital improvement works under the annual Medium Term Plan process. Data has been input to both a bespoke MS Access database and the Environment Agency's National Flood and Coastal Defence Database.

Aerial photography has been undertaken in 1999 (prior to the monitoring programme, but intended to help inform the original SMP development), 2003 and 2010. The latter survey also coincided with capture of topographic data using Lidar technology.

A wave-rider buoy was deployed off Newbiggin Ness in May 2010 for a period of 1 year to capture data relating to the wave climate and help inform post-project evaluation of the Newbiggin Bay capital recharge and offshore breakwater scheme.

2.1.3 Key Findings

Significant changes were recorded on a quite widespread basis across much of Northumberland County Council's coastal frontage over the winter of 2009/10. The most significant changes related to foreshore lowering, cliff recession, dune erosion, and erosion of protective foreshore slag banks. It is likely that the severe weather conditions that affected Great Britain that winter (Figure 3) caused much of the change that was observed, due to the heavy rainfall, snowfall and prolonged sub-zero temperatures which persisted and would have affected cliff stability through freeze-thaw cycles.

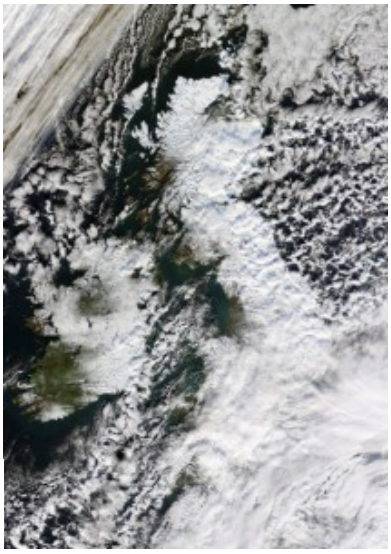

Figure 3 – Severe weather in Great Britain over winter 2009/10

This weakening of the cliff structure also coincided with a period of notable storms in February 2010 and very high tides and heavy storms towards the spring equinox in March 2010. The worst affected areas were the dunes along the southern inner bank of the River Tweed estuary, and the dunes at Goswick Sands, Beadnell Bay, Alnmouth, High Hauxley (see Figure 4), Druridge Bay and Blyth South Beach. Although dramatic because of the suddenness of the erosion, in most areas the cut-back remained within the bounds of previously recorded behaviour that extend back to 2002. In the recent historic records episodes of erosion in the dunes along these frontages have mostly been followed by a sustained period of slow and progressive recovery in upper beach and dune levels. This again has occurred in most locations following the severe winter of 2009/10 to the point where a similarly adverse winter in 2010/11 had no progressive effect in most areas.

Figure 4 – Dune erosion at High Hauxley following the severe winter of 2009/10

Key findings in specific areas have been (working along the coast from north to south):

- At Marshall Meadows Bay there have been a series of slumps in softer till which overlays the hard rock cliffs, cutting the cliff edge back to the footpath in places, and larger rock falls near the caravan park.

- Green Haven's Breakwater is in a poor condition and has deteriorated between the walkover inspections in 2008 and 2010.

- Local slumps have occurred in the cliffs along Magdelene Fields, including one area where fence posts have been lost.

- Whilst repairs were undertaken to the seaward end of the Berwick Breakwater in 2009, the condition of the structure was noted to have generally deteriorated between 2008 and 2010 inspections, including one area where missing blockwork had opened into a void on the inner face of the structure. This is now subject to a capital refurbishment scheme which started in 2011.

- Several defence structures along the River Tweed estuary are in poor condition, including a sloping concrete revetment and a set of rock-filled gabions, and at Spittal Quay.

- Significant inter-relationships have been identified at the mouth of the River Tweed estuary between the dunes, spit and beach, which appear to be dominated by changes in the position of the river channel. Sandstell Point spit undergoes notable variations in form due to prevailing marine and fluvial spate conditions and at times a secondary channel opens across the feature, changing the energy exposure in the inner estuary. The spit is often characterised by a redistribution of sediment between successive surveys with a berm on its crest varying in form from a wide, flat feature centrally located on the spit to a narrow, high feature towards the river side of the spit. The form seems to change periodically. The dunes at the mouth of the estuary have suffered measurable erosion and landward retreat, by up to several metres, since surveying began, but in the most recent surveys appears to have stabilised. The most measurable dune recession appears to occur when the estuary channel incises closely towards this shore and more stable periods arise when the channel is located further seaward.

- Along the Spittal coastal frontage, upper beach level changes can be quite large between successive surveys, but there is no clear and consistent trend in behaviour, suggesting the frontage is responsive to its high marine exposure conditions.

- A relatively large slippage occurred in the cliffs along one section at Scremerston; an area where the East Coast Main Line runs close to the cliff edge.

- Goswick Sands, Holy Island, Bamburgh, Beadnell village, Beadnell Bay and Embleton Bay all tend to be relatively stable and healthy, except for during particularly severe winters or individual storms when cut-back can particularly occur at Goswick Sands and Beadnell Bay, although this is usually followed by periods of progressive post-storm recovery in beach and dune levels. Some areas of dunes, such as at the northern end of Embleton Bay towards Newton Haven, are advancing through accretion.

- Aerial photographs from 1999 and 2010 indicate that the dunes at Ross Back Sands have accreted, building seawards. This is consistent with the longer-term changes at this site.

- There is undermining and voiding in the Main Pier at Seahouses which needs future attention.

- Boulmer has a persistent trend of small-scale lowering of the beach and dune toe.

- Alnmouth Bay demonstrates notable variation in the beach and dunes in the vicinity of the outfall channel of the River Aln estuary. There appear to be episodes of dune and upper beach erosion in front of the golf course and car park when the channel is diverted closer to this shore (i.e. running north-east along the foreshore), rather than exiting more directly to sea along a more easterly alignment.

- Warkworth Harbour has one section of quay wall which collapsed in 2008 at Broomhill Quay during the spate flows in the River Wansbeck following the extreme rainfall conditions that affected Morpeth. Additionally, the North Pier would benefit from further investigation into its condition and stability (the seaward end has fallen away from the main structure and yet is still used by anglers who jump across the gap) and the timber jetty is dilapidated.

- Hauxley has suffered from winter storm damage (as discussed previously) and erosion of rubble-strewn land behind a block revetment wall north of the Nature Reserve has occurred. Fossilised tree stumps have become exposed on the foreshore and within a peat layer at the base of the dunes as foreshore and dune erosion has occurred. A broader pattern of recession has been observed from comparison of aerial photographs from 1999 and 2010.

- Druridge Bay has generally experienced local slumps in the dune face, with the most recent beach profile surveys actually recording some measurable change in the southern part of the bay. The area was particularly affected by erosion during the severe winter of 2009/10.

- At Creswell, tipping of construction rubble down the seaward face of the rock revetment was noted during the walkover inspections in 2010 and brought to the attention of planning officers who stopped this activity. Extensive lengths of rock fall and fracturing of the cliffs has occurred behind Stank Letch Rocks, leading to slumping in the overlying till.

- Cliffs to the north of Snab Point (fronting the Creswell Caravan Park) are active and erosion has resulted in part of the road recently being lost. The failed condition of the gabions at the toe of the cliffs is the likely cause of this erosion.

- Irreversible foreshore erosion has been ongoing at Lynemouth Bay, to the north of the Power Station, where the slag bank has significantly cut landwards. Mechanical re-grading of the slag bank has recently been undertaken in attempt to slow this recession and the Coal Authority is actively looking into the issues.

- A classic text-book 'roll-over' process is occurring along the ridge south of Lynemouth Power Station, with wave action moving coarser material over the crest of the ridge to the back-face where it accumulates.

- There has been retreat of the coastal margin along parts of Newbiggin Moor Golf Course; a process the Golf Club is aware of through its involvement through consultation in the SMP2.

- The replenished beach within Newbiggin Bay has exhibited significant redistribution of sand following recharge and offshore breakwater construction in 2007, with the initial 'salient' feature in the lee of the breakwater now extending seawards to become a breakwater-connected 'tombolo' (Figure 5).

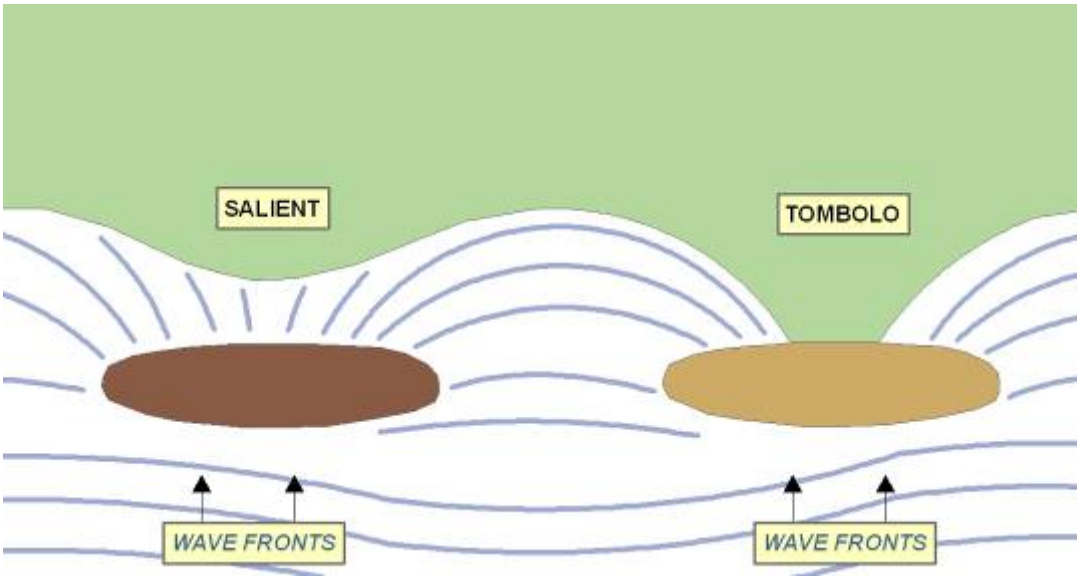

Figure 5 – Salient and Tombolo in Lee of Breakwater

Erosion of sand from the recharged face has occurred (Figure 6), resulting in two distinct 'embayments' which have been formed to the north and south of the breakwater. Sand liberated from the recharged beach due to this process has become deposited at both the northern-most and southern-most ends of the bay, where it is causing unwanted problems due to wind-blow deposition on the promenade (see Section 3.3.1).

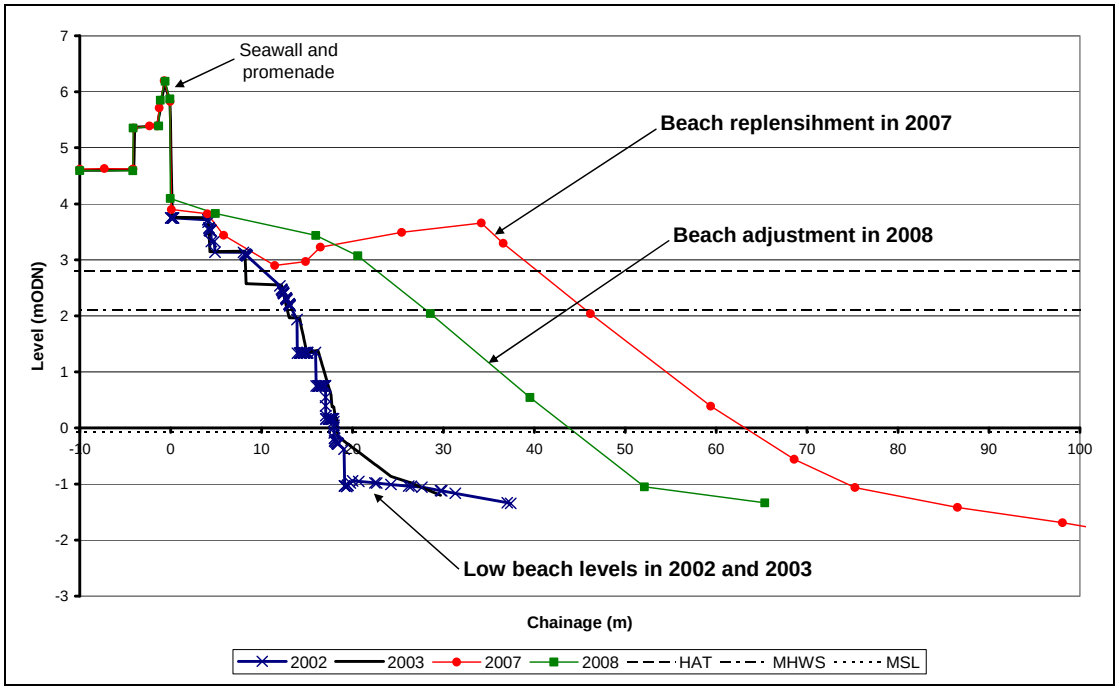

Figure 6 - Profile changes in Newbiggin Bay

- Along Newbiggin Caravan Park, the unprotected section of cliffs has been eroding in small discrete patches. In places, the cumulative cliff top cut back has reached up to 1m since September 2007.

- A cliff collapse occurred in the area south of Spital Point (Newbiggin) between around Coffin Rocks and Bull Rock. This occurred on 6th January 2010, during the severe weather conditions that the country was facing at that time, and tragically resulted in the death of a man who was sea fishing from the cliff top.

- Erosion of the cliff top has been occurring along Sandy Bay Caravan Park, with cut-back particularly severe at the southern boundary of the site (see Section 3.4.1).

- Toe erosion and cliff-face slips have occurred at the northern end of Cambois Bay. This is likely to be linked to changes in the position of the outfall channel of the River Wansbeck estuary, which has undergone notable change since construction of the amenity weir in 1975. The weir has, in effect, truncated the tidal prism of the estuary, causing changes to the flow and morphology.

- Minor erosion of the coastal margin was noted just to the north of the defended section of North Blyth, but more significantly the condition of the defences fronting the Alcan facilities at North Blyth is poor. This is currently being investigated by Northumberland County Council's in-house design team.

- Parts of Blyth South Beach are subject to high wave exposure and correspondingly suffer from periods of notable erosion. In particular the dunes fronting the access road to the Port of Blyth in the north of the bay (where many of the rock-filled gabions have split and become ineffective), the dunes near Meggie's Burn outfall, and the dunes in the centre of the bay have been the most vulnerable.

2.1.4 Future Recommendations

With nine full years of beach profile data available, together with good records from aerial photographs, walk-over surveys, and both topographic and cliff top surveys, behaviours have been observed at some locations which are clearly distinguishable from shorter term or seasonal variations as medium or longer term trends. These trends are important to understand for purposes of shoreline management planning and indeed have informed the SMP2 along this frontage. This demonstrates the value of long term data records and it is strongly recommended that data collection continues uninterrupted into the future.

Minor amendments have been made to the programme over the past nine years to add new of different types of survey in areas where changes have been identified but need more or different data to be better understood. Consequently, there are no major amendments needed to the future programme at the present time.

In relation to the Newbiggin Bay topographic survey, it is recommended that an ‘Edge of Sand’ line is recorded across Spital Carrs in each Full Measures Survey and in each Partial Measures Survey. This is to help understand whether recharge material from the 2007 scheme is spreading across the rocky foreshore area, resulting in smothering of important bird feeding areas.

2.2 North Tyneside

2.2.1 Monitoring Activities

North Tyneside Council's frontage extends from Hartley in the north to the River Tyne in the south. For the purposes of data analysis, it has been sub-divided into four areas, namely:

- Whitley Sands
- Cullercoats Bay
- Tynemouth Longsands
- King Edward's Bay (sometimes known as Tynemouth Shortsands)

Along North Tyneside Council's frontage, the following coastal monitoring has been undertaken between 2008 and 2011:

- Full Measures survey annually each autumn/early winter comprising:
  - Beach profile surveys along 8 no. transect lines (since 2002)
  - Beach profile surveys along an additional 2 no. transects (since 2010)
  - Topographic survey along Whitley Sands (commenced in 2010)

A topographic survey along Tynemouth Longsands is also planned for inclusion in the next Full Measures survey, which is likely to be undertaken in late autumn 2011 (subject to financial and contractual arrangements).

- Partial Measures survey annually each spring comprising:
  - Beach profile surveys along all 10 no. transect lines (since 2010)

- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010

- Walk-over inspections of coastal defences and natural assets in summer 2008 and summer 2010

Figure 7 – Whitley Sands

2.2.2 Rationale

The monitoring programme along the North Tyneside coast was initially designed in 2001 to incorporate beach profiles along eight transect lines, aerial photography and walk-over inspections in order to better understand changes in key areas highlighted by the St. Abb's Head to River Tyne Shoreline Management Plan, which was published in September 1998.

As much of the North Tyneside coast is defended, with most cliff top and riverside areas being heavily developed, each of Whitley Sands, Cullercoats Bay, Tynemouth Longsands and King Edward's Bay had at least one profile transect line.

The beach profiles were first surveyed in April 2002 along the eight transects. These were repeated in autumn 2002 and annually thereafter during what became know as the Full Measures surveys. From spring 2010, repeat beach profile surveys were undertaken along all eight of the transect lines in what became known as the Partial Measures surveys in order that seasonal cycles of behaviour could be captured.

In that first Partial Measures survey of 2010, a further two profile lines were added in order to better understand beach changes that were being observed along the southern end of Whitley Sands and the centre of Tynemouth Longsands. These have been repeated in each Full and Partial Measures survey since that time.

Topographic surveys were added to the monitoring programme at Whitley Sands in Full Measures 2010 to better understand the seasonal dynamics that the profile surveys are exhibiting.

Walk-over inspections of the coastal defences and natural assets, such as beaches, dunes and cliffs, commenced in 2002 and have been repeated at 2-yearly intervals since. These have informed the development of maintenance strategies and applications for funding for capital improvement works under the annual Medium Term Plan process. Data has been input to both a bespoke MS Access database and the Environment Agency's National Flood and Coastal Defence Database.

Aerial photography has been undertaken in 1999 (prior to the monitoring programme, but intended to help inform the original SMP development), 2003 and 2010. The latter survey also coincided with capture of topographic data using Lidar technology.

2.2.3 Key Findings

- The whole North Tyneside frontage experiences notable fluctuations in foreshore level and form due to seasonal variations in wave climate and individual storm events.

- A slip in the undefended cliff at Hartley Cove occurred in early 2010, resulting in temporary fencing to divert people away from the cliff edge. This slump is close to the foreshore access steps.

- The St. Mary's Island causeway would benefit from some minor repairs to prevent further break-up of the structure.

- There is a risk of outflanking at the southern end of the Trinity Road seawall which needs high priority attention.

- The undefended cliffs to the north of Whitley Sands (fronting the Council-owned Golf Course) have experienced some episodes of erosion, particularly following storm events. Some of the material released from the cliffs becomes temporarily deposited at the toe of the cliffs, providing a degree of protection before it becomes moved away from the area by tidal and wave action.

- The Whitley Links seawall requires some maintenance attention, particularly where joined by foreshore access steps and ramps. Some damage and deterioration was also noted

along the Central Lower Promenade and Southern Lower Promenade seawalls and the Brown's Bay seawall.

- The condition of the North and South Piers in Cullercoats Bay was previously identified as a concern, with signs of progressive deterioration between successive walkover surveys. A capital scheme was completed in 2011 to improve the condition of these structures.

- Over the severe winter of 2009/10 notable erosion of the dunes occurred in Tynemouth Longsands, but since that time the upper foreshore levels have recovered and the dunes have stabilised. Maintenance attention would benefit the Longsands walls and access ramps.

- Maintenance of the apron at the northern end of King Edward's Bay would be beneficial and the cracking in pathways through the coastal slopes should continue to be monitored for any signs of ongoing instability.

- The masonry walls around Sandy Goit are in an actively failing condition.

- Parts of the revetment along the riverside, leading from Tynemouth to the Fish Quay, have actively failed and are currently (September 2011) under repair.

2.2.4 Future Recommendations

With nine full years of beach profile data available, together with good records from aerial photographs, and walk-over surveys an understanding of behaviour of the North Tyneside beaches has improved, particularly in relation to the seasonal fluctuations that can occur.

The beach profile datasets were particularly useful in informing the SMP2 along this frontage, and the aerial photographs and Lidar data were a vital input to the *Northumberland and North Tyneside Rocky Foreshore Coastal Squeeze Study* (Royal Haskoning, 2010). This demonstrates the value of long term data records and it is strongly recommended that data collection continues uninterrupted into the future.

In the last Update Report, it was recommended that a topographic survey be introduced at Tynemouth Longsands (Tynemouth North Point to Sharpness Point) in each Full Measures Survey and in each Partial Measures Survey to further improve understanding of seasonal change in this area of potentially vulnerable dunes.

2.3 South Tyneside

2.3.1 Monitoring Activities

South Tyneside Council's frontage extends from the mouth of the River Tyne estuary in the north, to the outfall south of Whitburn. For the purposes of data analysis, it has been sub-divided into four areas, namely:

- Littlehaven Beach
- Herd Sands
- Trow Quarry (incl. Frenchman's Bay)
- Marsden Bay

Along South Tyneside Council's frontage, the following coastal monitoring has been undertaken between 2008 and 2011:

- Full Measures survey annually each autumn/early winter comprising:
  - Beach profile surveys along 17 no. transect lines
  - Topographic survey along Littlehaven (commenced in 2010)
  - Topographic survey along Herd Sands
  - Topographic survey along Trow Quarry (extending to Frenchman's Bay)

- Partial Measures survey annually each spring comprising:
  - Beach profile surveys along 11 no. transect lines
  - Topographic survey along Littlehaven (commenced in 2010)

- Cliff top survey (every 2 years) at:
  - Trow Point (during Full Measures survey)

- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010

- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples at:
  - Herd Sands

- Walk-over inspections of coastal defences and natural assets in summer 2008 and summer 2010

This element of the Cell 1 Regional Coastal Monitoring Programme is complemented by a Local Monitoring Programme, which incorporates cliff walkover inspections every 6 months.

2.3.2 Rationale

The monitoring programme along the South Tyneside frontage was initially designed in 2008 to incorporate beach profiles, beach topographic surveys, cliff top monitoring, aerial photography, bathymetric and sea bed characterisation surveys, and walk-over inspections to better understand changes in key areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan 2 (Royal Haskoning, 2007). Some aspects of the programme were also intended to capture suitable data to enable the post-project evaluation of the capital scheme at Trow Quarry, which was completed in 2008.

The beach profiles along 17 transects and topographic surveys at Herd Sands and Trow Quarry were first surveyed in autumn 2008 and then were repeated annually thereafter during the Full Measures surveys. From spring 2009, repeat beach surveys were undertaken along a represented sample of 11 of the beach transects in the Partial Measures surveys in order that seasonal cycles of behaviour could be captured.

From the Partial Measures survey in 2010 onwards, a topographic survey has also been undertaken at Littlehaven Beach to assist with the appraisal and design of sea wall re-alignment to a more sustainable plan form position (Royal Haskoning, 2009).

2.3.3 Key Findings

- The dunes along the northern section and the wide foreshore along the southern section of Littlehaven beach remain relatively stable, but in the central section, where the sea wall protrudes seawards (Figure 8), the foreshore levels can vary significantly. This, in part, is likely to be caused by reflection off the wall itself causing local mobilisation of beach material. The consequences of low beach levels at this location are: (i) greater wave forces act directly on the seawall, further worsening its already poor and deteriorating condition (Figure 9); (ii) wave overtopping is more likely to occur, leading the flooding and closure of the backing car park (Figure 10); and (iii) undermining of the foundations of the seawall starts to occur (Figure 11), leading to wash-out of the backing made ground and the creation of voids and, ultimately, local collapses.

Figure 8 – Plan Form


Figure 9 – Poor Condition


Figure 10 – Violent Overtopping


Figure 11 – Exposed Foundations

- Along Sandhaven, the dunes have a notable 'hollow' to the south of the children's play area. This is being addressed through implementation of the Sandhaven Dune Management Plan (Royal Haskoning, 2009), involving designated public walk-ways, vegetation planting and chestnut fencing.

- At Gypsies' Green there are relatively low and narrow beaches in front of the promenade which, at times, leads to some local flooding. During storm events, material can be drawn-down the beach. Over winter periods, chestnut fencing is erected and this has a positive effect in retaining some sand on upper beach areas that otherwise would be drawn down the profile and leave the promenade vulnerable to greater risk. At times of upper beach build up, wind-blown sand across the promenade can be problematic.

- Trow Quarry is now protected by a rock revetment and re-graded coastal slope which have been performing well since completion of construction in November 2008 (Royal Haskoning, 2008). The rock headlands of Trow Point and Frenchman's Point remain robust and continue to exert control over the alignment of the embayments, but the middle headland, Target Rock, is actively fragmenting, leading to rock falls and some erosion of the backing ground.

- Frenchman's Bay and Man Haven Bay have both suffered from notable cliff collapses following severe winters of 2009/10 and 2010/11, respectively. Other sections of cliff along this frontage remain unstable due to cracks in the rock structure, overhanging rocks and caves formed at the base of the cliffs.

- There is only a relatively narrow width of foreshore at the northern end of Marsden Bay and this has led to progressive damage to the Redwell Steps, which are now partially closed to public access due to safety reasons, and to collapse in February 2011 of a section of cliff adjacent to the disused Lifeguard Station adjacent to these steps (Fig. 12).

Figure 12 – Cliff Collapse, Marsden Bay – February 2011

- A cliff collapse in front of Lizard Point Car Park in March 2010 prompted closure of the car park and a decision was made by the National Trust to adapt to the ongoing coastal change through removal and 're-wilding' of the car park and access road (Cooper & Dolan, in press).

- Erosion at the rear of a deep cave caused breaching through the remaining limestone ridge in around 2004 at Whitburn Coastal Park. This lead to wash-out of the backing material that was used to infill a former quarry (Old Harbour Quarry) behind the ridge, and cause a shake hole to open (Royal Haskoning, 2009). This has progressively expanded since this time to a considerable size and is now fenced off to ensure public safety. During the walkover inspections, it has been noted that a second breach through the limestone ridge formed at the back of this cave in around 2010 and the expansion of the sink hole accelerated in response. Whilst none of the other caves have presently breached through the remaining limestone ridge, this does remain a likely future mechanism of change.

- There are some areas fronting Whitburn Nature Reserve where slumps in the upper till have eroded the cliff top back to the public footpath.

2.3.4 Future Recommendations

The data that has been collected since 2008 provides an excellent basis for identifying changes, but to fully understand the mechanisms governing the changes the monitoring should be continued. The complimentary approach of observing broad characteristics and trends through the Cell 1 Regional Monitoring Programme and then further investigating key concerns through more detailed Local Coastal Monitoring is suitable for this purpose.

The monitoring in its present form is providing suitable information for the appraisal, design and post-project evaluation of capital schemes, and for ongoing operational decisions and therefore is of value to continue.

2.4 Sunderland

2.4.1 Monitoring Activities

Sunderland City Council's frontage extends from The Bents to Ryhope Dene. For the purposes of data analysis, it has been sub-divided into three areas, namely:

- Whitburn Bay (also referred to as Sunderland North)
- Sunderland Harbour and Docks (also referred to as Sunderland Central)
- Hendon to Ryhope (also referred to as Sunderland South)

Along Sunderland City Council's frontage, the following coastal monitoring has been undertaken between 2008 and 2011:

- Full Measures survey annually each autumn/early winter comprising:
  - Beach profile surveys along 58 no. transect lines
  - Topographic survey at Whitburn Bay
  - Topographic survey at Hendon to Ryhope
- Partial Measures survey annually each spring comprising:
  - Beach profile surveys along 14 no. transect lines
- Cliff top survey bi-annually at:
  - Hendon to Ryhope
- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010
- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples at:
  - South Bents
  - Salterfen Rocks
- Walk-over inspections of coastal defences and natural assets in summer 2008 and summer 2010

2.4.2 Rationale

The monitoring programme along the Sunderland frontage included beach profile surveys that were initially designed and undertaken prior 2008 as part of a local monitoring programme, but became incorporated within the Cell 1 programme in Partial Measures 2009. Additionally, cliff top monitoring, aerial photography, bathymetric and sea bed characterisation surveys, and walk-over inspections were added as part of the Cell 1 programme from 2008 onwards to better understand changes in key areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan 2 (Royal Haskoning, 2007).

The monitoring contains a relatively dense network of beach profile, including seven closely spaced along the cliffs at Halliwell Banks specifically to investigate the cliff erosion rates in front of the historic landfill area (Royal Haskoning, 2008).

2.4.3 Key Findings

- Beach level fluctuations are common along the Whitburn and Hendon frontages and the monitoring to date is starting to characterise the envelope of that change.
- Beach variations at Seaburn sometimes result in low levels when high water mark intercepts the seawall, placing the structure under high pressure and vulnerable to damage or toe undermining. The seawall itself has some developing cracks adjacent to the outfall structures.

- The grouted masonry embankment at the Roker cliffs has some voids and loss of material.

- Variations in foreshore level along beaches contained within the harbour and docks demonstrate the high marine exposure along this frontage. Some maintenance is required to the Port of Sunderland pier structures, especially on the North East Pier and the South West Breakwater which have both shown signs of deterioration.

- Erosion of the cliff face has occurred in particular episodes along Shirley Banks and Halliwell Banks. This is caused by undercutting at the base by wave action (Figure 13) followed by collapses triggered by wave or tidal action, extreme rainfall, additional loading (such as heavy snow during severe winters) and freeze-thaw cycles. Erosion over the monitoring period has, in places, been of the order of several metres.

Figure 13 – Cliff Undercutting by Wave Action

2.4.4 Future Recommendations

The data that has been collected since 2008, combined with the earlier beach profile data, provides an excellent basis for identifying changes, but to fully understand the mechanisms governing the changes the monitoring should be continued.

Particular attention should be paid to Halliwell Banks where the ongoing cliff erosion has cut-back to within only a short distance from the edge of the historic landfill site.

2.5 County Durham

2.5.1 Monitoring Activities

Durham County Council's frontage extends from Ryhope Dene to Crimdon Beck. For the purposes of data analysis, it has been sub-divided into five areas, namely:

- Featherbed Rocks
- Seaham (Dawdon)
- Blast Beach
- Hawthorn Hive
- Blackhall Colliery

Along Durham County Council's frontage, the following the following coastal monitoring has been undertaken between 2008 and 2011:

- Full Measures survey annually each autumn/early winter comprising:
  - Beach profile surveys along 8 no. transect lines
- Partial Measures survey annually each spring comprising:
  - Beach profile surveys along 5 no. transect lines
- Cliff top survey bi-annually at:
  - Seaham (Dawdon)
- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010
- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples at:
  - Blast Beach
- Walk-over inspections of coastal defences and natural assets in summer 2008 and summer 2010

2.5.2 Rationale

The monitoring programme along the County Durham frontage was initially designed in 2008 to incorporate beach profiles, cliff top monitoring, aerial photography, bathymetric and sea bed characterisation surveys, and walk-over inspections to better understand changes in key areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan 2 (Royal Haskoning, 2007).

After the programme began in 2008, profile EA1 was re-located slightly further north to better capture the changes occurring at the southern end of Seaham promenade. An additional profile line was added at Blast Beach to quantify the rates of erosion at the northern end.

Some aspects of the programme are specifically intended to capture information relating to erosion of colliery spoil that historically was tipped along some County Durham beaches and the potential for re-activation of backing cliffs that are currently protected by these wide (but in some areas eroding) spoil beaches.

2.5.3 Key Findings

- Sediment accumulation at the southern end of the Seaham promenade causes an unwanted problem by acting as a 'ramp' across which wave action runs, resulting in overtopping of the seawall and wave action hitting the backing sea cliffs, causing local erosion.
- There is ongoing erosion of the undefended sea cliffs north of Seaham Harbour.

- There was substantial cliff top recession at parts of the Dawdon cliffs during two specific events.

- The colliery spoil beaches along many parts of County Durham remain wide and protect the backing relict cliffs from exposure to marine action. However, the colliery spoil is eroding along parts of Nose's Point, parts of Blast Beach and parts of Blackhall Colliery during specific storm events. Figures 14 and 15 show how erosion has occurred at the northern end of Blast Beach between 1999 and 2010.

Figure 14 – Blast Beach, 1999

Figure 15 – Blast Beach, 2010

- The outlet channels of Hawthorne Hive and Castle Eden Burn exhibit only relatively modest changes in morphology and position in their respective locations across the foreshore. Therefore these channels do not have a major influence on behaviour of the adjacent beaches and cliffs.

- A local slope failure has occurred within Crimdon Park Caravan Site and a temporary barrier has been erected from steel tubing and plastic fencing, with warning signs.

2.5.4 Future Recommendations

The data that has been collected since 2008 provides an excellent basis for identifying changes, but to fully understand the mechanisms governing the changes the monitoring should be continued.

In the future, it may be worth considering adding further surveys along Seaham beach (either beach profiles or beach topographic survey) to capture the changes occurring in beach level, and an additional cliff top survey point at Nose's Point to monitor the potential future re-activation of cliff recession once the narrow remaining width of colliery spoil has been eroded.

Rather than incorporating these changes into the future five year programme, Durham County Council is currently investigating the potential for undertaking these additional surveys in-house.

2.6 Hartlepool

2.6.1 Monitoring Activities

Hartlepool Borough Council's frontage extends from Crimdon Beck in the north to the North Gare Breakwater in the south. For the purposes of data analysis, it has been sub-divided into four areas, namely:

- North Sands
- Hartlepool Headland
- Middleton
- Hartlepool Bay

Along Hartlepool Borough Council's frontage, the following coastal monitoring has been undertaken between 2008 and 2011:

- Full Measures survey annually each autumn/early winter comprising:
  - Beach profile surveys along 9 no. transect lines
  - Topographic survey along part of North Sands (referred to as Hartlepool North)
  - Topographic survey along Middleton (referred to as Hartlepool Central)
  - Topographic survey along Hartlepool Bay (referred to as Hartlepool South)

- Partial Measures survey annually each spring comprising:
  - Beach profile surveys along 9 no. transect lines

Additionally, every five years (starting with 2008 as the baseline year), the Full Measures survey at Hartlepool North is extended to fully cover the whole of North Sands and Hartlepool Headland with a topographic survey. This extends across the boundary of jurisdiction between Hartlepool Borough Council and Durham County Council.

- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010

- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples at:
  - North Sands

- Walk-over inspections of coastal defences and natural assets in summer 2008 and summer 2010

Figure 16 – Hartlepool Headland, Harbour and Marina

2.6.2 Rationale

The monitoring programme along the Hartlepool frontage was initially designed in 2008 to incorporate beach profiles, cliff top monitoring, aerial photography, bathymetric and sea bed characterisation surveys, and walk-over inspections to better understand changes in key areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan 2 (Royal Haskoning, 2007).

2.6.3 Key Findings

- Hart Warren and North Sands are subject to seasonal variations in beach and dune form, with flatter, lower profiles in winter and steeper, higher profiles with occasional berms in summer. In the immediate vicinity of Crimden Beck, changes in the backing dunes appear to partly result from changes in the position of the channel of the beck.

- Along part of North Sands, the beach is backed by high and steep slag banks which front the disused industrial sites. Whilst there is only a narrow width of dune preventing marine action from eroding the slag bank, to date monitoring shows the area to be stable.

- Failing brick-filled gabion baskets fronting the former industrial unit south of the cemetery were removed due to public safety reasons between the 2008 and 2010 walkover inspections.

- The seawalls along Marine Drive and around Hartlepool Headland are intercepted by high water, leaving them susceptible to direct wave attack. There is evidence of concrete spalling and abrasion to these structures, with some areas of local undercutting.

- Along Fish Sands and Town Wall, low beach levels at times expose timber piles and concrete aprons. A capital scheme is presently being considered along this frontage.

- The beaches at Middleton can vary in level by up to 1.9m at the toe of the wall.

- The North Gare Breakwater appears to trap drifting beach sediment, causing accretion against its western face. However, the structure is deteriorating in condition, with evidence of settlement at the seaward end.

2.6.4 Future Recommendations

Following discussions with Hartlepool Borough Council, the following recommendations are made for inclusion in the future 5 year programme:

- One additional beach profile survey at a new transect mid-way between 1cHN2 and 1cHN3 along Hartlepool North Sands in each Full Measures Survey and in each Partial Measures Survey

- One additional beach profile survey at a new transect mid-way between 1cHN3 and 1cHN4 along Hartlepool North Sands in each Full Measures Survey and in each Partial Measures Survey

- One additional beach profile survey at a new transect mid-way between 1cHN4 and The Heugh Breakwater along Hartlepool Headland in each Full Measures Survey

- Extension of the Hartlepool Bay topographic survey to additionally include Hartlepool North Gare Sands (North Gare Breakwater to Nuclear Power Station Jetty) in each Full Measures Survey

In addition, Hartlepool Borough Council undertakes its own walkover inspections every quarter using in-house engineering staff and therefore the 2-yearly inspections as part of the Cell 1 programme may be superfluous.

2.7 Redcar & Cleveland

2.7.1 Monitoring Activities

Redcar & Cleveland Borough Council's coastal frontage extends from the South Gare Breakwater in the north to Cowbar Nab, near Staithes, in the south. For data analysis purposes it has been sub-divided into five areas, namely;

- Coatham Sands
- Redcar Sands
- Marske Sands
- Saltburn Sands
- Cattersty Sands (Skinningrove)

Along the Redcar and Cleveland frontage, the following surveying has been undertaken between 2008 and 2011:

- Full Measures survey annually each autumn/early winter comprising:
  - Beach profile surveys along 9 no. transect lines
  - Topographic survey along Coatham Sands
  - Topographic survey along Redcar Sands
  - Topographic survey along Marske Sands
  - Topographic survey along Saltburn Sands
  - Topographic survey along Cattersty Sands

- Partial Measures survey annually each spring comprising:
  - Beach profile surveys along 9 no. transect lines
  - Topographic survey along Redcar Sands
  - Topographic survey along Saltburn Sands
  - Topographic survey along Cattersty Sands

- Cliff top survey annually at:
  - Staithes

- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010

- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples in spring/summer 2010 at:

  - Saltburn Sands
  - Cattersty Sands (Skinningrove)

- Walk-over inspections of coastal defences and natural assets in summer 2008 and summer 2010.

2.7.2 Rationale

The monitoring programme along the Redcar & Cleveland coast was initially designed in 2008 to incorporate beach profiles along 9 transect lines, beach topographic surveys at 5 locations, cliff top monitoring at Staithes, aerial photography and walk-over inspections to better understand changes in areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan (Royal Haskoning, 2007).

The design of the programme adopted a risk-based approach, meaning monitoring was focused on beaches backed by development. Changes in more isolated bays or in hard rock cliffs were recorded using aerial photography and walk-over inspections.

The beach profiles and topographic surveys were first surveyed in autumn 2008 and then were repeated annually thereafter during the Full Measures surveys. From spring 2009, repeat beach surveys were undertaken along a represented sample of 3 of the topographic surveys and all 9 beach profiles in the Partial Measures surveys in order that seasonal cycles of behaviour could be captured.

A baseline bathymetry and sea bed sediment survey was undertaken at Saltburn-by-Sea and Cattersty Sands (Skinningrove) in 2010 to explore sea bed changes below low water. At this stage in the monitoring programme it is only possible to describe the morphology and sediments of the sea bed. Following subsequent surveys, at 5-year intervals, the findings can be reassessed to document changes in sea bed elevation and sediment character.

2.7.3 Key Findings

- The northern section of Coatham Sands beach is largely sheltered from wave attack, except those waves from north-easterly and easterly directions. This is results from the presence of the South Gare breakwater and German Charlies slag banks. The main frontage here is relatively featureless, with a fairly uniform cross-shore gradient. There is ongoing redistribution of beach sediments, with a net increase at Coatham Sands of 10,255m^3 since 2008.

- At Redcar town there is ongoing seasonal redistribution of beach sediments, with a net increase at Redcar Sands of 66,365m^3 since 2008. Construction of the Redcar Coast Protection Scheme is currently in progress.

- Whilst there is ongoing seasonal redistribution of beach sediments at Marske Sands, the overall trend is for a net increase of 13,445m^3 since 2008.

- The topographic beach surveys at Saltburn suggest that whilst there is ongoing seasonal redistribution of beach sediments, there is a net increase of 9,245m^3 since 2008. The bathymetric survey at this location is characterised by two distinct zones. A largely smooth and sandy nearshore zone, and an area further offshore which is characterised by rugged bedrock outcrops including saw-toothed dip and scarp features and isolated bedrock reefs.

- The walkover survey of summer 2010 identified high levels of cliff activity at Hunt Cliff and Warsett Hill, to the south of Saltburn Sands. A railway line runs very close to the cliff edge at this location.

Figure 17 – Railway Line at Warsett Hill

- The beach topographic data suggests during summer periods, Cattersty Sands often exhibits behaviour typical of a summer swell-dominated marine system. In the east, the influence of Skinningrove Beck on beach morphology is also observed. The Skinningrove bathymetric survey shows two main zones. The nearshore zone is predominantly sandy and smooth with some areas of rough bedrock. Further offshore, the sea bed features outcrops of jointed bedrock with patchy cover of sand where it has accumulated in hollows.

- The 2008 and 2010 walkover inspections noted the frontage between Boulby and Cowbar as an area of intense cliff erosion. Setback of the road has been necessary and a significant risk is posed to local traffic as this is the only access onto Cowbar Nab.

Figure 18 – Ongoing erosion and loss of access road between Boulby and Cowbar Nab

2.7.4 Future Recommendations

The data that has been collected since 2008 provides an excellent basis for identifying changes, but to fully understand the mechanisms governing the changes the monitoring should be continued.

Consideration should be given to more frequently monitoring the highly active cliffs at Hunt Cliff and Warsett Hill and between Boulby and Cowbar. This can be achieved by walkover inspection, topographic survey, or analysis of future aerial survey data, although the following ongoing activities should be noted:

- Network Rail closely monitors the cliffs at Warsett Hill, although their reports are not published but may be viewed by Redcar & Clelveland Borough Council subject to a non-disclosure agreement.

- Redcar & Cleveland Borough Council is currently using terrestrial laser scanning to monitor cliff recession at Cowbar as part of a more detailed local monitoring programme. Year 1 of a five year programme commenced in April 2011.

2.8 Scarborough

2.8.1 Monitoring Activities

Scarborough Borough Council's frontage extends from Staithes in the north to Reighton in the south. For data analysis purposes, this area has been sub-divided into eight areas;

- Staithes
- Runswick Bay
- Sandsend Beach, Upgang Beach and Whitby Sands
- Robin Hood's Bay
- Scarborough North Bay
- Scarborough South Bay
- Cayton Bay
- Filey Bay

Along the Scarborough Borough Council coastal frontage, the following surveying has been undertaken between 2008 and 2011:

- Full Measures survey annually each autumn/early winter comprising:
    - Beach profile surveys along 20 no. transect lines
    - Topographic survey at Runswick Bay
    - Topographic survey along the Sandsend to Whitby frontage
    - Topographic survey at Robin Hood's Bay
    - Topographic survey at Scarborough North Bay
    - Topographic survey at Scarborough South Bay
    - Topographic survey at Cayton Bay
    - Topographic survey at Filey Bay

- Partial Measures survey annually each spring comprising:
    - Beach profile surveys along 20 no. transect lines
    - Topographic survey at Runswick Bay
    - Topographic survey at Robin Hood's Bay
    - Topographic survey at Filey Bay (Town coverage)
    - Topographic survey along Sandsend to Whitby frontage (only in early 2011)
    - Topographic survey at Scarborough North Bay (only in early 2011)
    - Topographic survey at Scarborough South Bay (only in early 2011)

- Cliff top survey bi-annually at:
    - Staithes
    - Robin Hoods Bay *(*since Partial Measures 2010*)*
    - Scarborough South Bay (since Partial Measures 2010)
    - Cayton Bay
    - Filey

- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010

- Bathymetric multibeam transect surveys and sea bed characterisation using grab samples in spring/summer 2010 at:

    - Runswick Bay
    - Sandsend
    - Whitby Sands
    - Robin Hoods Bay
    - Scarborough North Bay
    - Scarborough South Bay
    - Cayton Bay
    - Filey Bay

- Walk-over inspections of coastal defences, assets and cliffs in summer 2008 and summer 2009. Inspections were originally planned for 2010, but were deferred and replaced with more detailed investigations of previously-identified priority areas as part of a local monitoring programme in 2010.

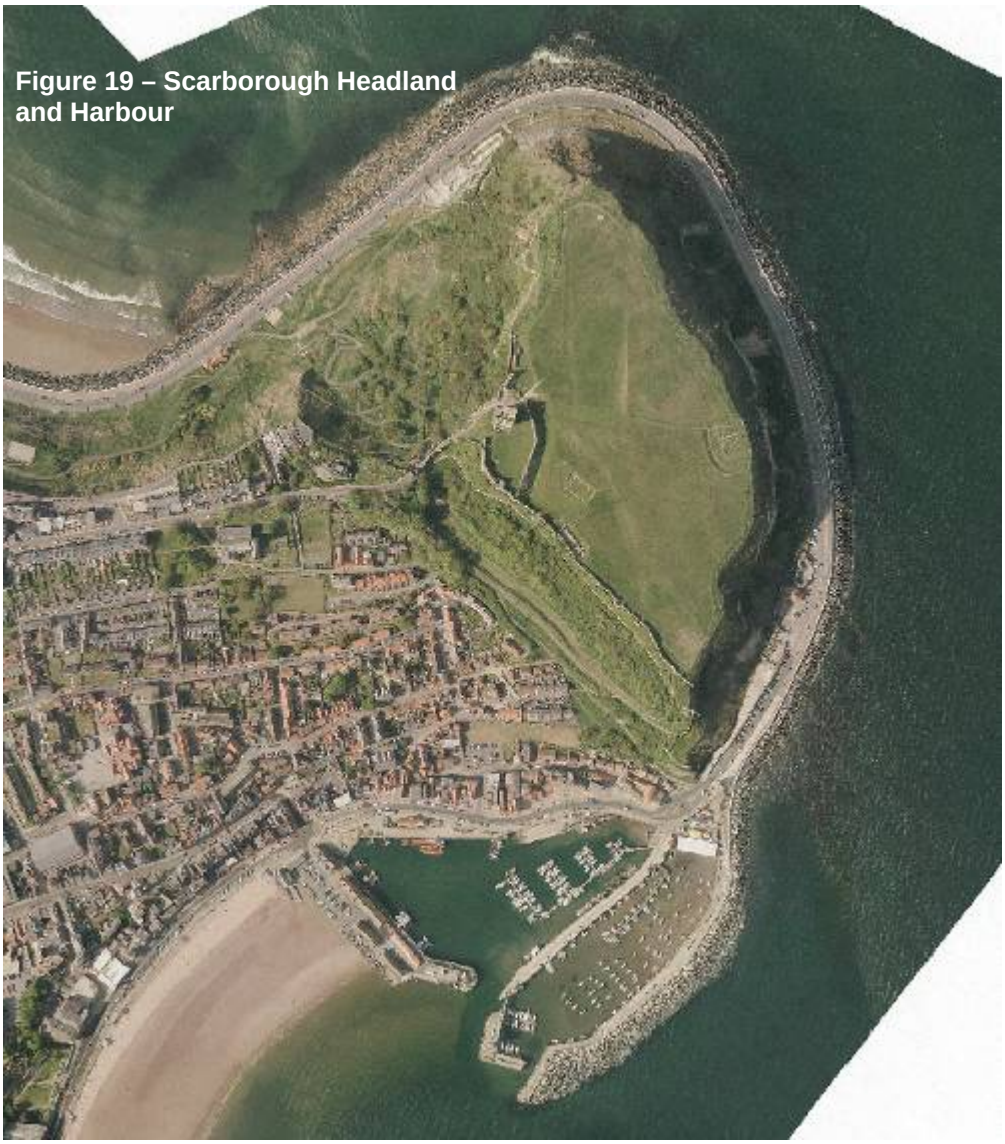

Figure 19 – Scarborough Headland and Harbour

2.8.2 Rationale

The monitoring programme along the Scarborough Borough Council frontage was initially designed in autumn 2008 to incorporate beach profiles along 20 transect lines, beach topographic surveys at 7 locations, cliff top monitoring at 3 locations, aerial photography and walk-over inspections to better understand changes in areas highlighted by the River Tyne to Flamborough Head Shoreline Management Plan (Royal Haskoning, 2007). Cliff top monitoring at a further 2 locations was added in Partial Measures 2010.

The design of the programme adopted a risk-based approach, meaning monitoring was focused on beaches backed by development or coastal communities. Changes in more isolated bays or in hard rock cliffs were recorded using aerial photography and walk-over inspections.

The beach profiles, topography and cliff top monitoring were first carried out in autumn 2008 and then were repeated annually thereafter during the Full Measures surveys. From spring 2009, repeat beach surveys were undertaken along a represented sample of 3 of the topographic surveys and all 20 beach transects in the Partial Measures surveys in order that seasonal cycles of behaviour could be captured.

During the 2011 Partial Measures survey, additional topographic surveys were undertaken at Scarborough North and South Bays and along the Sandsend to Whitby frontage which would normally only be acquired during the Full Measures programme. This resulted from concerns about exceptionally low beach levels fronting the revetments protecting Sandsend Road, running between Sandsend and Whitby, which were observed in January 2011. Additional data were also collected at Scarborough to support potential Project Appraisal Reports (PARs) in both the North and South Bays.

Baseline bathymetry and sea bed sediment surveys were undertaken to explore beach profile changes below MLW and to explore various issues highlighted in the SMP2, such as the links between beach erosion and offshore sediment movement. At this stage in the monitoring programme it is only possible to describe the morphology and sediments of the sea bed. Following subsequent surveys, at 5-year intervals, the findings can be reassessed to document changes in sea bed elevation and sediment character.

2.8.3 Key Findings

- Hotspots of ongoing cliff top retreat (noted in spring 2010, autumn 2010, spring 2011) are located to the west of Staithes adjacent to Cowbar Lane and above Staithes Harbour.

- Patterns of beach change at Runswick Bay are generally dominated by swell type systems during the summer, with a trend towards accretion at the upper beach, and storm type systems during the winter with erosion at the upper beach. The 2010 sea bed bathymetric survey indicated a nearshore zone characterised by a rugged boulder-strewn sea bed with smaller patches of smooth sand. Further offshore the sea bed becomes smoother and sandier with only occasional rocky outcrops and boulders.

- The Sandsend to Whitby frontage consistently shows dynamic shifts in the beach elevation (borne out by winter 2009-10, summer 2010 and winter 2010-2011 data) with laterally extensive bands of both accretion and erosion reflecting the combination of marine and, to a much lesser extent, fluvial influences. During the winter of 2010-11 there was an accumulation of material at the back of the beach beneath the Upgang mudslides. The pattern of change appears consistent with onshore-offshore movement, with material then moved along the coast in the nearshore zone (not directly along the shoreline), by tidal currents. The bathymetric survey at Sandsend shows a nearshore zone of bedrock and boulders with the grab samples recovering coarse sand. Further offshore the sea bed is smooth, sandy and largely featureless. At Whitby, the bathymetric survey revealed a highly variable sea bed including areas of smooth sand, rocky pinnacles, bedrock and sinuous sandy bedforms.

- The majority of beach data collected at Robin Hood's Bay shows a largely stable foreshore, especially in areas dominated by rock platforms. A small erosion hotspot is located beneath the cliffs at Dungeon Hole. The walkover inspections noted a small section of undefended cliff which is subject to intense marine erosion. The bathymetric survey for Robin Hoods Bay indicates three broadly different offshore zones. The nearshore is predominantly formed of bedrock which bedding planes clearly visible. The mid-section is smooth and largely featureless, and furthest offshore the sea bed is characterised by subtle linear bedforms.

- Scarborough North Bay shows a mixed pattern of beach change, with some identifiable summer-swell and winter-storm system behaviour. The most recent spring 2011 data shows deposition dominating the northern section and erosion more prevalent in the middle section of the Bay. This erosion is particularly intense in the area of Peasholm Gap. The bathymetric survey within North Bay indicated a sea bed which can be broadly

characterised by a highly variable nearshore zone of sand over rough bedrock and areas of pitted sea bed, and an zone further offshore which is smooth, sandy and largely featureless.

- Scarborough South Bay tends to exhibit typical summer-swell and winter-storm type behaviour with notable erosion at the back of the beach during winters and deposition during the summers. In January 2010, an *ad hoc* survey of Scarborough South Bay revealed that significant loss of material had occurred since October 2009 (in the order of 34,000m^3). This is known to result, at least in part, from removal of sand by the Council to de-ice roads during the very severe winter of 2009/10, although surplus sand was later returned to the beach. Hotspots of cliff top recession are located just south of the Holbeck Hall landslide run-out lobe and in the vicinity of Knipe Point which is likely related to recent landslide activity at the northern end of Cayton Bay (described below). The increased activity here was also identified in the walkover inspections of summer 2008 and summer 2009. The summer 2009 walkover inspection also noted increased activity and headscarp recession at the southern end of Cornelian Bay. The bathymetric survey of South Bay shows a nearshore area of rough bedrock outcrops which stand proud of the surrounding sea bed. Further offshore the survey indicates a smooth, sandy sea bed which is largely featureless.

- Variable patterns of beach change are observed within Cayton Bay, with areas of both accretion and erosion. The cliff top markers indicate recession of the cliff edge within Tenants' Cliff where active rockfalls are ongoing. Following the re-activation of a major landslide at Cayton Cliff in April 2008, erosion of the uplifted landslide toe was observed in the topographic data. The bathymetric survey at Cayton Bay indicates that the sea bed is mostly smooth and sandy, but is punctuated by occasional rocky outcrops in the nearshore zone.

- Zones of both beach erosion and accretion are noted within Filey Bay, which most recently (spring 2011) reflect the influence of winter storm systems with erosion at the back of the beach. The cliff top marker surveys indicate a large amount of recession recorded immediately south of Filey itself where the seawall ends and therefore represents ongoing outflanking activity at this location. Widespread damage was caused in Filey Town by a significant rainstorm event in 2007, the impacts of which have now been remediated. The 2009 walkover inspection noted the ongoing and intensifying erosion of Filey Brigg, which may pose a risk to beach and cliff users. The bathymetric survey shows the sea bed to be largely smooth and sandy with some sandbars and isolated depressions in places.

2.8.4 Future Recommendations

The data that has been collected since 2008 provides an excellent basis for identifying changes, but to fully understand the mechanisms governing the changes the monitoring should be continued.

The 2008 and 2009 walkover inspections recommended that careful monitoring should be undertaken at the active areas of north and south of Knipe Point, between Cayton and Cornelian Bays and at Filey town and Filey Brigg.

Action should also be taken to address the small section of undefended cliff at Robin Hood's Bay in order to prevent the development of instability in this area.

Repeat bathymetric surveys are recommended to cover the same locations over 5-yearly cycles. These should ideally be synchronised with beach surveys. Analysis of subsequent bathymetric data sets would allow assessment of morphological change and sea bed process regimes, sediment budget and nature of materials moving in the coastal system.

2.9 East Riding of Yorkshire

2.9.1 Monitoring Activities

The short length of East Riding of Yorkshire Borough Council's frontage that is located within Cell 1[(1)] extends from Reighton in the north to Flamborough Head in the south. Along this frontage, the following surveying has been undertaken since 2008:

- Aerial photography and Lidar survey along the whole frontage in spring/summer 2010.
- Walk-over inspections of coastal defences, assets and cliffs in summer 2008 and summer 2010.

2.9.2 Rationale

This frontage is characterised by high chalk cliffs with a till cap. There are few beaches and few coastal assets along this frontage and consequently topographic and beach profiles are not carried out here under the Cell 1 programme.

2.9.3 Key Findings

During both the 2008 and 2010 walkover surveys, the majority of units were found to be posing little risk to coastal assets. Exceptions included areas at Thornwick Nab and Stottle Bank Nook where footpath diversion has been necessary as a result of cliff top recession. Loss of golf course land at the latter was also observed. Coast protection assets were also inspected and some defects were found, but none of these were considered serious.

2.9.4 Future Recommendations

East Riding of Yorkshire Council will be leading its own Coastal Monitoring Programme into the future and therefore it is recommended that the future aerial photographs and walkover surveys fall within the remit of that programme, although Flamborough Head remains a useful 'breakpoint' for completion of the aerial flight paths.

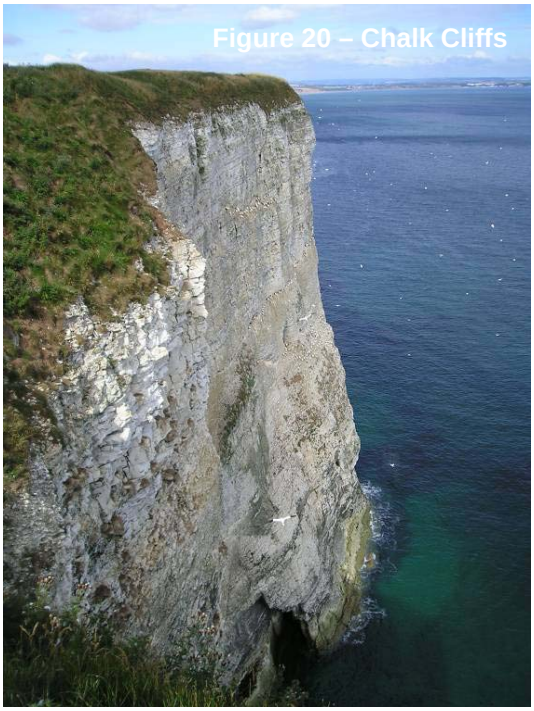

Figure 20 – Chalk Cliffs

[1] Only a small frontage length within ERYC's jurisdiction extends north of Flamborough Head into Cell 1, the remainder is located within Coastal Sediment Cell 2.

3. Case Studies

3.1 Background

This section presents a series of Case Studies to demonstrate where each of the data types obtained during the Cell 1 Regional Coastal Monitoring Programme have been used for some practical coastal management purpose or for the development of further understanding of key processes or behaviour.

3.2 Beach Profiles

This technique gives a snapshot of the cross-sectional form of coastal defence structures, cliffs of dunes and their fronting beaches, tidal flats and shore platforms. Data captured from different years or seasons can be compared to highlight patterns or trends of change in a two-dimensional manner.

3.2.1 Lynemouth Bay

Lynemouth Bay has a strong industrial heritage and as a legacy of this there are extensive slag banks composed of colliery spoil and other industrial waste which front the toe of dunes and low cliffs to the north of Lynemouth Power Station.

Spoil from Ellington Colliery was tipped onto the beach and foreshore for many years, advancing and subsequently maintaining the position of the shoreline in the bay through this 'beach feeding'.

Figure 21 – Slag Banks

These activities finally ceased with closure of the colliery in 2005. The beach profile data derived from the monitoring programme is enabling the response of the shoreline to these changes to be quantified.

Where the slag banks remain located above the limit of marine activity, such as towards the north of Lynemouth Bay, they are presently stable, but the fronting beach changes are quite rapid, causing lowering of levels and reductions in beach width (Figure 22. If these processes continue, the presently stable slag banks will become subject to marine conditions in the mid term.

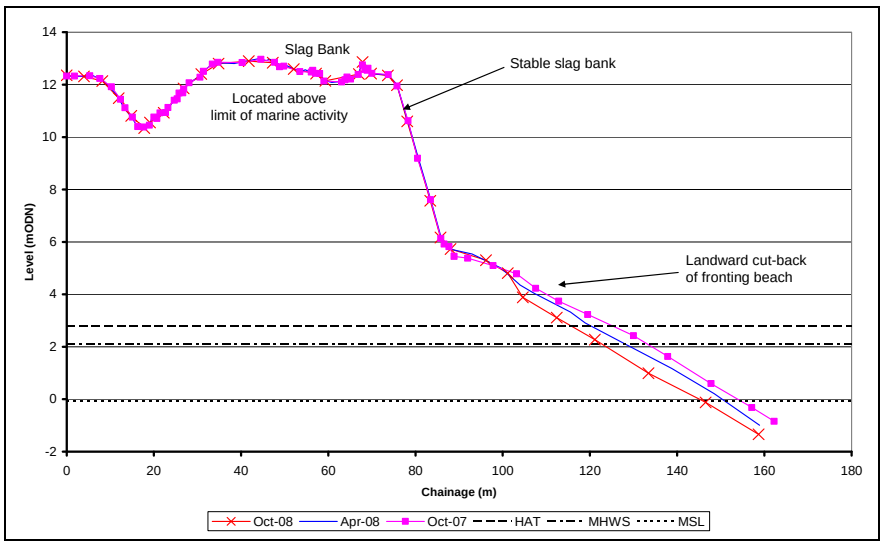

Figure 22 - Profile changes in northern Lynemouth Bay

Further towards the centre of Lynemouth Bay, the slag banks front a coal stocking yard. Here the banks are presently eroding, with around 2m landward retreat between October 2007 and 2008 (Figure 23). The effect is that a much steeper seaward face to the slag bank now exists, and this is likely to erode further due to unstable conditions as well as ongoing marine processes. In response to these findings Rio-Tinto Alcan, as owner of the land and Lynemouth Power Station, has mechanically re-graded the slag bank to a shallower profile in attempt to slow or arrest this recession. Ongoing beach profile surveying will be used to determine the success, or otherwise, of this operation.

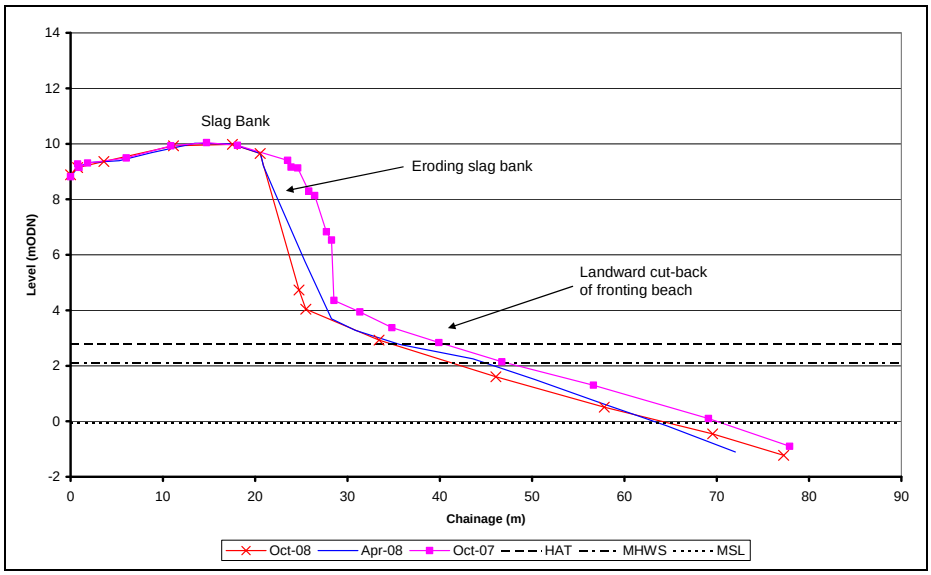

Figure 23 - Profile changes in central Lynemouth Bay

3.2.2 *Littlehaven Sea Wall*

Littlehaven Sea Wall has an alignment which protrudes seawards at its centre to intercept the high water mark, which leaves it vulnerable to direct wave damage and foreshore lowering due to wave reflection. Beach levels at the toe of the wall can vary considerably between successive surveys and when they become particularly low, the wall is highly vulnerable to both undermining and wave overtopping. The latter can lead to sea flooding of the backing promenade and car park.

The beach profile surveys along this frontage showed particularly low levels at the toe of the wall in March 2010. Shortly after this survey was completed violent wave overtopping of the wall occurred, leading to substantial flooding of the backing car park. While this mechanism was previously hypothesised, the beach profile surveys give tangible evidence of the link between low beach levels and overtopping events, and support the case for landward re-alignment of the wall to reduce this risk.

Figure 24 – Car Park Flooding

3.3 Beach Topographic Surveys

This technique gives a snapshot of the morphology of beaches and shore platforms. Data captured from different years or seasons can be compared to highlight patterns or trends of change that provide a spatial picture of changes in a three-dimensional manner.

3.3.1 Newbiggin Bay Beach Management

A succession of topographic surveys at Newbiggin Bay has helped to identify and quantify changes that have occurred following beach replenishment as part of a capital scheme in 2007. The changes have been much influenced by the presence of an offshore breakwater built as part of that scheme, which has segmented Newbiggin Bay into two small embayments, encouraging the build up of sediment immediately in its lee on the lower foreshore, creating a tombolo feature.

Figure 25 – Newbiggin Bay

Figure 26 (overleaf) shows the beach changes since scheme completion in 2007 and the Partial Measures 2011 topographic survey. This indicates that wave diffraction around the ends of the breakwater has resulted in wave focusing into the replenishment material in the central section of the bay, causing cut-back of the beach in this area (red zones show erosion) and the mobilisation and transport of sediments to the very northern and southern ends of the bay (blue zones show accretion). Where sand is accreting, it is causing unwanted problems through wind-blown sand across the promenades (Figures 27 and 28) and smothering of a designated rocky foreshore habitat.

Figure 27 – Wind Blown Sand

Figure 28 – Wind Blown Sand

Difference between Topographic Surveys
18th June 2007 and 21st February 2011

AREA 1

AREA 2

AREA 3

AREA 4

AREA 5

AREA 6

AREA 7

N

0 50 100 200 Metres

Change in Elevation (m OD)

Gain	> 2.0
	1.75 - 2.0
	1.5 - 1.75
	1.25 - 1.5
	1.0 - 1.25
	0.75 - 1.0
	0.5 - 0.75
	0.25 - 0.5
	0.1 - 0.25
Change < 0.1m	0.0 - 0.1
	-0.1 - 0.0
Loss	-0.25 - -0.1
	-0.5 - -0.25
	-0.75 - -0.5
	-1.0 - -0.75
	-1.25 - -1.0
	-1.5 - -1.25
	-1.75 - -1.5
	-2.0 - -1.75
	< -2.0

Areas not covered by both surveys:
- Assumed Accreted Areas
- Assumed Eroded Areas

Analysis of the topographic survey data has identified and quantified specific zones of accretion and erosion along the frontage, and assisted in planning a beach management scheme that was undertaken in September 2011 to recycle sand from areas of unwanted accretion back to areas where the erosion was reducing the sea defence and amenity functions of the beach, thereby restoring the beach to its design configuration.

3.3.2 Scarborough South Bay

The latest comparison of beach topographic surveys within Scarborough South Bay shows a clear trend towards erosion at the back of the beach during the winter of 2010-2011, and a complex pattern elsewhere (see Figure 29). Initially this suggests that there has been a seaward movement of beach materials between September 2010 and February 2011 which is a typical pattern of change related to winter storm activity. Information on beach changes within the Bay is currently being used to appraise and design management options at the Scarborough Spa complex.

The continued collection of beach topographic data in the future provides the opportunity for ongoing monitoring of erosion or sand removal from the beach as well as the potential for calculating changes in volume of material forming the beach.

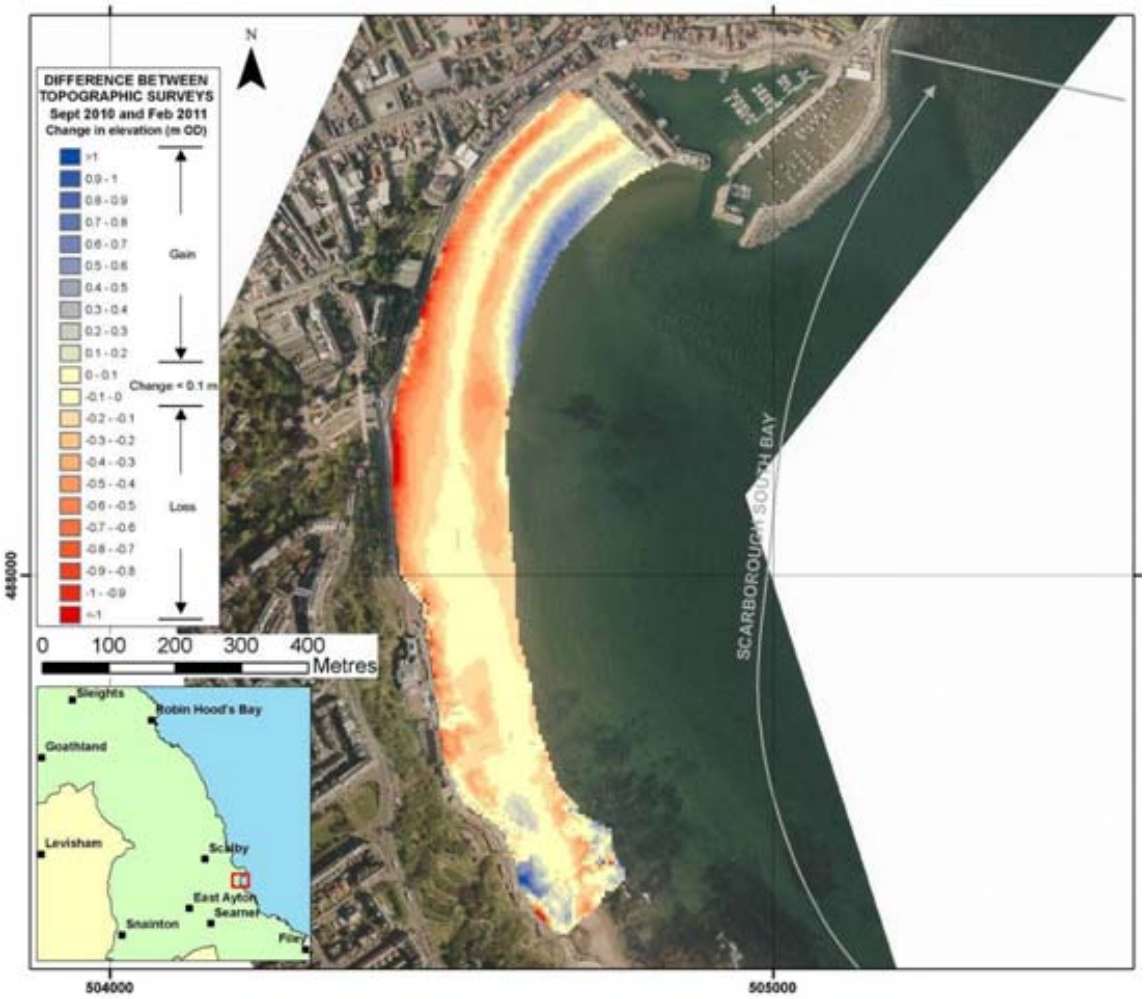

Figure 29 - Comparison of beach topographic surveys within Scarborough South Bay

3.4 Cliff Top Monitoring Surveys

This technique provides data on changes in the position of the cliff edge, either as a continuous survey line or as a distance measurement from the cliff edge relative to an inland datum. It is intended to give quantitative data on cliff recession to support visual inspections of cliff activity.

3.4.1 Sandy Bay

Cliff top monitoring has been undertaken at Sandy Bay Caravan Park since Full Measures 2007 as a continuos cliff top survey line. Recession has been greatest at the southern end of Caravan Park and in places exceeded 3m between September 2009 and March 2010. As can be seen from Figure 30, the site owners have had to re-locate some caravans to accommodate the ongoing change.

Figure 30 - Cliff Top Recession at Sandy Bay Caravan Park

3.4.2 *Cornelian Bay and Knipe Point*

The cliff top monitoring programme at Scarborough South Bay extends southwards into Cornelian Bay and to Knipe Point (Figure 31). The cliffs at this southern extent are formed in till. At Knipe Point the re-activation of a large landslide occurred in April 2008 and increased cliff recession activity was also noted at the southern end of Cornelian Bay. There are three monitoring markers situated here, all of which have shown notable cliff recession since they were installed. This recession has been of the order of 0.2 - 0.4m/yr at the southern end of Cornelian Bay (markers 11 and 12) and 0.9m/yr at Knipe Point (marker 13). This information has helped to inform understanding about the rate of cliff top change occurring here.

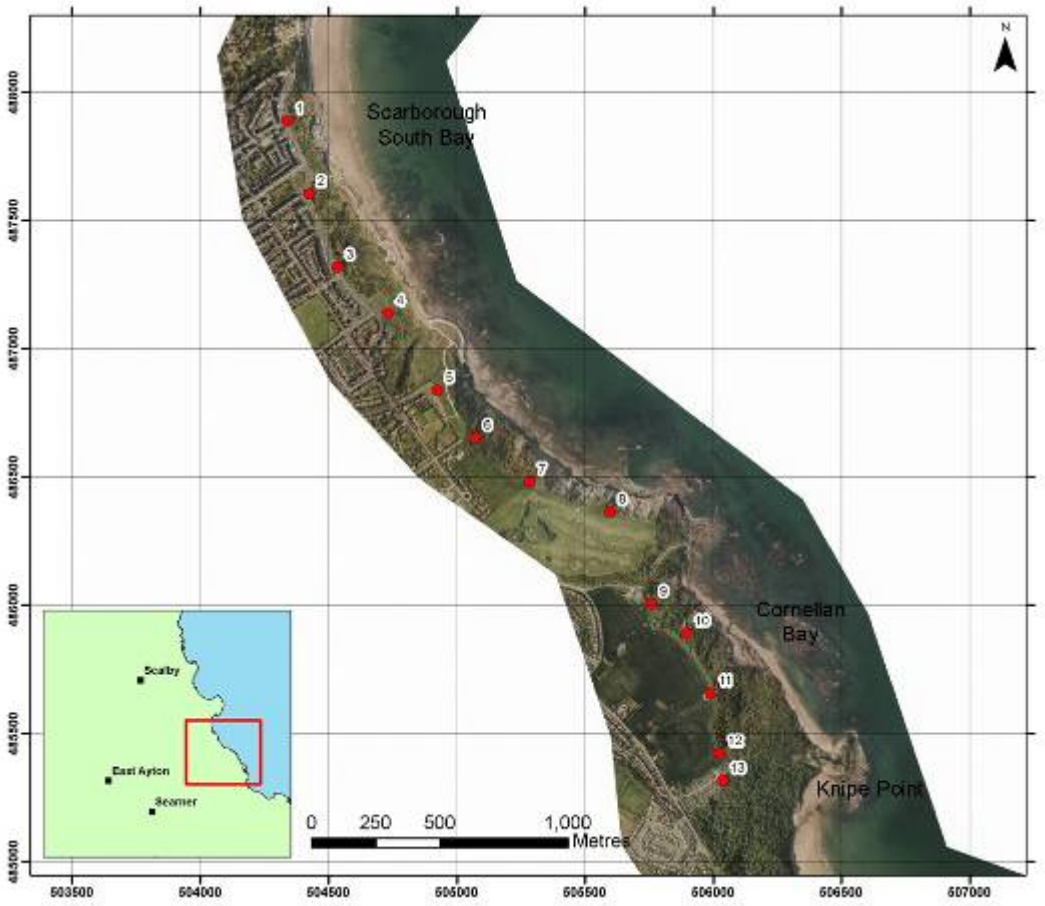

Figure 31 - Location of cliff top monitoring points within Scarborough South Bay

3.4.3 Filey Bay

Within Filey Bay there are 27 cliff top monitoring positions. Of these, the most notable cliff recession is recorded at marker 5, immediately south of the seawall and rock armour at Filey town. Since the marker was installed in November 2008 it has shown a consistent trend of cliff top retreat so that by March 2011 there has been a total of 5.5m of recession. This information suggests that outflanking of the Filey seawall is occurring which may require attention in terms of coastal management. Such activity is currently being examined by the Filey Coastal Stability and Outflanking Study.

Figure 32 – Cliff Erosion in Filey Bay
(Marker 5 is located to the left, beyond the extent of the rock armour)

3.5 Aerial Photographs and Lidar

An aerial flight was undertaken in 2010 that comprised synchronous vertical aerial photography and Lidar survey. Oblique photography was also taken to capture images of the cliff faces. The vertical photography and Lidar were processed to generate an ortho-photograph which is accurate to ±0.1m. The ortho-photograph can be compared to past and future aerial survey to measure change in feature positions and calculate rates of change. In addition, the Lidar can be used to monitor changes in beach elevation and volume and the photographs can be used to assist mapping of geology, geomorphology and habitats.

3.5.1 Rocky Foreshore Coastal Squeeze Study

The Northumberland and North Tyneside Shoreline Management Plan 2 was 'signed-off' and adopted by the relevant authorities in 2009. In signing-off the document, Natural England identified an issue considered to be of national significance relating to the potential impact of SMP2 policies on designated areas of inter-tidal rocky reef and foreshore within the Berwickshire and North Northumberland Coast Special Area of Conservation, the Northumbrian Coast Special Protection Area, and the various Sites of Special Scientific Interest. This was particularly associated with SMP2 policies in future epochs due to ongoing concerns relating to climate change and predicted sea level rise and the effect policies of Hold the Line may have due to a process known as coastal squeeze (Figure 33).

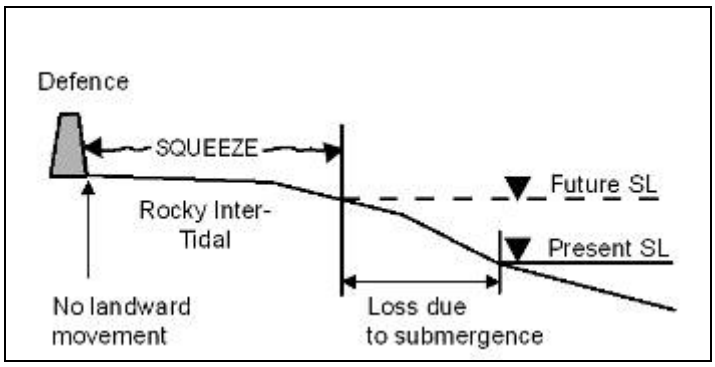

Figure 33 – Schematic Representation of Coastal Squeeze

To address this outstanding concern, a rocky foreshore coastal squeeze study was undertaken to quantify the future habitat gains and losses across the SMP2 area. The aerial photography and Lidar data collected as part of the Cell 1 programme were vital data input to this work, enabling the existing extent of rocky foreshore habitat to be defined and digital ground models of the foreshore to be established, enabling the superimposition of future sea level values and the quantification of habitat changes within a GIS.

3.5.2 Cliffs and Slopes

The aerial photography and Lidar data has proved to be useful mapping tool for projects concerned with cliff stability and coastal outflanking at Flat Cliffs, Filey and Scarborough. At these sites, the data have unpinned the geomorphological mapping, which is essential to developing understanding of the contemporary cliff behaviour. Furthermore, the ongoing Coast Protection Scheme at The Spa in Scarborough South Bay has made use of the data to support characterisation of the geomorphology, cliff behaviour and develop a digital ground model. In this respect, the data has been vital in furthering understanding of the cliff systems and for managing the coastal environment. An example of the geomorphological mapping carried out at the Scarborough Spa is provided in Figure 34.

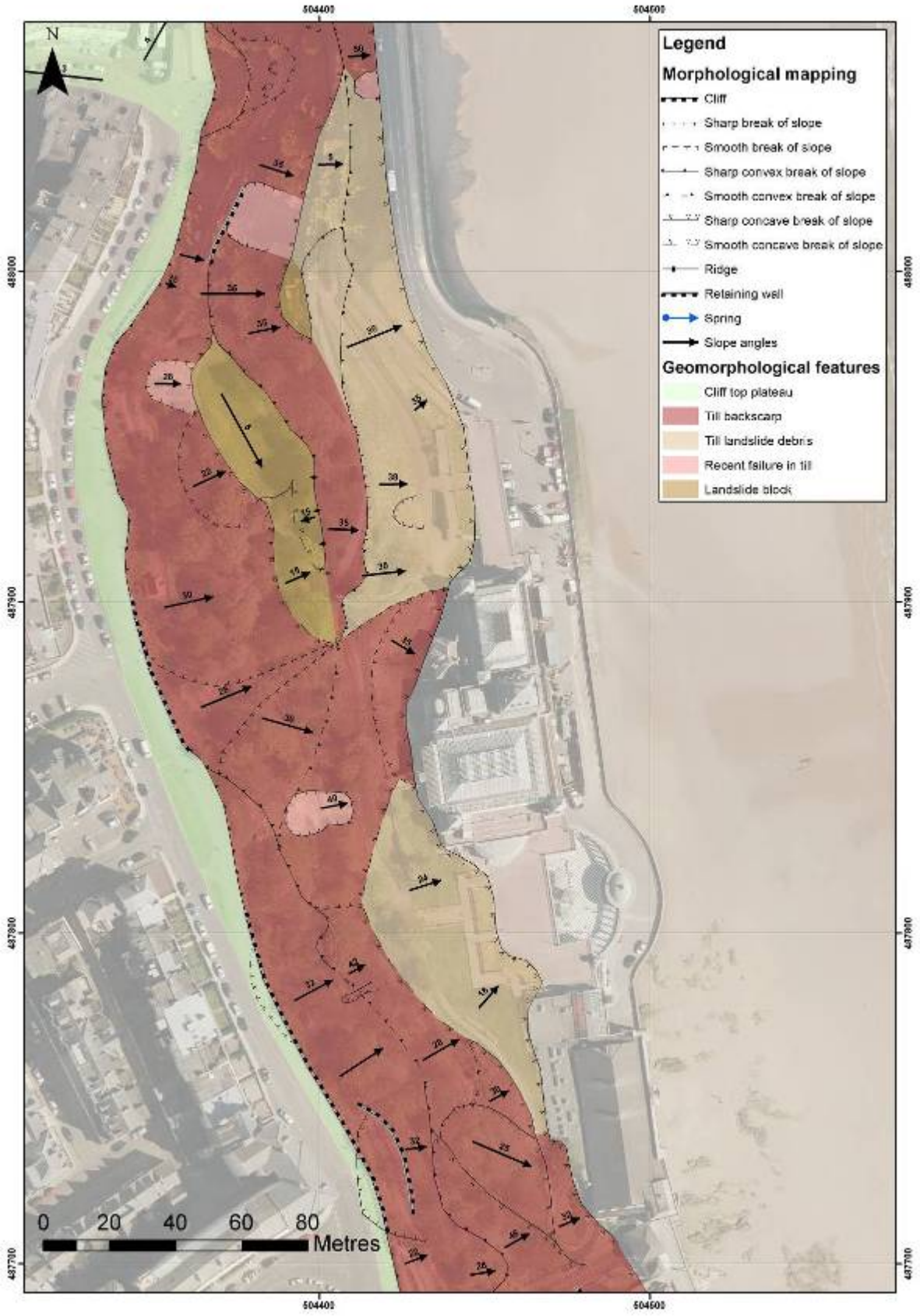

Figure 34 - Geomorphological mapping for an area near the Scarborough Spa Complex, based on aerial photography and Lidar ground model data

3.6 Waves

Wave data has been captured at two sites, Newbiggin Ness and Whitby, for the period May 2010 to May 2011 using waverider buoys. The resulting data help to define the wave climate in these areas as part of the appraisal and design of capital works (Whitby) and the post-project evaluation of a beach replenishment scheme (Newbiggin Bay), as well as providing characterisation of the general wave climate across Cell 1.

3.6.1 Whitby Urgent Works

The wave data from the Whitby wave buoy (Figure 35) have been used during the construction of Urgent Works at the East Pier Extension. Following a problematic period of on-site working with the scheme over the winter of 2010/11, the data were used to assess the best time of year to re-mobilise in 2011 and to estimate the anticipated number of days where wave height at the location of the works would exceed allowable limits, given the tolerances of the plant being used.

To help determine the favourable time to start in 2011, the wave heights for the preceding year were reviewed and these indicated calmer conditions between May to Sept 2010. This period exhibited markedly lower wave heights and longer periods between storms. To estimate the anticipated number of days lost due to excessive wave heights, the days actually worked on site between August through to December 2010 were plotted against the wave heights derived from the buoy for the same time period. This identified a wave height threshold of 1.2m measured at the buoy. The 14 weeks of works planned in 2011 to complete the works had the potential for 65 days where the wave heights were well below this threshold (based on the previous year's data) and so could be taken as a possible working day.

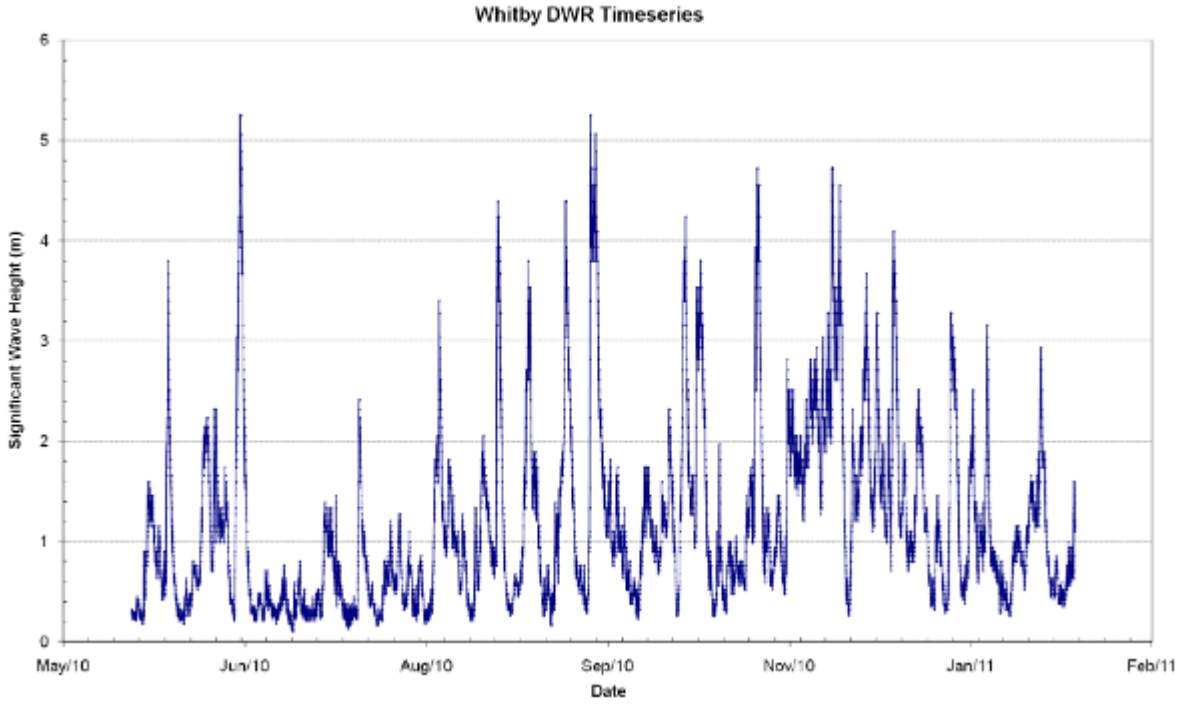

Figure 35 – Sample of Wave Heights Recorded at Whitby Waverider Buoy

3.7 Bathymetric & Sea Bed Characterisation Survey

Sea bed bathymetry was captured using a multibeam echosounder that returned data at a resolution of 2m. The survey comprised 15 shore-normal transects that extended from mean high water neap tides (MHWN) to a depth of 20m. An additional survey line was also captured between each of the 15 transects at a nominal depth of 20m. Sea bed sediment grab samples were taken at nominal 1km intervals along each shore-normal transect and British Geological Survey sea bed sediment mapping was purchased for the whole of the Cell 1 coastline. These data are useful for describing the morphology and sediment character of the sea bed.

3.7.1 Scarborough

Baseline bathymetric survey and sea bed grab sample data were collected at selected locations along the Cell 1 frontage for the first time during 2010. An example of the data collected at Scarborough is shown in Figure 36. A nearshore area of rough bedrock outcrops can be identified which stand proud of the surrounding sea bed and, further offshore, an area of smooth, sandy sea bed exists, which is largely featureless.

These data have allowed an insight into the sea bed morphology and material composition at Scarborough, and at other selected locations. Used in conjunction with shoreline survey data from the beach and cliffs this data helps to develop an understanding of the interactions between the shoreline and the nearshore zone.

It is anticipated that future surveys undertaken in the same locations will provide a long term monitoring record, showing changes in sea bed morphology and composition. Such data can be combined with Lidar data from the cliffs and beaches to understand sediment dynamics and calculate changes in the volume of beach materials. In the future it may also provide a basis for sea bed habitat mapping. An understanding of such dynamics is required for developing beach management and coast protection strategies, both of which are highly important for areas such as Scarborough.

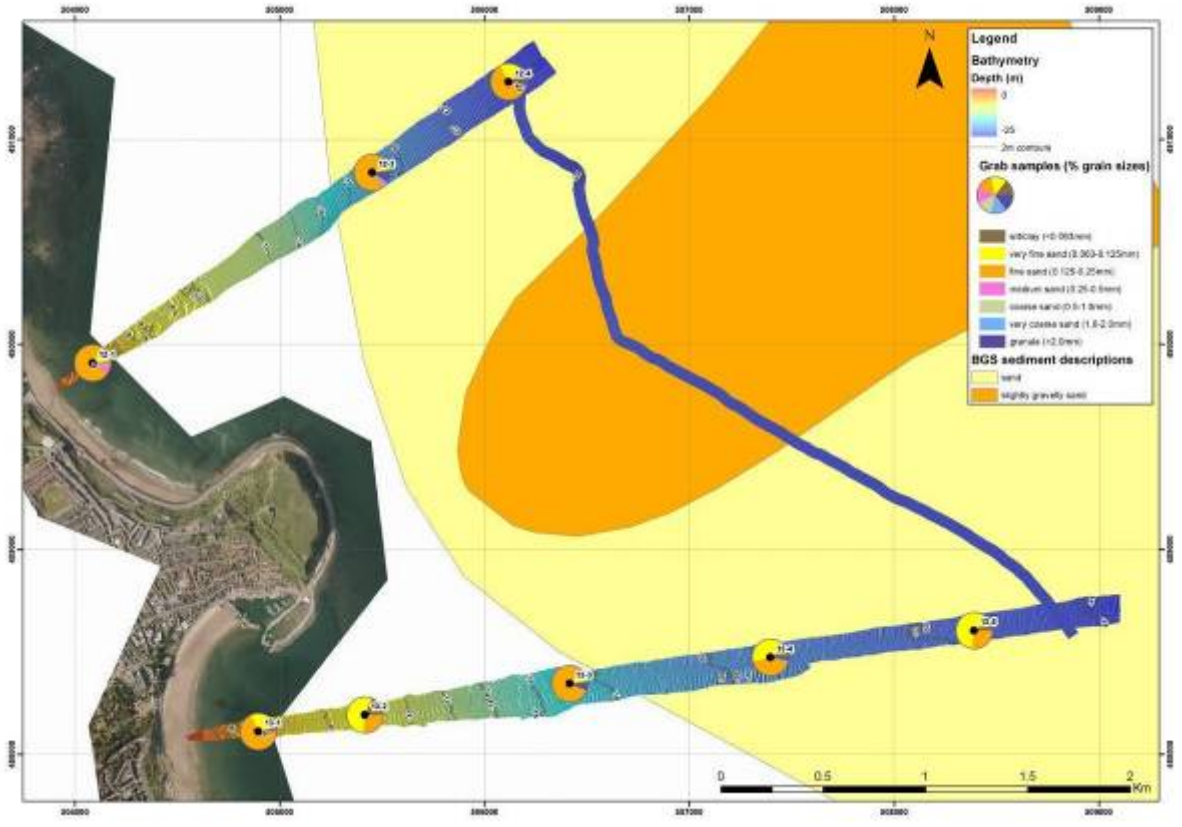

Figure 36 - Bathymetric and sea bed sample data collected at Scarborough in 2010

3.8 Walkover Inspections

Walkover inspections of the coastline have been undertaken in 2008 and 2010 to visually assess the condition of coastal defence assets and the condition of the beaches, dunes, slopes and cliffs.

The condition of engineered assets was classified using standard Environment Agency Condition Assessment Manual (CAM) methods and all results were entered into the National Flood and Coastal Defence Database (NFCDD), with the results from Northumberland and North Tyneside also being entered into a more user-friendly MS Access database that contains records from inspections that extend back at 2-yearly intervals to 2002.

Slope and cliff activity in more complex cliff areas within the Redcar & Cleveland and Scarborough boroughs has additionally been considered by identifying Cliff Behavior Units (CBUs) and classifying their activity using a standard scale that ranges from 'dormant', where no activity was observed, to 'totally active', where 100% of the cliff was active.

Walkover inspections were initially planned to cover Scarborough Borough Council's frontage annually with other local authority frontages inspected every two years. The additional focus on Scarborough's frontage was due to the large number of defence assets in along the frontage, and particularly the high number of cliffs present, with the specific concern over cliff activity following the Holbeck Hall landsliding of 1993. However, in view of the relative stability of both defences and cliffs observed in the early part of the programme, and the availability of accurate aerial survey data, it was decided that inspections of all frontages would be 2-yearly.

3.8.1 North Tyneside Council Maintenance Regimes

Upon receipt of the walkover survey report every two years, North Tyneside Council plans its future maintenance regimes. By undertaking successive surveys, a good understanding of deterioration can be identified, to help prioritise the best use of the finite budgets available. Surveys also identify where maintenance and repairs have been undertaken, and how these repairs continue to perform. This demonstrates the operational value of the walkover inspections.

3.8.2 Knipe Point, Cayton Bay

The walkover inspections at Knipe Point (Cayton Bay) were undertaken in 2008 and again in 2009. The inspection in 2008 was undertaken a few months following the re-activation of a major landslide, the effects of which were observed, as shown in Figure 37. By 2009, the activity at this site had reduced somewhat but ongoing changes were still noted. For example, Figure 38, taken in the same location demonstrates that the tree in the foreground has moved from the cliff top to someway down slope. Whilst a separate investigation was launched here in 2008/9, the walkover surveys provided an update concerning activity at the site, thereby contributing to the understanding of cliff behaviour. It is anticipated that future walkover surveys will highlight any further changes at sites such as this.

Figure 37 – Knipe Point, 2008

Figure 38 – Knipe Point, 2009

3.8.3 *Flat Cliffs, Filey Bay*

Flat Cliffs comprises a small community of properties located about 1.5km south of Filey. Concerns about the stability of the cliffs in this area have been suggested in recent years. The Cell 1 walkover inspections have provided an opportunity to capture any evidence of recent activity including changes in the cliff and beach morphology and damage to property and infrastructure. Figures 39 and 40 show the beach and cliff toe at Flat Cliffs in 2008 and 2009, respectively. In the later photograph, there appears to have been erosion of storm beach gravels from the back of the beach.

Figure 39 – Flat Cliffs, 2008

Figure 40 – Flat Cliffs, 2009

4. Website and Data Usage

4.1 Website

Data and reports produced from the Cell 1 Regional Coastal Monitoring Programme have been stored on a purpose built and ongoing maintained website called the North East Coastal Observatory (NECO) (Figure 41).

www.northeastcoastalobservatory.org.uk

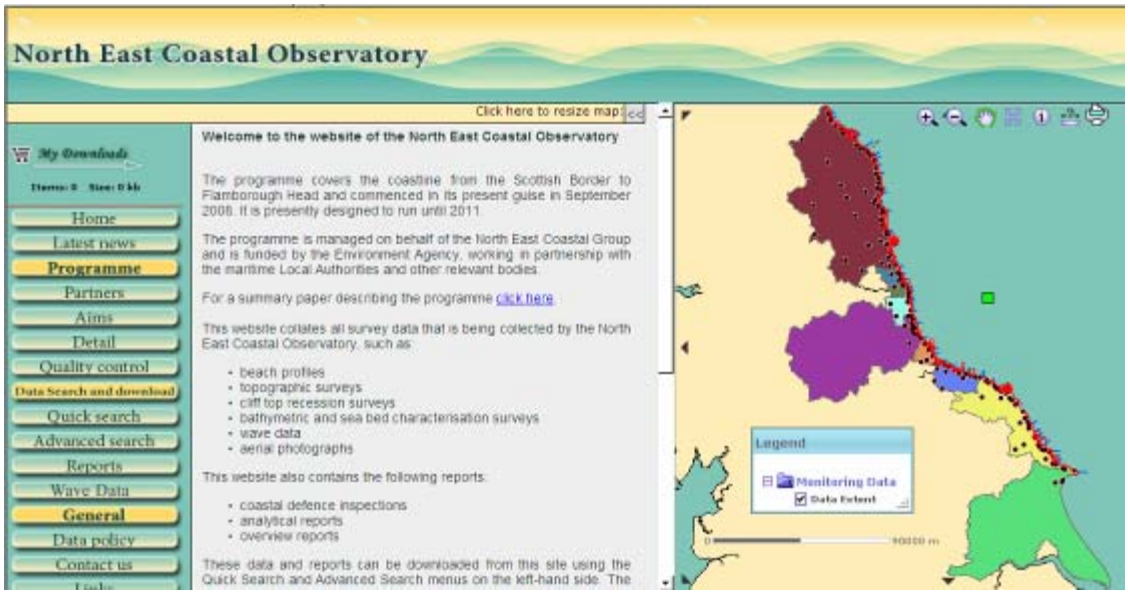

Figure 41 – NECO Homepage

The website contains the following pages:

- **Home** – background information about the programme
- **Latest News** – updates on progress with surveys and reporting
- **Partners** – details of all the programme's partners
- **Aims** – description of the overall aims of the programme
- **Detail** – a more detailed description of the content of the programme
- **Quality Control** – a statement on the quality control procedures that have been used, with links to detail about file specifications
- **Quick Search –** a facility for undertaking a search of the site for data and reports available to download
- **Advanced Search –** a more sophisticated search facility that can be used to specify keywords (e.g. geographical areas), data types and survey dates
- **Reports –** access to PDF versions of all reports produced from the programme
- **Wave Data –** a facility to plot or tabulate, in near-real time, wave height, period and direction data from the two wave buoys deployed as part of the programme

- **Data Policy –** a statement of the conditions of use of the data
- **Contact Us –** contact details for the lead officer managing the programme
- **Links –** hyperlinks to SMP documents, organizations and other useful websites
- **Glossary –** a definition of commonly used terms in the various reports
- **My Account –** a facility to create a username and password to enable download of the data

In addition, the NECO website has a GIS-enabled map viewer which can be used to display survey locations and extents, and various background layers, such as backdrop maps.

Aerial photographs from the 2010 campaign across the whole of Cell 1 are also available to view, when zoomed-in at the appropriate scale, and available to download. Historic aerial photographs from 2003 and 2008 are also available to view and download covering select parts of the frontage.

Data can also be selected using the map viewer and added to a 'shopping cart' facility that can be used for downloads.

The NECO site went 'live' on 6th October 2009. Between this date and 7th July 2011, the site received 435,699 hits.

Figure 42 shows the types of PDF files that have been downloaded in the period between 6th October 2009 and 7th July 2011, containing both the total number and its relative percentage. In total, some 2,040 PDF files were downloaded in this period. The most common download was the Summary Paper that describes the programme, which is the most accessible download on the Home Page. A large number of Analytical/Update Reports and Walkover Inspection Reports have also been downloaded, showing the interest that exists in reports that present findings from the programme.

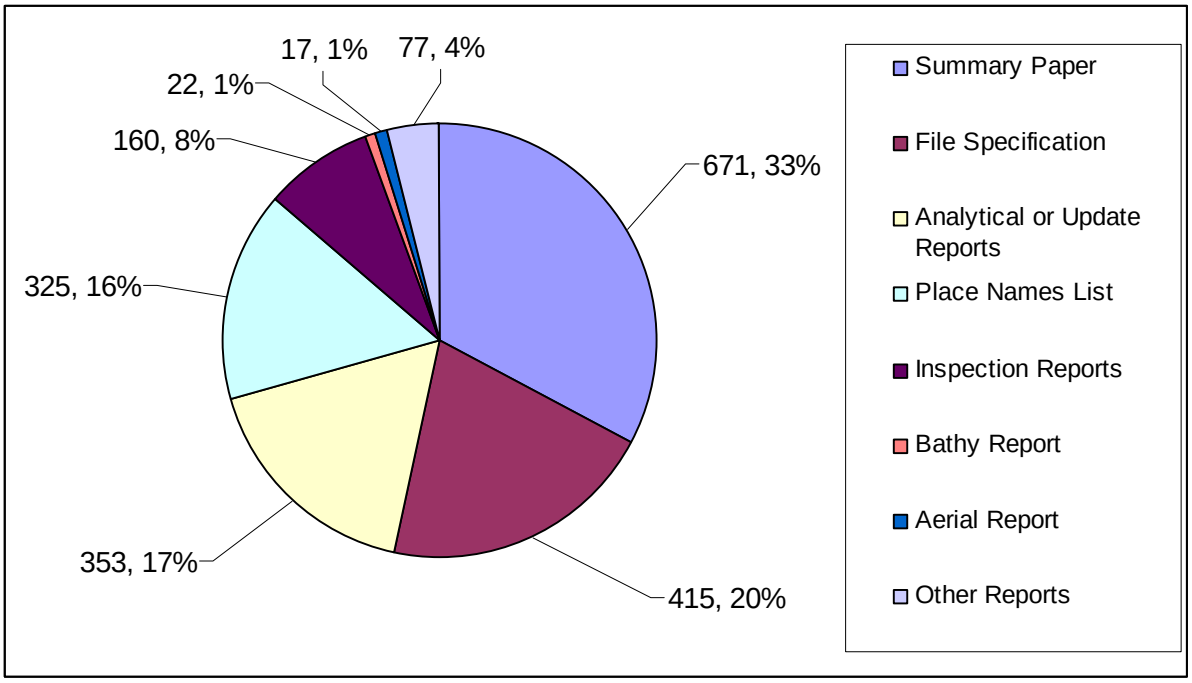

Figure 42 – PDF Downloads (October 2009 – July 2011)

Figure 43 shows the types of data files that have been downloaded in the period between 6th October 2009 and 7th July 2011, containing both the total number and its relative percentage. In total some 1,319 data files were downloaded in this period. By far the greatest download is of site location photographs, with a large number of aerial photograph downloads also made. Of the survey data, a reasonable number of beach profile and topographic survey data have also been downloaded.

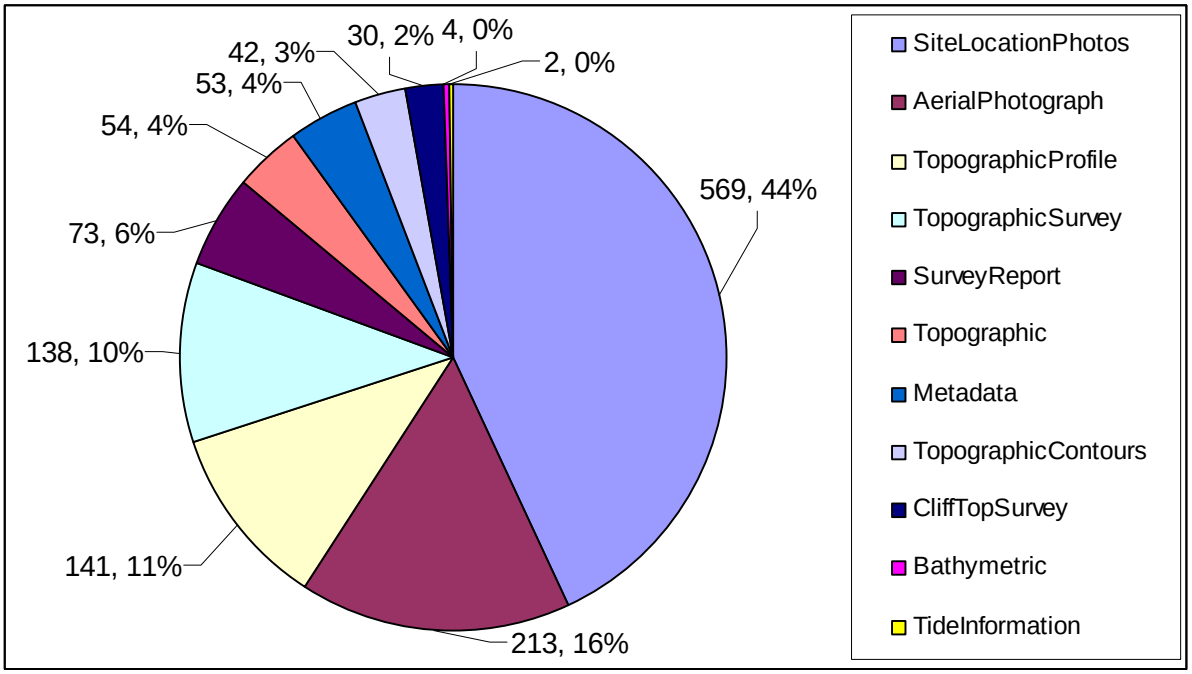

Figure 43 – Data Downloads (October 2009 – July 2011)

4.2 Data Usage

Based on results from an individual meeting with each Local Authority in April/May 2011, data from the Cell 1 Regional Monitoring Programme is known to have been used extensively between 2008 and 2011 on a number of studies (Figure 44), including:

(i) European research framework projects;
(ii) national studies and initiatives;
(iii) high level plans and associated studies across the region;
(iv) coastal strategy plans, studies or local investigations;
(v) coastal defence scheme appraisals;
(vi) outline or detailed design of coastal defence schemes;
(vii) post-project evaluation of coastal defence schemes;
(viii) dune management and habitat creation;
(ix) coastal adaptation;
(x) flood and coastal defence operational activities;
(xi) development proposals;
(xii) port and harbour studies;
(xiii) renewable energy developments (offshore wind and wave power); and
(xiv) miscellaneous other activities.

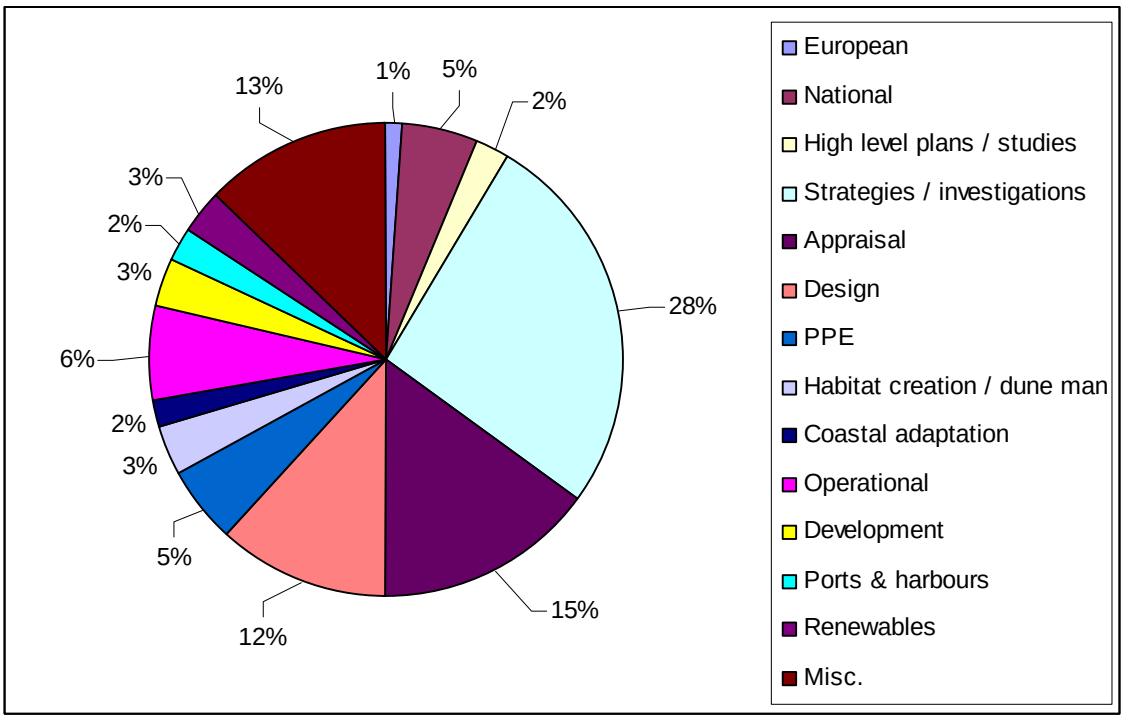

Figure 44 – Data Uses

Appendix D contains a series of spreadsheets which detail the use of specific data types within the above categories, making reference to the specific projects that have benefited from access to, and use of, the data.

In addition, many of the data downloads described in Section 4.1 will have been used for additional unknown purposes, assumed to be academic or personal research, private development proposals, and so on.

5. Future Coastal Monitoring (2011-2016)

From 2011 onwards, coastal monitoring in the North East of England will be undertaken as a regional framework within the *National Network of Strategic Regional Coastal Monitoring Programmes* (the National Programme).

The purpose of the National Programme is to ensure a nationally consistent approach to data type, format and quality, with specific coastal monitoring requirements remaining defined by a suite of regional frameworks that better understand the local and regional risks and requirements.

When commenced in 2008, the Cell 1 Regional Coastal Monitoring Programme adopted an approach to data specification, quality control and data management that was consistent with what has become the standard of the National Programme, and therefore there will be only minor change in the new North East Regional Framework 2011-2016 compared to the Cell 1 Regional Coastal Monitoring Programme 2008-2011.

In order to ensure that the new North East Regional Framework 2011-2016 remains focused on better understanding coastal behaviour and coastal risks, and still meets the requirements of the principal users and beneficiaries of the data, a meeting was held with each maritime Local Authority in April/May 2011 to examine the value of the data collected to date and identify where and how the programme needed to be 'fine-tuned'.

This process led to the development of a suite of tender documents to establish the new North East Regional Framework 2011-2016, covering the following lots:

- Hydrodynamic Services (wave data)
- Swath Bathymetric Services (bathymetric and sea bed characterisation survey)
- Topographic Surveys (beach profile, beach topographic and cliff-top surveys)
- Aerial Photography (including Lidar survey and infra-red photography)
- Ecological Mapping
- Analytical Services

Following a Pre-qualification Exercise that was co-ordinated for the National Programme as a whole, tenders have been submitted by survey contractors and consultants for the above lots and are currently being assessed. The new North East Regional Framework 2011-2016 will then commence with the appointment of preferred survey contractors or consultants to each lot.

Due to the timescales involved in procurement, the Full Measures 2011 survey has been tendered and awarded in advance of the above process, using the same set of survey contractors who successfully pre-qualified for the Topographic Surveys lot under the National Programme exercise. The contract was let in September 2011, ensuring that there will be no gap in data collection across the region.

In keeping with the work undertaken to date, there will be regular analysis and reporting on the findings from the data collection, with all data and reports being stored on the NECO website.

6. Conclusion

The Cell 1 Regional Coastal Monitoring Programme has run for three years in its present guise between 2008 and 2011. Prior to 2008 a Strategic Coastal Monitoring Programme ran for six years across Northumberland and North Tyneside, and a five year programme ran across NECAG, focusing in particular detail on the frontage between Staithes and Speeton, with additional local monitoring programmes undertaken by some authorities.

During the last three year period, valuable datasets have been collected arising from:

- Beach profile surveys
- Beach topographical surveys
- Cliff top surveys
- Aerial photography and Lidar surveys
- Bathymetric and sea bed characterisation surveys
- Wave data collection
- Walkover inspection surveys

These data have been regularly analysed and reported, with key findings used to beneficially inform various management plans, coastal process studies and coastal defence schemes in North East England, as well as informing operational management activities, such as the Environment Agency's operational North East Tidal Flood Forecasting System and ongoing maintenance programmes for existing defences.

Data and reports arising from the programme are available free of charge, subject to registering user details and complying with a Data Policy, via a website named the North East Coastal Observatory. Between its live launch in October 2009 and July 2011, this site had over 435,000 hits, with over 1,300 data files being downloaded.

The coastal monitoring is set to continue for the next five years, between 2011 and 2016, via the National Programme, through a North East Regional Coastal Monitoring Framework that is currently being established. It is expected that the data and findings arising from this programme will continue to be of high value to strategic planning, appraisal, design, evaluation and operational activities in the region.

7. Bibliography and References

The report bibliography produced as output from the 2008 - 2011 programme is:

Cell 1 Regional Coastal Monitoring Programme
(individual reports for each Authority within Cell 1):

- Analytical Report 1: Full Measures Survey 2008
- Update Report 1: Partial Measures Survey 2009
- Analytical Report 2: Full Measures Survey 2009
- Update Report 2: Partial Measures Survey 2010
- Analytical Report 3: Full Measures Survey 2010
- Update Report 3: Partial Measures Survey 2011
- Coastal Walkover Inspections 2010 (except Scarborough Borough Council)
- Coastal Walkover Inspections 2009 (only Scarborough Borough Council)

Cell 1 Regional Coastal Monitoring Programme
(reports produced collectively for all authorities within Cell 1):

- Bathymetric and Sea Bed Characterisation Survey 2010
- Aerial Photographic Survey 2010
- Overview Report 2008 – 2011 (this document)

NECAG Coast Protection Assets and Coastal Slope Condition Analysis
(individual reports for each Authority between the River Tyne and Flamborough Head):

- Walkover Inspection Report 2008

Northumbrian Coastal Monitoring Programme
(report produced collectively for all Authorities between the Scottish Border and the River Tyne):

- Defence Inspection Overview 2008

References cited in this Overview Report are:

- Cooper N & Dolan N, in press. *Adaptation to Coastal Erosion at Lizard Point, Tyne & Wear, UK*. Proceedings Institution of Civil Engineers Maritime Engineering Themed Issue on Coastal Adaptation.

- Posford Duvivier, 1998. *St. Abb's Head and the River Tyne Shoreline Management Plan.* Report to Northumbrian Coastal Authorities Group.

- Royal Haskoning, 2007. *River Tyne to Flamborough Head Shoreline Management Plan 2.* Report to North East Coastal Authorities Group.

- Royal Haskoning, 2008. *Halliwell Banks Ryehope – Determining the Edge of Fill.* Report to Environment Agency.

- Royal Haskoning, 2008. *Trow Quarry Coastal Defence Scheme Project Appraisal Report.* Report to South Tyneside Council.

- Royal Haskoning, 2009. *Sandhaven Dune Management Plan.* Report to South Tyneside Council.

- Royal Haskoning, 2009. *Littlehaven Sea Wall Options Appraisal.* Report to South Tyneside Council.

- Royal Haskoning, 2009. *Old Harbour Quarry Options Appraisal.* Report to South Tyneside Council.

- Royal Haskoning, 2009. *Northumberland and North Tyneside Shoreline Management Plan 2.* Report to Northumbrian Coastal Authorities Group.

- Royal Haskoning, 2010. *Northumberland and North Tyneside Rocky Foreshore Coastal Squeeze Study.* Report to Northumbrian Coastal Authorities Group.

Appendices

Appendix A
Beach Profile and Topographic Survey Locations

Appendix B
Clifftop Survey Locations

Appendix C
Bathymetric and Sea Bed Characterisation Survey Locations

Appendix D
Data Usage