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Dynamic Coast - National Coastal Change Assessment: Cell 10 - Orkney

Main report here

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National Coastal Change Assessment
Steering Committee

Coastal Change & Vulnerability Assessment

Dynamic Coast – Scotland's National Coastal Change Assessment

Executive Summary

- Cell 10 covers the Orkney Islands.
- In Cell 10 Mean High Water Springs extends 1,024 km which makes up 5% of the Scottish coastline. Of this length, 61% (623 km) has been categorised as hard and mixed, 36% (373 km) as soft and 28.3 km (3%) as artificial.
- Within the historical period of 1890-1970s (74 years) much of the soft shoreline did not change significantly (76%), accretion occurred along 19% of soft coasts with erosion occurring along 4%.
- The period from the 1970s to modern spans 37 years, so the historical period data has been normalised to 37 years to allow comparison with the modern period. When this adjustment has been applied the extent of erosion has increased from 3% to 4%, whilst accretion has reduced from 9% to 4% and stability has increased from 89% to 93%.
- Rates of change have also increased, with erosion rising from 0.2 m/yr to 0.4 m/yr and accretion from 0.3m/yr to 0.75 m/yr.
- Taken together the modest changes in extent, with quickening in rates of change, is comparable with other more rock-dominated cells, where the level of protection offered by adjacent rocky shores is higher, than on more exposed cells. So whilst compared with more open cells the situation in cell 10 (Orkney) is not as bad, the increase in erosion rate is a concern.

Disclaimer

The evidence presented within the National Coastal Change Assessment (NCCA) must not be used for property level of scale investigations. Given the precision of the underlying data (including house location and roads etc.) the NCCA cannot be used to infer precise extents or timings of future erosion.

The likelihood of erosion occurring is difficult to predict given the probabilistic nature of storm events and their impact. The average erosion rates used in NCCA contain very slow periods of limited change followed by large adjustments during storms. Together with other local uncertainties, not captured by the national level data used in NCCA, detailed local assessments are unreliable unless supported by supplementary detailed investigations.

The NCCA has used broad patterns to infer indicative regional and national level assessments in order to inform policy and guide follow-up investigations. Use of these data beyond national or regional levels is not advised and the Scottish Government cannot be held responsible for misuse of the data.

Contents

Document Structure

This document outlines the Historical Change Assessments and Vulnerability Assessment for Scotland's soft coastline. The methodologies used within the NCCA are detailed in a separate report. The document is structured to conform to the Scottish coastal sediment cell and sub-cell boundaries that were first delimited by Ramsay and Brampton (2000) in a series of 11 reports. The concept of coastal cells as a science based management unit for the coast is based on a recognition that the processes that shape and alter the coast, while unrelated to administrative boundaries are related to changes in sediment availability and interruptions to that availability. As a management unit, the coastal cell can be seen to fulfil a similar function to that of a catchment area of a river for terrestrial flood management. Changes in erosion, accretion and sediment supply in one coastal cell are seen to be largely unrelated to, and unaffected by, conditions in adjacent coastal cells, and are therefore seen as self-contained in terms of their sediment movement. For example, at many sites net sediment movement is in one direction and may pass around a headland (the major cell boundaries) only in very small volumes. Within a cell, any engineering structures that interrupt alongshore sediment delivery on the updrift side of a coast may impact on the downdrift coast but not vice versa given the "one-way" nature of net sediment movement. As sediment sinks, estuaries might be suitable cell boundaries, however subdivision of an estuary where sediment may circulate freely between both banks is inconvenient and so the inner portions of major firths and estuaries have been defined as sub-cells (Ramsey and Brampton, 2000). Whilst the cell system is ideal from a scientific perspective, it remains that Local Authorities may straddle a cell boundary. The results and statistics for each Local Authority area and for Marine Planning Regions are contained in a separate report.

Commencing with a national overview, this report summarises key locations whose positions of Mean High Water Springs (MHWS) have changed between the periods 1890s to 1970s and 1970s to modern time, although the exact time of survey may vary slightly around those dates and between coasts. The locations are arranged within sub-cells, which progress around Scotland in an anticlockwise direction, followed by the Western Isles, Orkney and Shetland. A short narrative summarises the historical changes and current situation at each location, followed by a vulnerability assessment which considers the implications of assets adjacent to areas of erosion. This narrative is to allow the reader to appreciate the overall findings from the evidence on coastal changes. The report is concluded by a series of tables summarising the statistics for cell one. Each of the 11 coastal cells has a similar report to this, which sits alongside a national overview to collate the national picture and consider the implication for Scotland's coastal assets. Where appropriate, mention is made of the existence of a shoreline management plan for particular sections of the coast.

The full results of each cell are available on the webmaps (www.dynamiccoast.com) and have been designed to be highly accessible. Within the webmaps the user is able to navigate across the whole country, display various shorelines and click on each of the shorelines, to quantify the changes.

The National Context

For a full national overview of the aims, methodology, characteristics and underlying factors that control Scotland's coastline, the reader is directed to the National Overview report where a Whole Coast Assessment and results from the historical and recent changes are presented. Here only a short summary of the national changes identified are presented to place this individual coastal cell report into context.

Since the 1970s, 12% of the soft coast length across Scotland has been subject to erosion, 11% to accretion and 77% stable or has shown insignificant change (Figure 1). National comparisons from the historical period (1890 to 1970) to recent period (1970-modern), accounting for the different time periods, show an increasing proportion of erosion (8% to 12%), similar stability (from 78% to 77%) and falling accretion (14% to 11%). Where coastal changes occur, they are faster than before. Nationally, average erosion rates after the 1970s have doubled to 1.0 m/yr whilst accretion has almost doubled to 1.5 m/yr.

The national pattern is an aggregation of different results from different parts of the country (Figure 2). The more exposed mainland east coast cells (1,2,3) and Solway Firth (7) have greater proportions of soft coast erosion and accretion (i.e. significant change) and lower proportions of stability. On the rock-dominated cells (for example cells 8,9,10, 11), soft coast stability is far higher and the extent of erosion and accretion lower. Whilst the natural level of protection offered to the soft sections of coast by the surrounding rocky coast has not changed through time, the proportion of soft coast experiencing erosion and accretion has. Considering the changes through time, the exposed coastal cells of the east coast have seen greater increases in change, with more modest changes occurring on the rock-dominated cells.

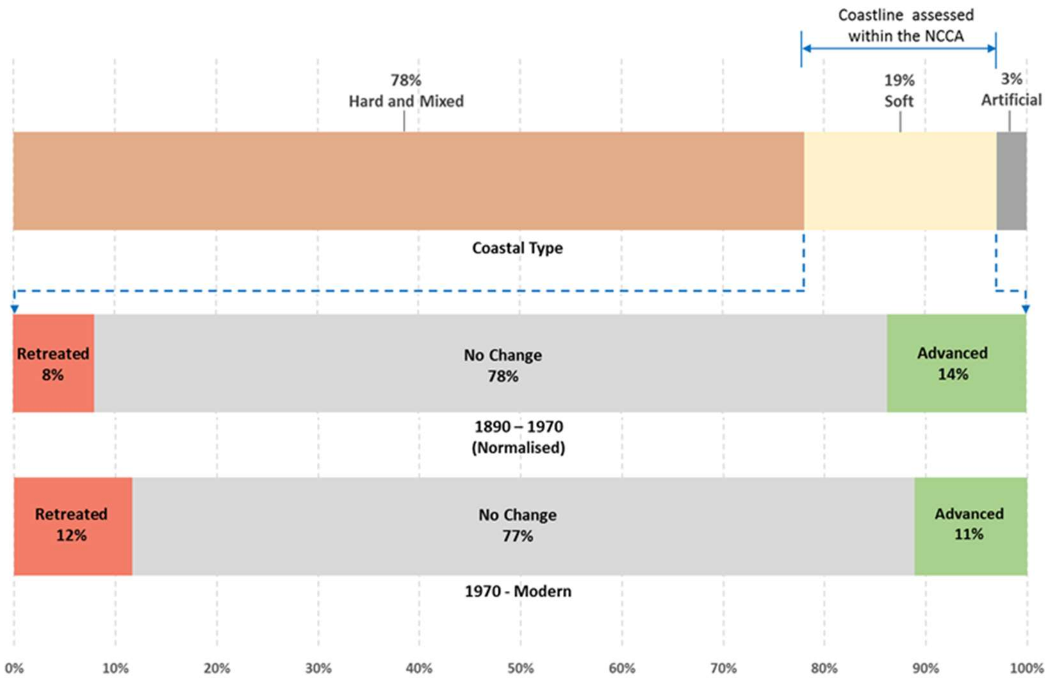

Figure 1: National coastal change results showing the proportion of soft coast within each change category in the historical (ca. 1890-1970 normalised) and recent (ca. 1970-Present) time periods.

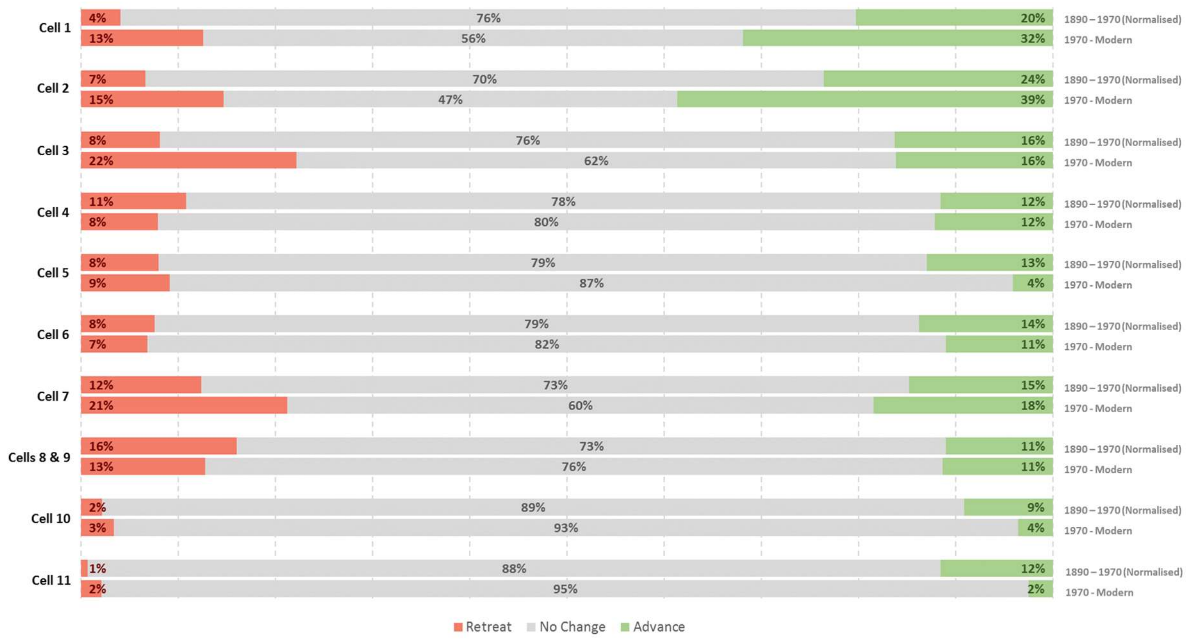

Figure 2: National coastal change results showing historical (ca. 1890-1970, normalised for time period) and recent (ca. 1970 Present.) % of coastal cell showing retreat (red), stability (grey) and advance (green) for soft coast within each cell.

Two other trends are worthy of mention here. The first relates to the propensity for the outer coast to be more exposed to wave impact than the inlets, bays and firths of the inner coast and so the potential for wave-driven erosion is greater along the outer coast. This is exacerbated by a reduction in sediment supply to the outer coast from the higher levels experienced a few thousand years ago. These outer coasts constantly lose sediments to inlet infilling via longshore drift (currents that transport sediment from a source area updrift to an accepting area downdrift). As such, erosion has progressively become the dominant trend on the outer coast in all places except where the import of longshore drift sediments feeds downdrift beaches. Conversely inlets, embayments and firths are sediment sinks that accept soft coastal sediments derived from erosion of the outer coast (the sediment sources) in addition to sediment freshly delivered by rivers. The result is that whilst the inner coast has a bias toward accretion, the outer coast, hard or soft, has a bias toward erosion.

A second trend is the close coincidence between coastal defences and erosion of the adjacent coast. Unsurprisingly, the insertion of defences is in response to a coastal erosion or flooding event, yet there are many instances where the defences themselves have exacerbated the pre-existing erosional condition, either on-site or on adjacent coastline downdrift. The reasons are three-fold. First, a defence structure is aimed at halting or slowing an existing erosion condition and so a successful structure not only halts erosion but also the supply of eroded sediment that had previously reached the fronting beach. The result is a reduced sediment supply and beach lowering. Second, most structures reflect wave energy and, indirectly, sediment leading to beach lowering. Third, the insertion of a defence structure on a coast that is affected by longshore currents not only prevents the supply of sediment to the fronting beach, it also reduces the supply of sediment previously exported leading to downdrift beach lowering and erosion.

Cell 10 - Orkney

Cell 10 covers the Orkney Isles and the sub cell boundaries are shown in Figure 10.1 below. As outlined by Ramsey and Brampton (2000), *"The concept of coastal cells, is not really applicable to Orkney as there are few areas of continuous, or semi-continuous, "soft" coastline. Beach areas tend to be pocket beach types which, at present sea levels, tend to have little longshore continuity. The cell has been split into four sub-cells based on the exposure to the wave climate and the grouping together of coastlines with similar characteristics. Sub-cell 10a encompasses much of the high energy outer coastline of The Mainland and Hoy. Sub-cell 10b covers the relatively more sheltered Scapa Flow coastline. The sheltered north eastern coastline of the Mainland is defined as Sub-cell 10c with the remaining islands to the north east covered in Sub-cell 10d."* This is a view echoed by Hansom et al., (2004). Further contextual information about the processes operating in Cell 10 can be found in Ramsay & Brampton (2000).

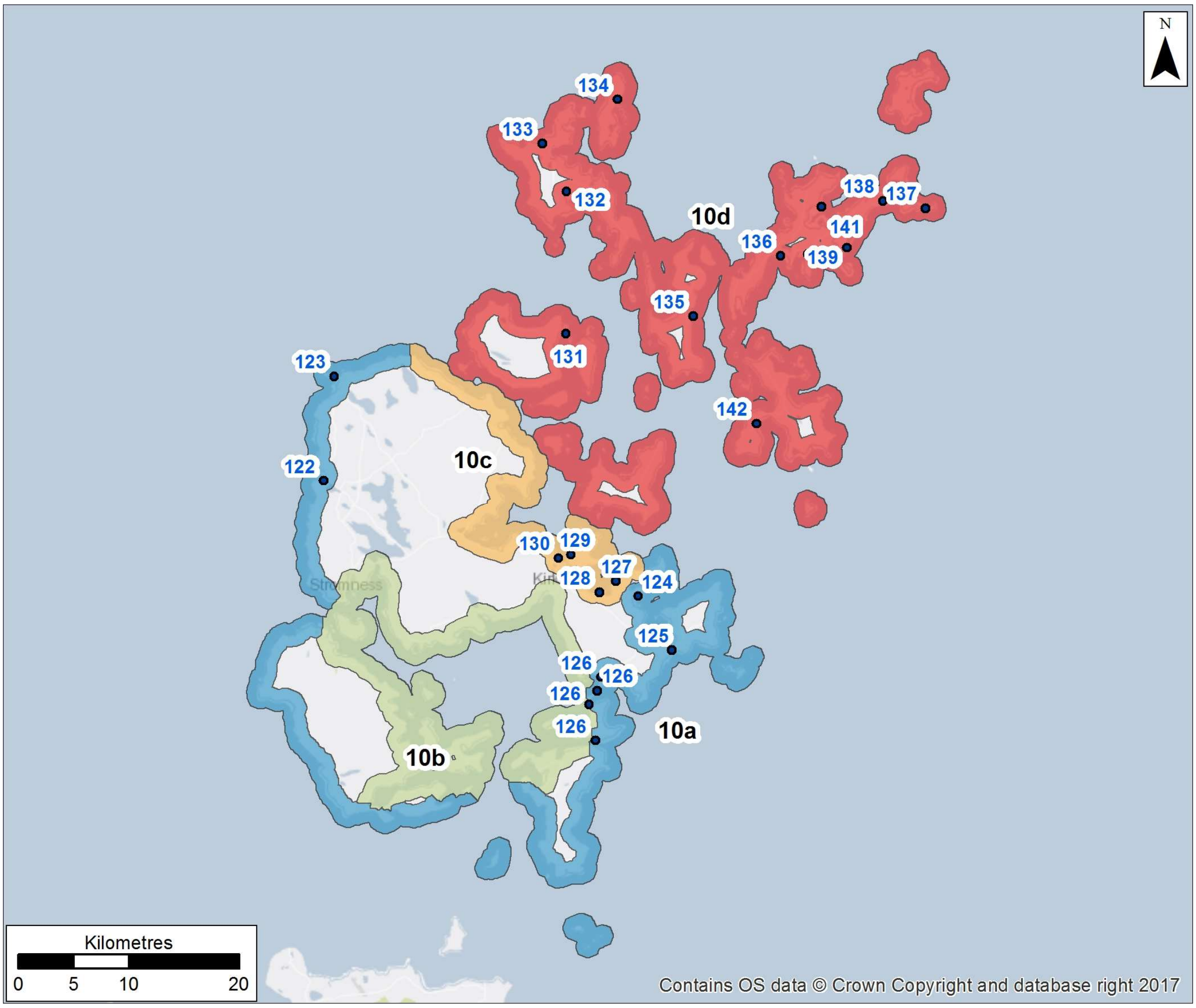

Figure 10.1: The sub-cell boundaries of Cell 10 and locations of sites discussed in this report (blue numbers).

Physical Overview

The length of Mean High Water Springs (MHWS) in Cell 10 has been calculated at 1,024 km which makes up 5% of the Scottish coastline. Of this length, 61% (623 km) has been categorised as hard and mixed, 36% (373 km) as soft and 3% (28 km) as artificial (Table 10.1).Within the historical period much of the soft shoreline has not changed significantly (76%), accretion has occurred along 19% of soft coasts with erosion occurring along 4% (

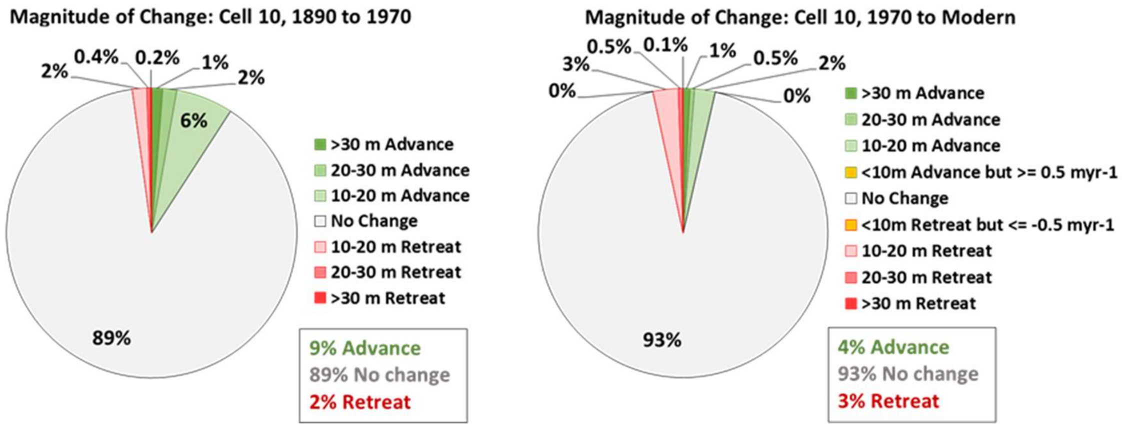

Figure 10.2).

The period from the 1970s to modern spans 37 years, so the historical period data has been normalised to 37 years to allow comparison with the modern period. When this adjustment has been applied the extent of erosion has increased from 3% to 4%, whilst accretion has reduced from 9% to 4% and stability has increased from 89% to 93% (

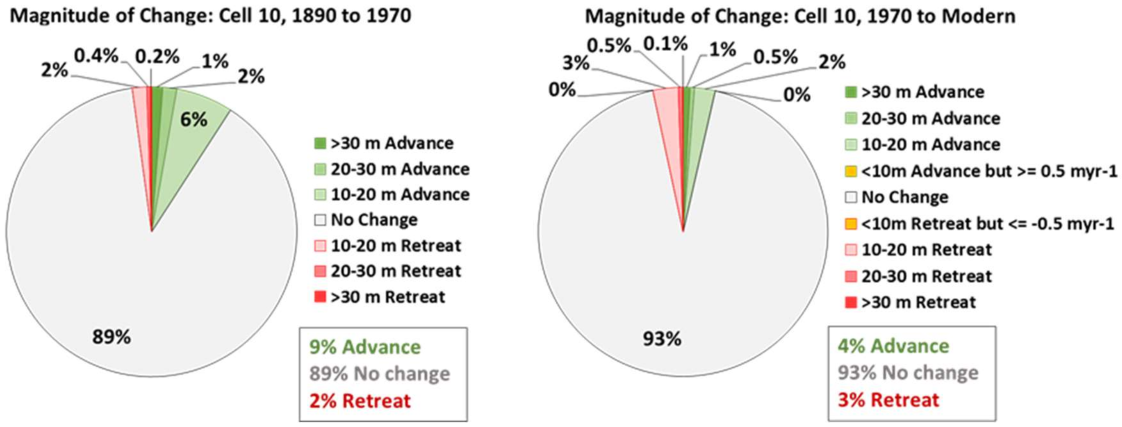

Figure 10.2). Rates of change have also increased, with erosion rising from 0.2 m/yr to 0.4 m/yr and accretion from 0.3m/yr to 0.75 m/yr. Taken together the modest changes in extent, with quickening in rates of change, is comparable with other more rock-dominated cells, where the level of protection offered by adjacent rocky shores is higher, than on more exposed cells. So whilst compared with more open cells the situation in cell 10 (Orkney) is not as bad, the increase in erosion rate is a concern.

. Further statistics for Cell 10 can be found in Table 10.2 and Table 10.3 at the end of this report. It should be noted that for much of Orkney the position of the MHWS line has not been accurately resurveyed since the 1970s and so the 2014 Ordnance Survey (OS) line, which is plotted to closely match the 1970s line, may be inaccurate. Only a small number of locations have LiDAR available to update MHWS. Where necessary for information purposes, a MHWS line interpreted from recent aerial photography has been used here.

Table 10.1: Proportion of each coastal type within Cell 10.

Modern Coastal Type	Length	
	km	%
Soft	372.5	36%
Artificial	28.3	3%
Hard and Mixed	623.1	61%
Total Length (excluding tidally influenced inlets)	1023.8	100%

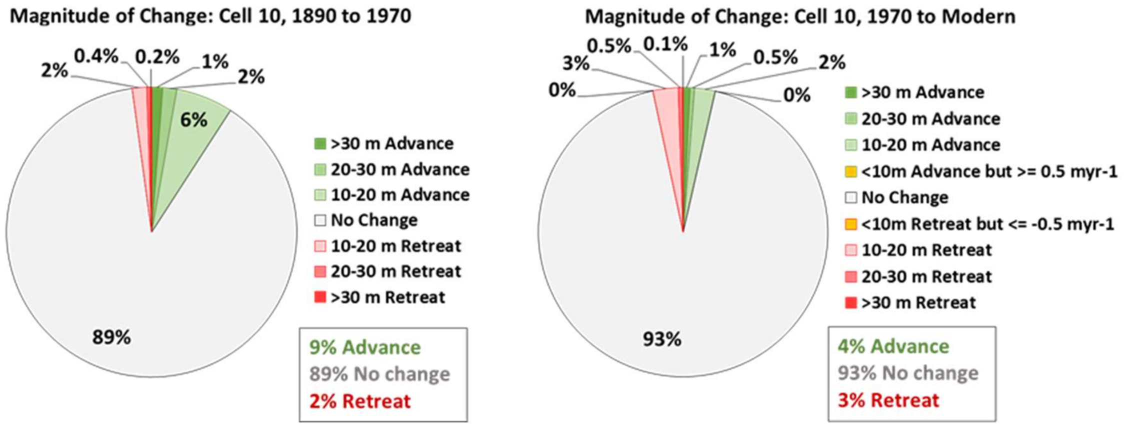

Figure 10.2: Coastal change results for Cell 10 showing the proportional amount of change in the historical (ca. 1890-1970 normalised) and recent (ca. 1970-Present) periods. Rounding errors may produce small % differences between Figure 2 and Figure 10.2.

Asset Vulnerability Overview

The Vulnerability Assessment methodology serves to project the known past erosion rates forward into the future to the year 2050 and is viewable on the online webmaps at www.dynamiccoast.com.. Within Cell 10 a total land area of 12.2 ha, which supports various assets, is anticipated to be lost by 2050. No residential or non-residential properties within the areas expected to be eroded by 2050. A further 12.2Ha of land supporting various types of assets is anticipated to be lost by 2050. When areas that erosion may influence are included then one-residential property is anticipated to be affected by 2050. For a full summary of vulnerable assets see Table 10.4 at the end of this report.

Sub-cell Summaries

Sub-cell 10a - Cost Head to Mull Head

10a.1 Bay of Skaill (Site 122)

Historic Change: Orkney's mainland coast is dominated by sandstone cliffs interrupted by 'bay-head' beaches or 'pocket beaches' where sediment has accumulated between two headlands. The best known of these is the Bay of Skaill, located on the west coast and open to the Atlantic. The best-preserved Neolithic settlement in Western Europe, Skara Brae is located here and part of the UNESCO Heart of Neolithic Orkney World Heritage. When the village was built some 5,000 years ago, it overlooked a freshwater loch within a shallow depression separated from the sea by a sand dune system to the west. Around 3,000 years ago, the barrier breached, opening the loch to Atlantic waves and allowing wind-blown sand to bury the Neolithic village, resulting in its abandonment. Since then, and similar with many beaches and dune systems in the west and north of Scotland (see May and Hansom, 2003), the beach and dunes at Skaill have been driven landward by sea level rise until, in 1850, the stone walls of the buried village were exposed by storm wave erosion. Defences were installed in 1927 following another storm in 1924, that have since been added to, in a piece-meal fashion, in response to the development of wave-driven erosional bights (mainly) to the north.

Figure 10.3: MHWS position in 1890, 1970s, and Modern datasets at Bay of Skaill. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Between 1900 and 1972 the position of MHWS has remained largely stable with some isolated areas of accretion over the 72 years (Figure 10.3). At first glance this contrasts with the evidence of long-lived storm driven coastal erosion. However, this is inconsistent in that short-term changes can mask longer term trends. In addition, it is also possible for the upper beach to respond differently to waves than lower sections of the beach so that the upper beach (above MHWS) may experience erosion whilst other parts of the beach may remain stable. Within the NCCA an inherent limitation of the method is the use of a single contour of MHWS to characterise the whole beach.

Whilst the 1972 MHWS is largely coincident within the vicinity of the sea wall at Skara Brae, accretion has occurred between the end of the defences and the Mill at Voydale to the east, with the tide line moving some 14 m seaward (0.2 m/yr) (Figure 10.4). The Mill House appears at the edge of the beach in 1972, with all four walls intact. Since all that now remains is the landward wall before the seaward edge of the dune is encountered, this indicates upper beach and dune retreat despite apparent MHWS stability. Additionally, the changing position of the dune vegetation edge within air photography commissioned by Historic Scotland in 2003, showed 0.3-0.4 m/yr erosion. Further north east of the Mill the 1972 and 1900 tidelines are largely coincident for the next 400 m, northward of which MHWS has advanced seawards between 1900 and 1972 by up to 20 m (0.3 m/yr). Within the remainder of the bay (to the north) MHWS has advanced seawards between 1900 and 1972, by up to 20m (0.3 m/yr) (Figure 10.3).

In 2014 and 2016, Historic Environment Scotland undertook Terrestrial Laser Scanning (TLS) of Skara Brae and its surrounding beach. Comparing these TLS surveys with 1900, 1972 and published map data within 300 m of the village it appears that MHWS has not eroded further inland than its 1900 position (Figure 10.5). The upper beach in front of the village shows the stability expected of a protected shore, however further east and north there has been more instability with MHWS moving seawards due to upper beach accretion. Whilst MHWS may show stability, the beach crest and vegetation edge have nevertheless eroded landward to the east and north of the village over recent decades. Mean Low Water Springs (MLWS) has also moved landward, indicating foreshore steepening and sediment loss in the lower beach (Figure 10.5). Although the 2014 survey shows MHWS to lie 15m landwards of the OS modern published line, subsequent accretion between 2014-16 reduces this.

Future Vulnerability: Whilst the Neolithic village at Skara Brae lies behind a sea wall, the remainder of the bay is largely undefended apart from unofficial tyre and netting defences fronting a house further north (Sea View). The Mill House at Voydale has been largely lost since 1972. The changes at the Bay of Skaill may highlight a possible disconnect between MHWS and the beach crest / vegetation edge, as such further analysis is required before a detailed vulnerability assessment can be carried out. Rates of recent MHWS retreat shown by the TLS in the rest of the bay are modest (15m in 44 years = 0.3 m/yr) (Figure 10.6), however it is not clear if this sample of the bay is representative of a wider pattern.

Figure 10.4: MHWS position in 1890, 1970s, and Modern datasets at Skara Brae. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

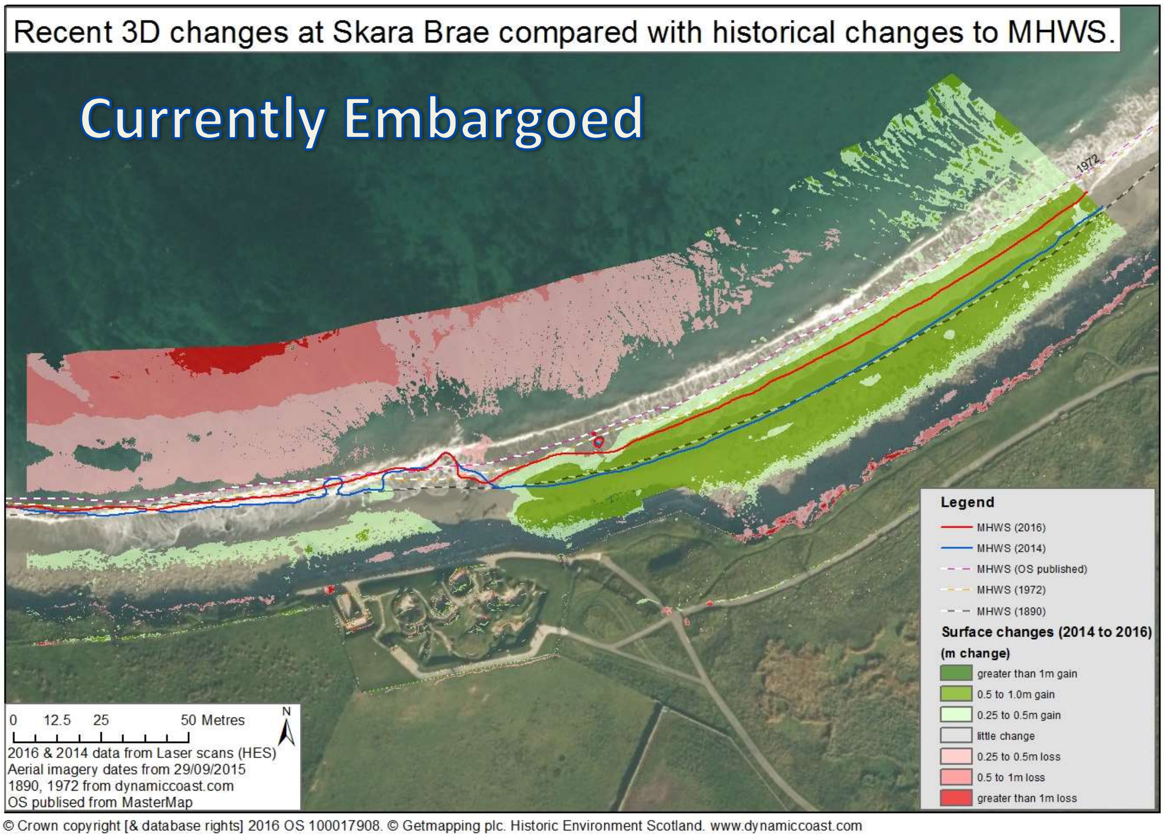

Figure 10.5: Recent 3D changes at Skara Brae compared with historic changes to MHWS.

Figure 10.6: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Bay of Skaill. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10a.2 Brough of Birsay & Birsay Bay (Site 123)

Historic Change: In the northwest corner of Mainland Orkney, the Brough of Birsay is surrounded by high cliffs that ordinarily would exclude these sections from further discussion in the cell reports. However, the changes are briefly discussed here to highlight the accuracy of the surveys of the first and second edition maps and to demonstrate that rocky shorelines may be more dynamic in some locations than we would anticipate. Cliffs and cliff top storm deposits (CTSDs) are subject to substantial change in exposed places such as in Shetland, Orkney and elsewhere (Hall et al., 2008; Hansom et al., 2008).

At Brough Head modest changes occur to the alignment of the gravel beach at the end of the tidal causeway. More significant changes occur at the eastern end of the causeway on both Mainland Shores of the Point of Buckquoy. On the north shore, the 1974 MHWS line lies some 30 to 40 m inland of the 1900 equivalent and suggests that the soft erodible glacial tills that lie on top of the bedrock shore platform have been removed over this period. Indeed, the current position of the cliff line and vegetation limit lies up to 20 m landward of the 1971 MHWS position along much of this stretch of exposed coast.

Further south within Birsay Bay there has been very modest and statistically insignificant erosion within the vicinity of the Earl's Palace (up to 7m between 1903 and 1971, 0.1m/yr). However, given the density of cultural heritage within the bay this may present a significant risk. Some 60 m of defences were installed in front of the historically important graveyard that reclaimed 2-3 m of land from the beach, although the 1903 map shows the buildings were then just as perilously close to the beach as they are currently.

Further south from the Earl's Palace, towards Point of Snusan and Mount Misery, erosion increases with up to 20 m losses occurring between 1900 and 1974 (0.3m/yr). This is compounded by a further 10 m of loss beyond the 1971 line to where the vegetation and cliff line is depicted in the modern air photography. Like many of the exposed beaches here, extensive storm deposits lie above MHWS.

Figure 10.7: MHWS position in 1890, 1970s, and Modern datasets at Birsay Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 10.8: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Birsay Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest MHWS line is the same as the 1971 MHWS position, 'no change' is seen to have occurred at this location (Figure 10.8). Possible future change is therefore not estimated here. Apart from the farm buildings and church at Birsay, much of the land lies in agricultural use. However, from an archaeological perspective vulnerability might be gauged to be higher since there are known archaeological and cultural heritage interests within this area and there is potential for unknown sites that remain to be found.

10a.3 Tankerness (Site 124)

Historic Change: Between 1900 and 1969, the southward extending 1km long spit at Tankerness has undergone accretion along much its east face, but erosion of up to 13 m on its west face (Figure 10.9). Between 1969 and 2014, this has been reversed to show up to 12 m of erosion on the north, east, and west faces.

Figure 10.9: MHWS position in 1890, 1970s, and Modern datasets at Tankerness. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Since there are no assets within the vicinity, any vulnerability relates to undeveloped and semi-natural shore. The lagoon that is enclosed by the east facing shore may become breached to threaten the integrity of the spit point to the south (Figure 10.10).

Figure 10.10: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Tankerness. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10a.4 Dingieshowe Bay (Deerness) (Site 125)

Historic Change: Dingiehowe is a tombolo linking Deerness in the east of Orkney Mainland and was identified by Ramsay and Brampton (2000) as being particularly vulnerable to erosion. The mapping analysis between 1903 and 1968 shows erosion on the western half of the northern-facing coast, where up to 20 m was lost over the 63 years (0.3 m/yr) (Figure 10.11). The southern-facing shore shows greater stability with changes of less than 10 m. Tombolos (known as Ayres locally) often carry roads in Orkney and in this case, it is the main road to Deerness. The area of greatest erosion before the 1970s was on the north side and this continued to erode a further 10 m until its current position was reached by 2014. Further west the road lies immediately adjacent to the 1968 MHWS and in the centre of the tombolo, MHWS is within 8 m of the road (A960).

Figure 10.11: MHWS position in 1890, 1970s, and Modern datasets at Dingieshowe Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 10.12: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Dingieshowe Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The low rates of erosion at Dingiehowe mean that the site is not identified by the future look assessment (Figure 10.12). Nevertheless, the modern MHWS is so close to the roadway as to allow its mention as a vulnerable area and of concern for the future, especially if there are short-term changes in the rate of movement of MHWS on both sides of the tombolo. Tombolos have two shorelines and are doubly at risk in comparison with ordinary beaches that have only one shoreline.

10a.5 Churchill Barriers (1 to 4) (Site 126)

Historic Change: The Churchill Barriers were formed in the Second World War from cement blocks to connect Mainland Orkney to the islands of Lamb Holm, Glimps Holm, Burray and South Ronaldsay and so close off the pre-existing narrows. Small changes can be found on the shores adjacent to the first three northern barriers. Here, the blocking of the narrows has resulted in the advance of MHWS by up to 80 m metres (1m/yr) or the retreat of MHWS of up to 60m metres (0.7m/yr) as shown at Churchill Barrier No. 3 at Weddell Sound (Figure 10.13). However, the most impressive changes have occurred along the eastern flank of the fourth barrier that connects South Ronaldsay with Burray (Figure 10.14). The construction of the barrier interrupted the westward sediment supply from the North Sea into Scapa Flow. Between 1903 and 1983 up to 120 m accreted on the southern shore at Ayres of Cara (1.5 m/yr) and 70m on the northern shore (0.8 m/yr) However, the barriers were constructed between 1940 and 1944, meaning the rates are double that stated. Block ships that were scuttled in deep water before WW2 have been submerged by accreting sand for decades and are now found buried within the interior of the dunes. Such was the rate of accretion of sand that Orkney Council used the interior of the dunes as a sand quarry for many years.

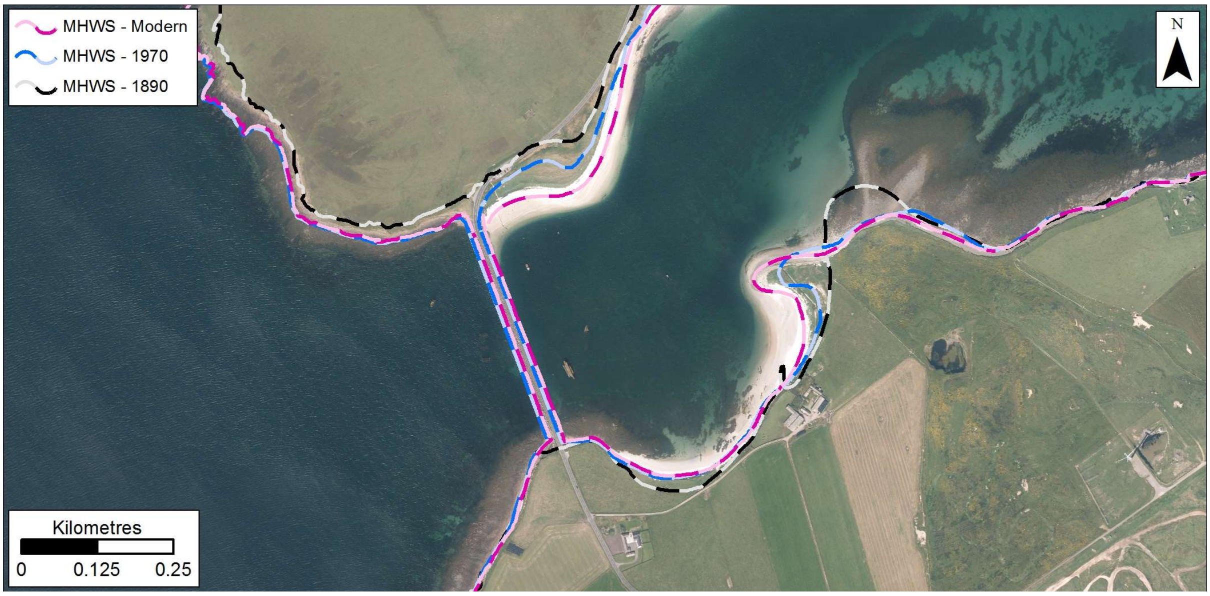

Figure 10.13: MHWS position in 1890, 1970s, and Modern datasets at Churchill Barrier No. 3. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

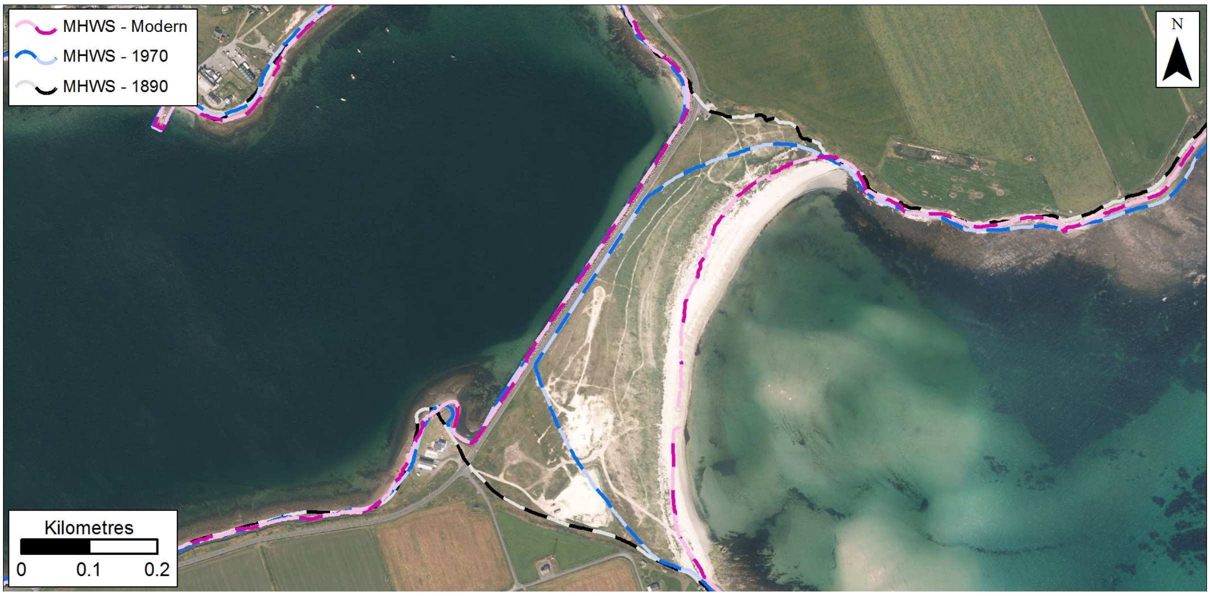

Figure 10.14: MHWS position in 1890, 1970s, and Modern datasets at Churchill Barrier No. 4. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The NCCA future vulnerability assessment depends on movements in MHWS and these do not indicate any issues at the Barriers other than accretion and seaward movement (Figure 10.15 and Figure 10.16). However, it is well documented that the construction of the barriers, involving concrete blocks at a steep angle into water of varying depths, lends them susceptible to wave overtopping during high tides and storms. Since this is likely to increase in the future with sea level changes, then the vulnerability of the barriers is of concern from this perspective.

Figure 10.15: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Churchill Barrier No. 3. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 10.16: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data Churchill Barrier No. 4. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Sub-cell 10b - Scapa Flow

There are no substantial changes to report within this sub-cell.

Sub-cell 10c - Mull Head to Cost Head

10c.1 Long Ayre on Inganess Bay (Site 127)

Historic Change: Long Ayre is a 700 m gravel spit that extended west by 80 m between 1900 and 1964 (1.3 m/yr), enclosing a lagoon (Figure 10.17). Up to 37 m of erosion (0.5 m/yr) at the eastern (proximal) end of the spit fuels accretion of the westward (distal) end. Since 1964, modest changes have occurred (less than 10 m on the open coast:) but the southward movement continues at its eastern end with the distal end extending west by 15 m over 46 years (0.3 m/yr). The lagoon is not yet fully enclosed and there is tidal exchange at its western end as well as overwash during stormy conditions.

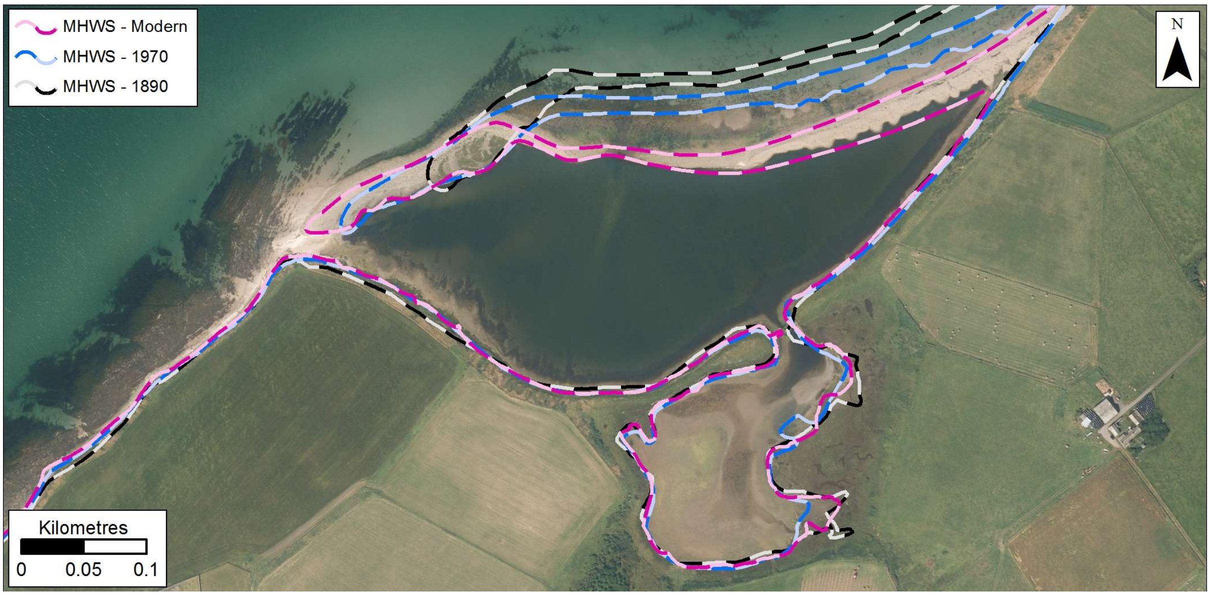

Figure 10.17: MHWS position in 1890, 1970s, and Modern datasets at Long Ayre. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: No built assets occur in this area, so vulnerability remains low (Figure 10.18).

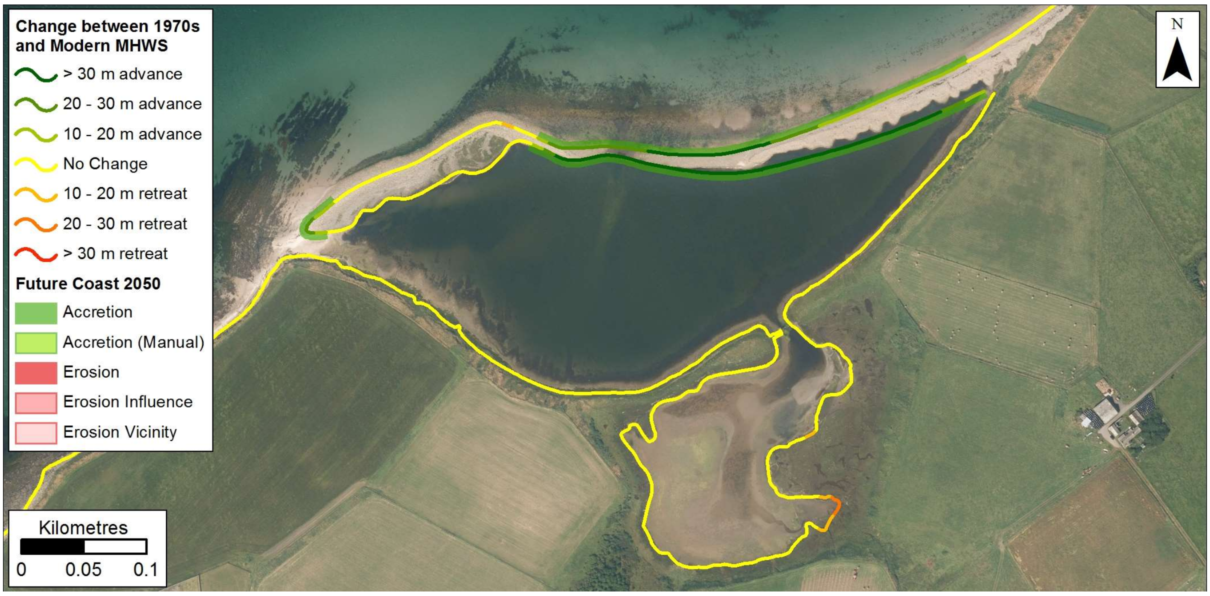

Figure 10.18: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Long Ayre. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10c.2 Sands of Essonquoy & Sand of Wideford (Kirkwall Airport) (Site 128)

Historic Change: Although much of Kirkwall Airport lies adjacent to a rocky foreshore, there has been significant historical erosion along its length (up to 20 m) at both adjacent bays to the west and east. West of the airport up to 13 m was lost between 1903 and 1968 (0.2 m/yr) and up to 23 m on the Sand of Essonquoy to the east (0.3 m/yr) (Figure 10.19). Between 1968 and 2014, there has been limited change along the shore but it is not clear if this is remains a natural shore or if it has been defended. In places, both bays are backed by minor roads that lie close to MHWS and where the vegetation and coastal edge abuts the roadway itself over significant stretches.

Figure 10.19: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Sands of Essonquoy and the Sands of Wideford. Getmapping providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The latest MHWS line is the same as in 1968 so 'no change' has occurred here. Minor roads run along this stretch of shore and give cause for concern over the medium to long term.

Figure 10.20: Anticipated coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Sands of Essonquoy and the Sands of Wideford. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10c.3 Bay of Weyland (Site 129)

Historic Change: The shoreline at the Bay of Weyland lies within Kirkwall Bay and appears to have advanced almost 40m between 1900 and 1964 (0.4m/yr) and a further 40m before 2012. However, given that the main roadway closely follows the 1900 line and the otherwise irregular outline of the adjacent coast it is suspected that the smooth outline of the bay is the result of land claim.

Figure 10.21: MHWS position in 1890, 1970s, and Modern datasets at the Bay of Weyland. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The advance of the coastline in the Bay of Weyland is due to human activity, therefore this advance is not expected to continue in the future (Figure 10.22).

Figure 10.22: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Bay of Weyland. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10c.4 Kirkwall Bay (Site 130)

Historic Change: Kirkwall Bay has seen multiple phases of coastal development over the last 93 years but very little natural change. Whilst MHWS ran along the Ayre in front of the 'Peedie Sea' in 1900, it has since been fortified with defences along its length moving MHWS seaward 10 m and up to 20 m in the western corner by 1993 (0.2 m/yr) (Figure 10.23). Whilst the two western piers were in place in 1900, they have been widened by up to 20 m in places. Between 1992 and 2014 the pier was developed to further enclose a marina to the east and a new extension to the (now) central pier. To the west of the harbour a new car park was claimed resulting in MHWS moving 45 m seawards.

These recent changes are the latest in a series which have changed the shape of the bay and town of Kirkwall over the centuries. The history of Kirkwall can be traced back at least to the 11th Century, where visitors to *Kirkjuvagr* (from the Old Norse meaning 'Church Inlet') arrived by boat, around the incomplete Ayre (barrier beach) into a lagoon which is now the Peedie Sea. The Peedie Sea inlet was tidal in 1881 in the First Edition OS maps but had been enclosed by 1972 (link).

Figure 10.23: MHWS position in 1890, 1970s, and Modern datasets at Kirkwall. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: MHWS is artificial within Kirkwall, and has not retreated during either the historical or recent period and therefore no assets are gauged to be vulnerable (Figure 10.24).

Figure 10.24: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Kirlkwall. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Sub-cell 10d - The Northern Isles of Orkney

10d.1 Mae Sand, Rousay (Site 131)

Historic Change: Mae Sand is a beach on the North-east corner of Rousay, backed by a tombolo (Ayre in Orkney). Whilst there are no mapped assets nearby the changes are briefly discussed here due to their broader significance. The shoreline in 1900 is largely coincident with that in 1980 and in the modern published OS maps purported to be 2014 (Figure 10.25). However, the more recent aerial photography clearly shows the tombolo to be breached, overwashed and realigned. Whilst this may inconvenience the landowner/farmer and does not affect any fixed assets, it serves to highlight that the tombolos/ayres, commonplace in the Northern Isles, are often used for roads and can be highly dynamic features that are vulnerable to change.

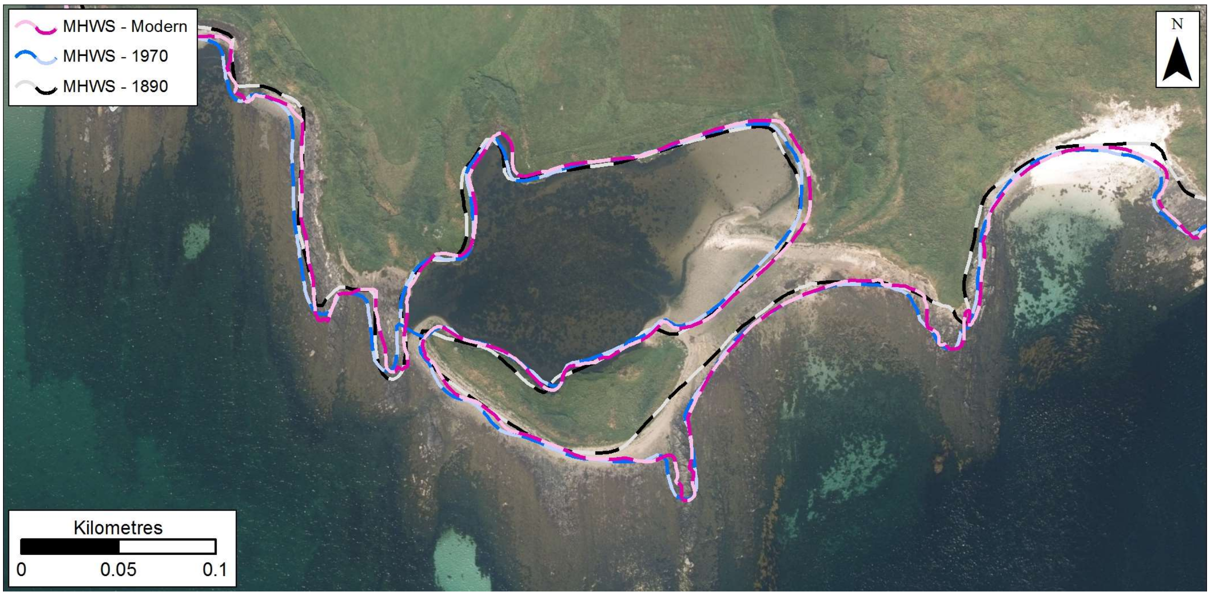

Figure 10.25: MHWS position in 1890, 1970s, and Modern datasets at Mae Sand. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest MHWS line is the same as the 1980 MHWS position, 'no change' is seen to have occurred at this location (Figure 10.26). Possible future change is therefore not estimated here.

Figure 10.26: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Mae Sand. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10d.2 Bay of Tuquoy, Westray (Site 132)

Historic Change: Within the Bay of Tuquoy, the Ayre of Fribo has undergone substantial changes over the last 116 years. In the 1900 map, a narrow 480 m long spit extends in a south-westerly direction but by 1975 it had retreated up to 70 m over 75 years (1 m/yr) and become more compact. Since 1975, the retreat has continued by up to 50 m and the spit has now (2014) coalesced with the adjacent shore to form a brackish lagoon (Figure 10.27). Whilst the published MHWS correctly shows the modern position as verified by recent aerial photography, annotations within the OS maps still refer to the feature which has now been lost.

Figure 10.27: MHWS position in 1890, 1970s, and Modern datasets at the Bay of Tuquoy. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: There are no anticipated vulnerability issues at this site.

Figure 10.28: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Bay of Tuquoy. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10d.3 Links of Notland, Westray (Site 133)

Historic Change: The Links of Notland have experienced considerable changes to the extent and vegetation cover of the sand dunes over the last 116 years, although the actual coastal changes are more modest and contrasting. Between 1900 and 1972 the western half of the bay accreted seawards up to 23 m (0.3 m/yr), while the eastern half of the bay retreated landwards by up to 16 m over the same period (0.2 m/y) (Figure 10.29). The modern position of MHWS (OS master map dated at 2014) closely mirrors that of the 1972 line, showing apparent stability despite apparent recession of the coastal edge as shown on the photography. This has contributed to an ongoing wind-erosion issue associated with rabbit infestation and surface disruption by archaeological excavation over the last few decades.

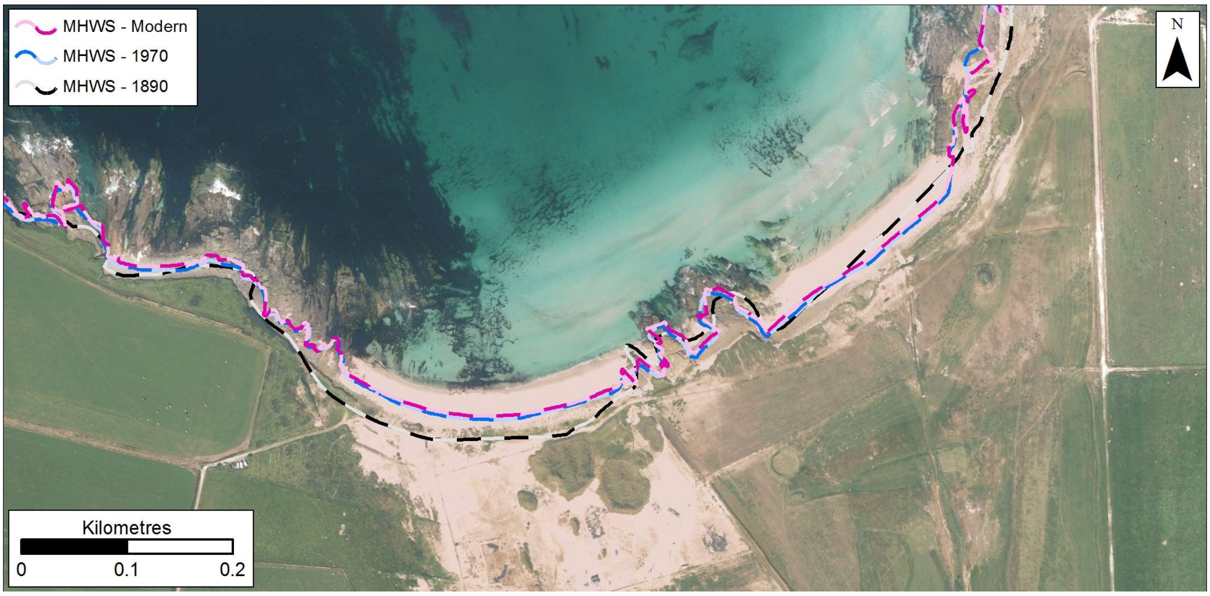

Figure 10.29: MHWS position in 1890, 1970s, and Modern datasets at the Links of Notland. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest OS MHWS line is the same as the 1975 MHWS position, 'no change' is seen to have occurred at this location (Figure 10.30). Nevertheless, the recent aerial pgotography show that recession is ongoing with the dune crest and likley position of MHWS moving landward. The coast then is mobile but has no built assets so vulnerability is judged to be low.

Figure 10.30: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Links of Notland. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10d.4 Papa Westray (Site 134)

Historic Change: The north-east shore of Papa Westray (locally Papey) has undergone varying amounts of erosion and accretion between 1900 and 1972. On the east coast, South Wick has seen accretion of up to 12 m between 1900 and 1972 whilst North Wick has seen up to 10m in the south and 30 m in the north. Since then there has been slow but ongoing erosion as shown by the 2014 OS modern lie that purports to date from 2014. However, close examination of the aerial photography indicates that the coast edge along both bays is eroding landward slowly and that it now approaches within 1 m of the road that hugs the shore at two places in South Wick (north of the pier) and lies within 3 m of the road over a length of about 1 km (Figure 10.31). The farm buildings and residential property that lie on the seaward side of the road at Surhoose Taing (between Mayback and Via) have suffered from coastal recession over recent years resulting in a variety of unofficial, unsightly and largely ineffectual coastal defences.

Figure 10.31: MHWS position in 1890, 1970s, and Modern dataset son Papa Westray. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest MHWS line is the same as the 1975 MHWS position, 'no change' is recorded at this location (Figure 10.32). Nevertheless, the modern aerial photography shows that recession continues and the viability of the road that parallels the coast and provides access to the coastal properties that lie on both sides of the road is vulnerable in places and is a cause for concern in the future.

Figure 10.32: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data on Papa Westray. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10d.5 Bay of London and Sand of Doomy/Sands of Mussetter, Eday (Site 135)

Historic Change: At the Bay of London (Figure 10.33) on the east side of Eday there has been up to 10m accretion since 1900 and 1971. Prior to that the roadway crossed the bay on a causeway that has been eroded before 1900 but whose traces remain. Over the modern period some 8m of accretion has occurred in the bay centre, according to the OS MHWS. However in reality, 28m of accretion is shown by the photography although this does taper away to zero at the north and south ends.

At the 2km long Sands of Doomy/Mussetter on the west side of the island, a similar amount of erosion of up to 12 m occurred between the 1890s and 1970s, particularly in the north of the bay (Figure 10.34). In the extreme south, there was a substantial amount of accretion amounting to 30m over the earlier period. Since the 1970s there has been limited change in the centre of the bay and the OS 2014 line lies close to the coastal edge and is supported by the aerial photography. In the north of the bay, a further 6 m or so has been lost over the northernmost 300m, judging by the aerial photography depiction of the eroded dune edge. Over about 300m of the southern end of the bay, the OS 2014 line lies some 40m seaward of the actual MHWS position, judging by the aerial photography depiction of the eroded dune edge. This equates to an erosion rate of 1m/yr.

Figure 10.33: MHWS position in 1890, 1970s, and Modern datasets at the Bay of London. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 10.34: MHWS position in 1890, 1970s, and Modern datasets at the Sand of Doomy/Sands of Mussetter. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the the latest MHWS line is the same as the 1971 MHWS position, 'no change' is recorded at this location (Figure 10.35 and Figure 10.36). Nevertheless, accretion has recently dominated the Bay of London and so vulnerability is deemed low. At Sands of Doomy on the west side of Eday, there has been erosoin in the central and northen part of the bay but since there are no built assets nearby (the southen end of the Eday Airport runway lies some 180m landward of the eroding coastal edge), vulnerability by 2050 is deemed to be low. Similarly at the extreme southern end of the bay, no assets are nearby and vulnerability is low despite an erosion rate of 1m/yr.

Figure 10.35: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Bay of London. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 10.36: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Sand of Doomy/Sands of Mussetter. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10d.6 Backaskail Bay, Sanday (Site 136)

Historic Change: Backaskail is a 1.6 km long beach on the south side of Sanday and lies between two long peninsulas which offer reasonable protection. Between 1900 and 1972 there has been up to 35m of accretion (0.5 m/yr), dominating the western half of the bay (Figure 10.37). The changes on the eastern half of the bay are more modest and fall below the 10 m threshold of significance. In the absence of updated data from the OS, the aerial imagery suggests that the accretion has continued in places.

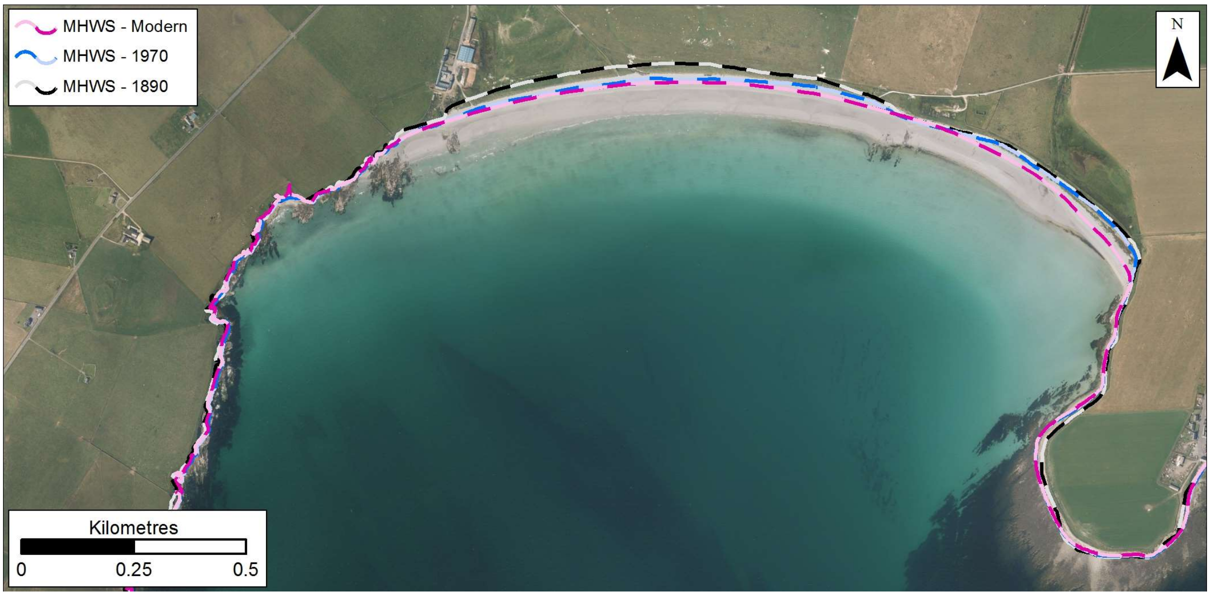

Figure 10.37: MHWS position in 1890, 1970s, and Modern datasets at Backaskail Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Given accretion at Backaskaill and the absence of build assets (apart from a farm access track), no vulnerability assessment has been carried out (Figure 10.38).

Figure 10.38: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Backaskail Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10d.7 Start Point, Sanday (Site 137)

Historic Change: Earlier sections of this report have discussed the behaviour of tombolos or ayres (in Orkney). Within the low-lying island of Sanday, there are several sets of ayres often located on either side of the approaches to tidal inlets. These normally have a gravel core and can be capped with sand or dunes, although some may be rock based with a till cap that has been eroded or submerged by sea level rise, as at Start Point. These features are highlighted here, as they are the most dynamic sections of beaches on Sanday, with the extensive beaches appearing to have remained largely stable between the 1890s and 1970s maps. The ayre that extends south toward Tres Ness has moved east and thickened from its narrow 1890s width, although recent aerial photography shows it to have breached in two places. To the north in the Bay of Lopness the modern and 1890s shorelines lie very close to each other, yet the roadway that runs along the entire length of the bay is less than 4 m from the actual coastal edge in places depicted on the photography. A notable ayre is arguably the one towards the island of Start Point. Early map evidence shows Start Point connected to the island of Sanday, although all maps after 1846 clearly show a tidal breach (Figure 10.39).

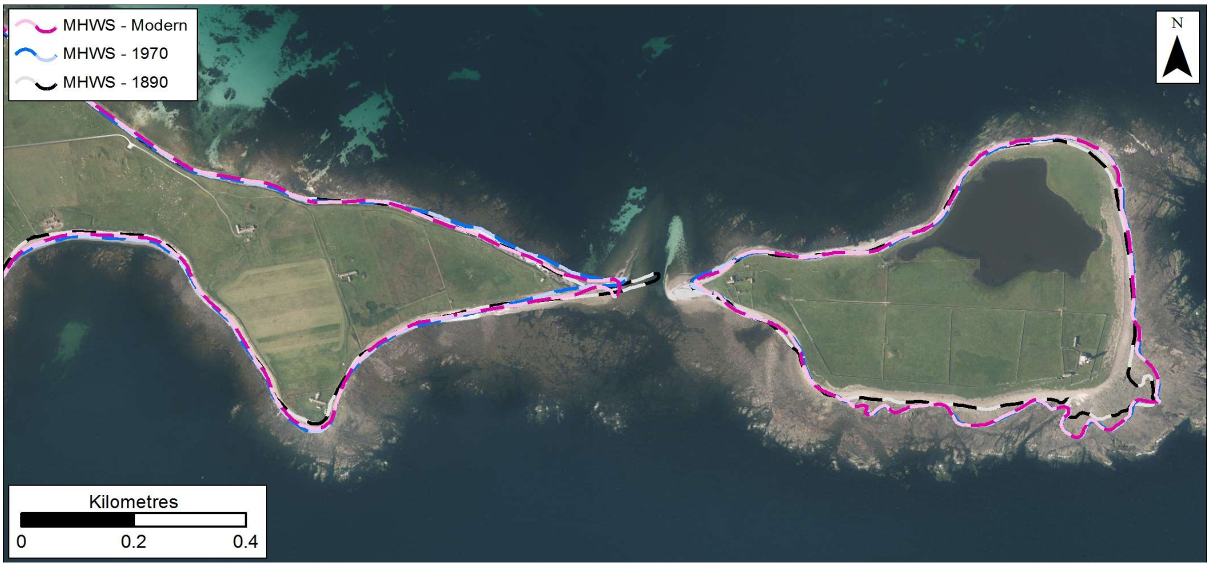

Figure 10.39: MHWS position in 1890, 1970s, and Modern datasets at Start Point. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Given the historical and sedimentological evidence supporting the separation of Start Point, and other islands, from the mainland of Sanday as a result of sea level rise, then the future vulnerability is related to whether the existing gap is set to increase and whether this enhances vulnerability (Figure 10.40, Rennie, 2006). At Start Point this is not the case and the vulnerability relates to anticipated erosion on the north shore of mainland Sanday, west of the widening gap. Since no built assets occur on thus shore then the vulnerability is expected to be low.

Figure 10.40: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Start Point. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10d.8 Bay of Sandquoy and Lopness, Sanday (Site 138)

Historic Change: These twin bays lie at the eastern end of Sanday with Sandquoy on the northern side, and Lopness on the southern side, of the island (Figure 10.41). They are separated from each other by a 600 m wide strip of land much of which lies close to or below MHWS. On both beaches the 2014 Master Map line for MHWS lies over a 1972 line that is not thought to have been updated since, and is thus unreliable. On both beaches the vegetation line is represented by an undercut dune edge that very probably represents the approximate position of the MHWS of 2016. Using this coastal edge line as a proxy for MHWS then up to 17 m of erosion may have occurred since 1972 at rates of up to 0.4 m/yr.

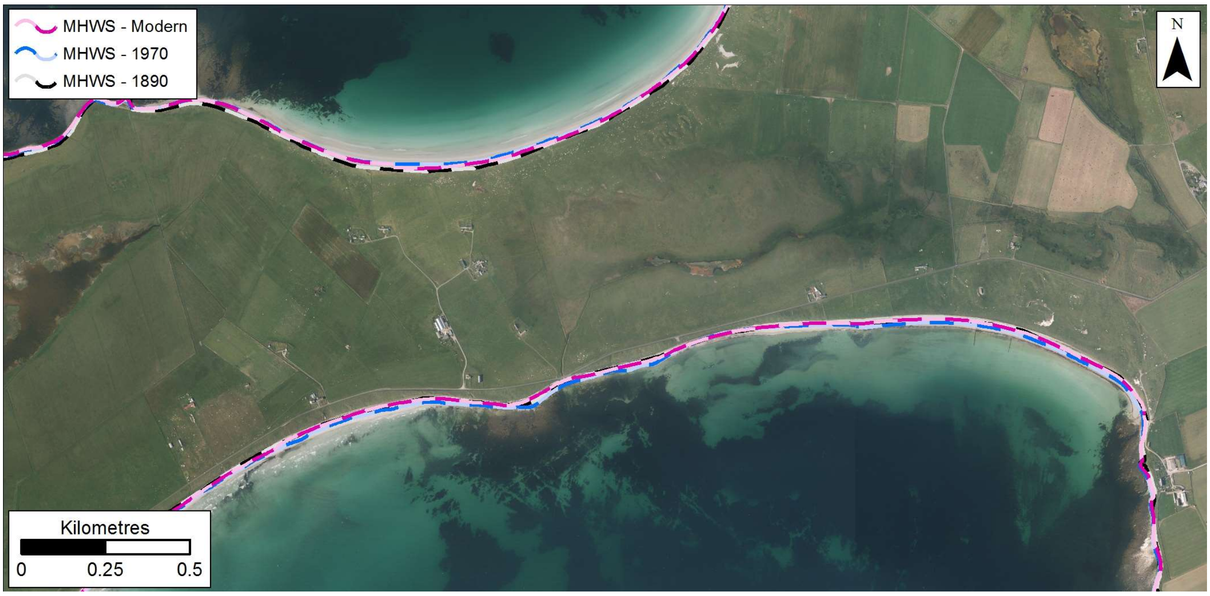

Figure 10.41: MHWS position in 1890, 1970s, and Modern datasets at the Bay of Sandquoy and Lopness. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 10.42: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Bay of Sandquoy and Lopness. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Both beaches are backed by low dunes that give way to a negative gradient inland to very low-lying ground. In Sandquoy, a 130 m length in the centre of the bay is anticipated to erode by another 13 m by 2050, and in the south at Lopness, nine areas covering 2.2 km of the east of the 4.5 km long bay give cause for concern (Figure 10.42). The anticipated erosion affects 150 m of the B9069 at the Loch of Langamay burn exit, and a further 1.2 km lies within the area of erosion vicinity. Given that the dune gradients fall landward then the erosion vicinity overlap onto the road is a real cause for concern. There is further cause for concern if erosion progresses into the future and removes either, or both, of the dune ridges that back both bays and allowing marine incursion into the areas to the rear. This will raise the possibility of the area of Northwall and Tofts Ness becoming separated from mainland Sanday. The B9069 roadway closely parallels the arc of Lopness Bay and in places lies within 2 m of MHWS at the exit of the Loch of Langamay burn, where a short seawall occurs. By 2050 this length of road and the low-lying area behind is anticipated to be vulnerable to erosion and flooding.

10d.9 Cata Sands, Sanday (Site 139)

Historic Change: Cata Sands is enclosed by a spit that is approximately 3 km long, its southern half extending from mainland Sanday to connect with the rocky islet of Tres Ness (Figure 10.43). From its narrow 1890s width, the Cata sands ayre has moved east and thickened at its southern end from 16 m in the 1890s to 30 m currently. This is despite some recent erosion that cut back the 1970s shore by about 15 m. Despite this thickening, recent aerial photography shows it to have breached in two places with the main ridge devoid of dune grasses. The accretion in the south has been fed by up to 20 m of erosion in the northern part of the spit. On the inner face of the spit within the shelter of Cata Sands, accretion has occurred along all its length other than a small section at the extreme south where erosion and overwash has occurred.

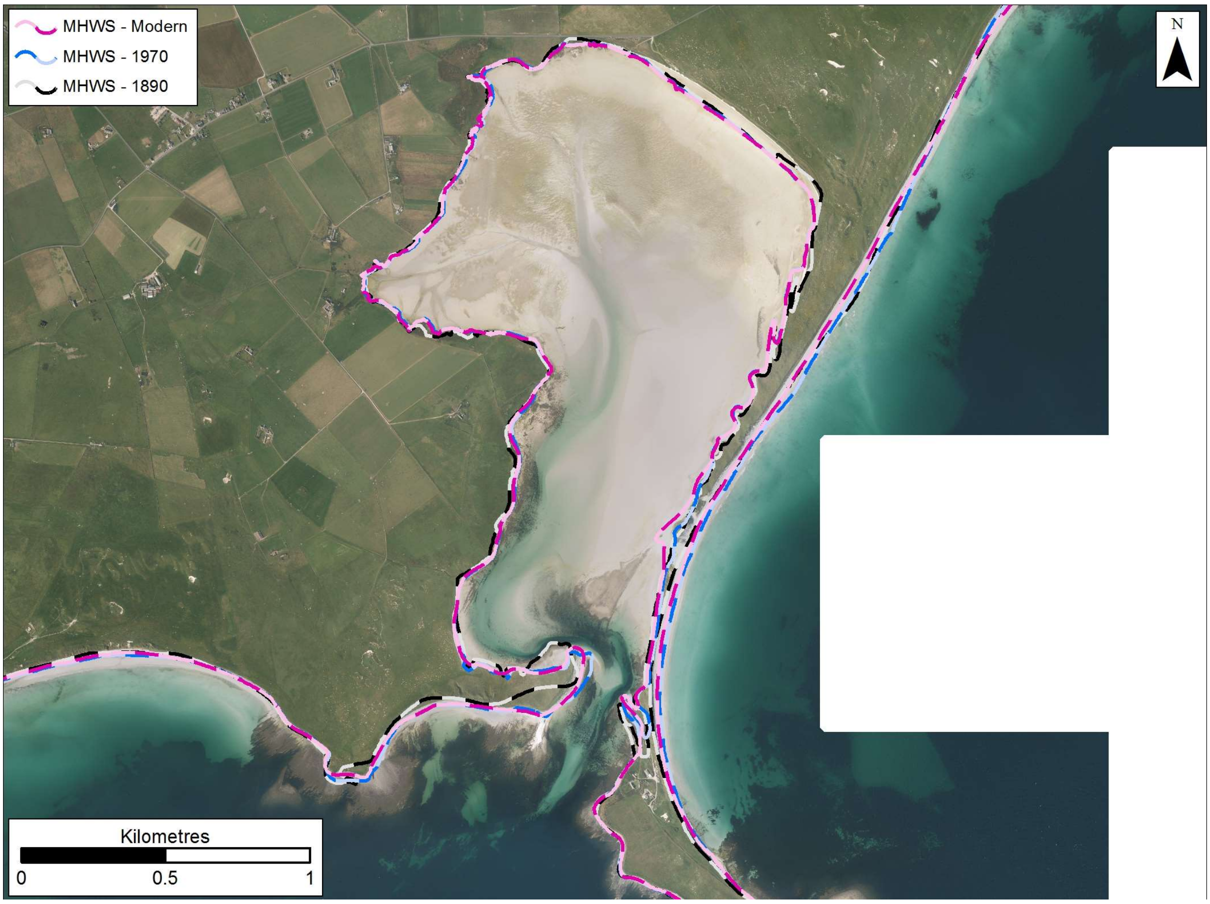

Figure 10.43: MHWS position in 1890, 1970s, and Modern datasets at Cata Sands. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The entire length of the Cata Sands ayre is anticipated to be eroded by up to 25 m by 2050 (Figure 10.44). Whether this simply results in its relocation further landward will depend on the nature and dynamic of the tidal exit from Cata Sands via The Clog (which is itself already eroding). Given that much of the core of Cata Sand is composed of gravel ridges that underlie the sand dunes and beach (Rennie, 2006), then the rate of recession is anticipated to be less in the northern part. It seems likely that the narrowing connection with Tres Ness will breach, allowing Tres Ness to again become an island (Rennie, 2006). Whatever the outcome, it remains that the Cata Sands ayre is highly vulnerable at present and this seems set to worsen.

Figure 10.44: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Cata Sands. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

10d.10 Little Sea, Sanday (Site 140)

Historic Change: Little Sea is a tidal inlet lying a few kilometres to the west of Tres Ness (Figure 10.45). On its southern side it is separated from the open sea by a sandy, 1.7 km long beach of Sty Wick. The western 600 m of this beach is a gravel-cored spit that now connects Els Ness to the mainland. In the east, the position of MHWS has remained stable. Moving west the 1890 line lies landward of the 1970 line indicating accretion of up to 30 m in the centre of the spit, although this tapers to zero at the western extremity. Between 1970 and modern the beach has begun to erode along all its length, reaching 11 m of recession in the spit centre, although tapering to zero at the extremities.

On the northern side of Little Sea, the B9069 hugs the coastal edge for 700 m and although the 1890s MHWS accreted to 1970s this was followed by up to 12 m of erosion to 2014. This prompted the insertion of a low defence wall along 200 m of the western part of this stretch to support the roadway.

Future Vulnerability: At Sty Wick, up to 15 m of erosion is anticipated to occur over 150 m of the central section of the spit, with a further 15 m lying in the area affected by erosion. This area overlaps the access road along the spine of the spit to Els Ness farm. As such, concerns are attached to the vulnerability of this section of the spit (Figure 10.46).

On the northern side, the rate of recession has been arrested by the insertion of a defence wall but concern remains about the vulnerability of the road here and the farm and cottages that sit on the north side of the road. This concern extends to the 500 m section of the B9069 lying to the west of Little Sea, which appears to be unprotected and subject to minor erosion during storms.

Figure 10.45: MHWS position in 1890, 1970s, and Modern datasets at Little Sea. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 10.46: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Little Sea. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc

10d.11 Otterswick, Sanday (Site 141)

Historic Change: Otterswick lies on the north coast of Sanday, its northern entrance guarded by a 200 m long spit that connects a small islet to the mainland (Figure 10.47). The spit reduced in width from 30 m in the 1890s to 15m by 1970 but then slowed so that the 2014 MHWS coincides with the 1970s line. This change was accompanied by a westward shift in overall position (Figure 10.47).

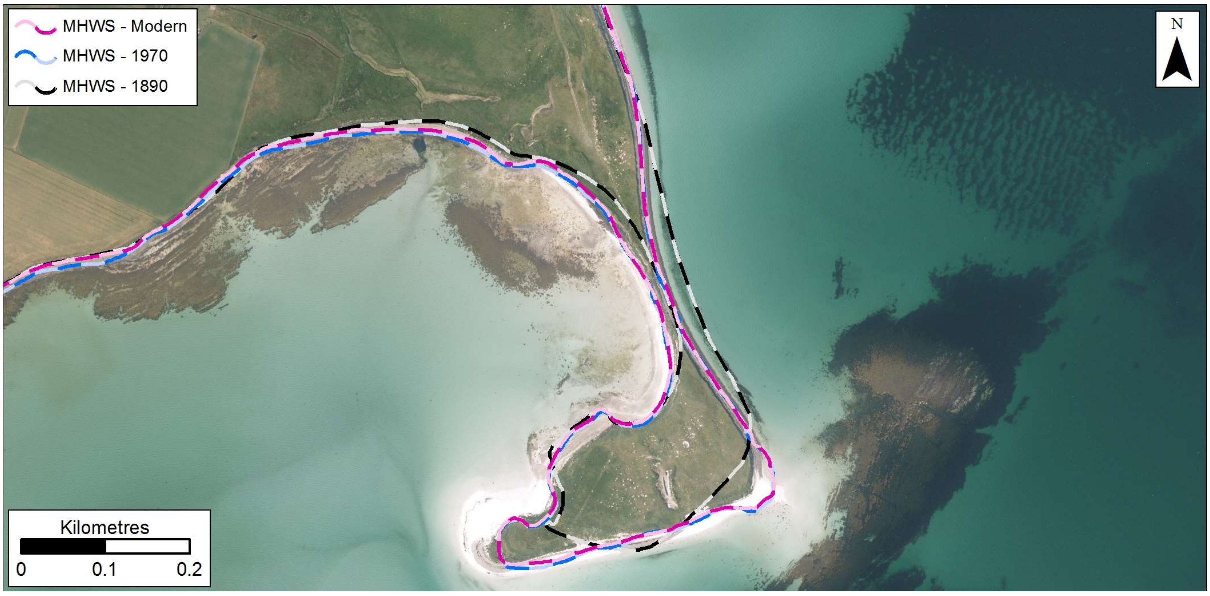

Figure 10.47: MHWS position in 1890, 1970s, and Modern datasets at Otterswick. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

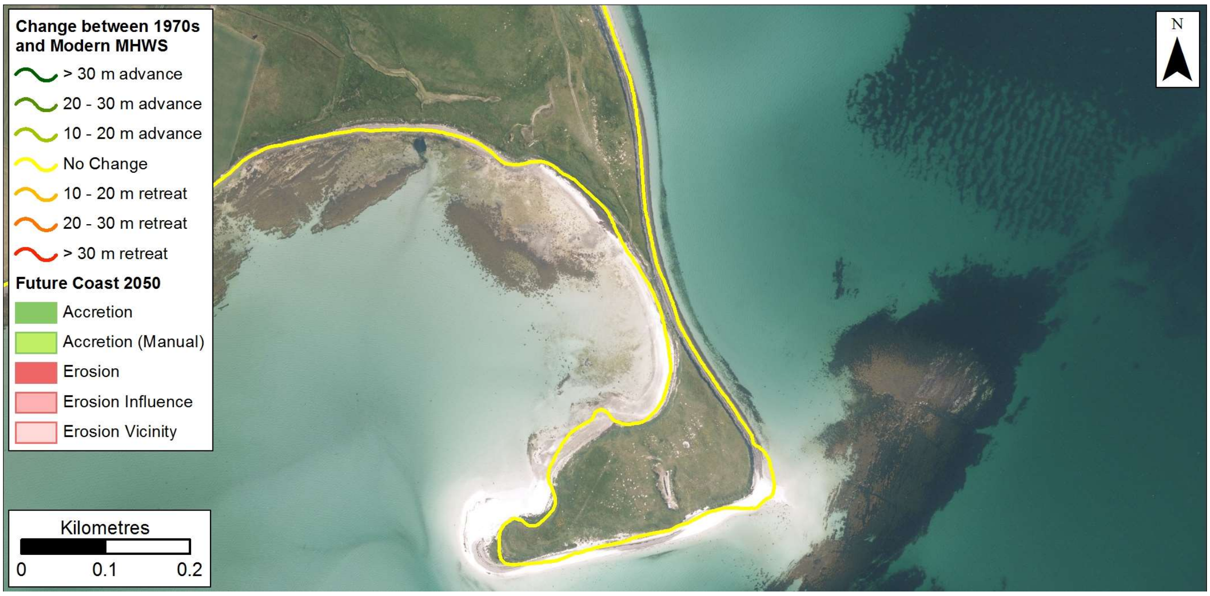

Figure 10.48: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Otterswick. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Although the narrowing of the spit seen between the 1890s and modern has slowed, there remain concerns about the vulnerability of the spit and its anticipated demise (Figure 10.48).

10d.12 Sands of Rothiesholm, Stronsay (Site 142)

Historic Change: The Sands of Rothiesholm is a 1.7 km beach towards at the head of the Bay of Holland in the south of Stronsay. It has remained largely stable between 1903 and 1973 with a modest amount of accretion towards the Loch of Rothiesholm which has advanced up to 12 m (0.2 m/yr) (Figure 10.49). However, this has subsequently retreated by a comparable amount between 1973 and 2012 as mapped by LiDAR.

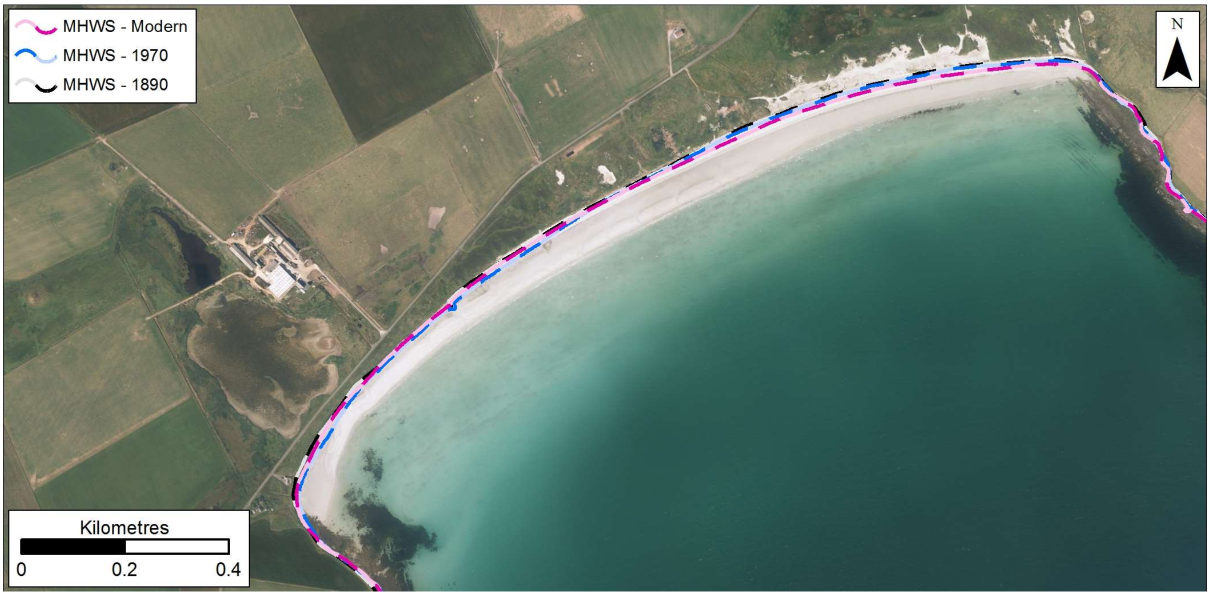

Figure 10.49: MHWS position in 1890, 1970s, and Modern datasets at the Sands of Rothiesholm. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 10.50: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the Sands of Rothiesholm. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: At the south end of the Sands of Rothiesholm the recent erosion approaches the roadway that connects Rothiesholm to mainland Stronsay. This results in a vulnerable connection with 150 m of the road in the erosion vicinity of 2050 and approximately 50 m in the erosion influenced area (Figure 10.50).

Statistics for Cell 10

Within the soft sections of Cell 10, **19%** has been **advancing** between **1890 and 1970**; compared with **4%** between **1970 and modern data**.
Within the soft sections of Cell 10, **5%** has been **retreating** between **1890 and 1970**; compared with **3%** between **1970 and modern data**.
Within the soft sections of Cell 10, the **average rate of advance** is **0.3 m/yr** between **1890 and 1970**, and **0.8 m/yr** between **1970 and modern data**.
Within the soft sections of Cell 10, the **average rate of retreat** is **-0.2 m/yr** between **1890 and 1970**, and **-0.4 m/yr** between **1970 and modern data**.
Within the soft sections of Cell 10, **77%** has **not changed** significantly between **1890 and 1970**; compared with **93%** between **1970 and the modern data**.

Table 10.2: A summary of the average rates, average change distances, and lengths of advance, retreat, and no change within sub-cells of Cell 10.

Coastal Cell	Overall change (1)			Advance (2)			Retreat (3)			Insignificant change (4)		
	Average 1890 to 1970 Change on Soft Coast (m)	Average 1890 to 1970 Change Rate on Soft Coast (m/year)	Length of Soft Coast (km)	Average 1890 to 1970 Soft Coast Advance (m)	Average 1890 to 1970 Advance Rate on Soft Coast (m/year)	Length of Soft Coast Advance (km)	Average 1890 to 1970 Soft Coast Retreat (m)	Average 1890 to 1970 Retreat Rate on Soft Coast (m/year)	Length of Soft Coast Retreat (km)	Average 1890 to 1970 Soft Coast Insignificant Change (m)	Average 1890 to 1970 Retreat Rate on Soft Coast (m/year)	Length of Soft Insignificant Change (km)
Sub-cell 10a	4.6	0.06	60.7	23.5	0.30	13.7	-18.0	-0.26	4.8	1.0	0.01	42.3
Sub-cell 10b	2.6	0.04	72.9	24.2	0.33	7.6	-15.1	-0.20	2.3	0.7	0.01	63.0
Sub-cell 10c	1.7	2.04	42.1	16.1	0.21	5.0	-18.0	-0.25	3.2	1.4	0.02	34.0
Sub-cell 10d	5.2	0.07	185.6	18.2	0.25	42.5	-17.4	-0.24	6.0	2.2	0.03	137.0
Cell 10	4.2	0.05	361.3	19.7	0.26	68.8	-17.4	-0.24	16.3	1.5	0.02	276.4
	-	-	-	-	-	19.0%	-	-	4.5%	-	-	76.5%

Coastal Cell	Overall change			Advance			Retreat			Insignificant change (4)		
	Average 1970 to Modern Change on Soft Coast (m)	Average 1970 to Modern Change Rate on Soft Coast (m/year)	Length of Soft Coast (km)	Average 1970 to Modern Soft Coast Advance (m)	Average 1970 to Modern Advance Rate on Soft Coast (m/year)	Length of Soft Coast Advance (km)	Average 1970 to Modern Soft Coast Retreat (m)	Average 1970 to Modern Retreat Rate on Soft Coast (m/year)	Length of Soft Coast Retreat (km)	Average 1890 to 1970 Soft Coast Insignificant Change (m)	Average 1890 to 1970 Retreat Rate on Soft Coast (m/year)	Length of Soft Insignificant Change (km)
Sub-cell 10a	0.3	0.02	62.6	40.0	1.33	3.1	-17.6	-0.53	3.2	-0.8	-0.22	56.4
Sub-cell 10b	0.3	0.01	74.3	16.0	0.39	2.4	-12.1	-0.31	0.3	0.2	-0.01	71.6
Sub-cell 10c	-0.8	-0.03	43.0	28.0	0.62	1.0	-13.6	-0.33	0.5	-1.4	-0.04	41.4
Sub-cell 10d	0.4	0.01	192.2	26.4	0.62	6.8	-13.9	-0.33	8.5	-0.5	-0.01	176.9
Cell 10	0.2	0.00	372.0	27.9	0.75	13.3	-14.8	-0.38	12.5	-0.6	-0.02	346.2
	-	-	-	-	-	3.6%	-	-	3.4%	-	-	93.1%

1 Overall change shows the mean value for the whole cell / sub-cell, averaging gains and losses.
2 Advance shows the mean value for the shoreline gains, where there has been greater than 10 m of change, or change which is faster than 0.5 m/yr.
3 Retreat shows the mean value for the shoreline losses, where there has been greater than 10 m of change, or change which is faster than 0.5 m/yr.
4 Insignificant change shows the lengths of coastline which have changed less than 10 m.

NB: Avoid comparing distances of change (i.e. km) but rather use proportions (i.e. %) to avoid cartographic differences between the years.

Table 10.3: A summary of the length of change within each change distance category in the historical (ca. 1890-1970) and recent (ca. 1970-Present) time periods in Cell 10.

1890-1970	**Cell 10**		**Sub-cell 10a**		**Sub-cell 10b**		**Sub-cell 10c**		**Sub-cell 10d**	
	Length (km)	**Length (%)**	**(km)**	**(%)**	**(km)**	**(%)**	**(km)**	**(%)**	**(km)**	**(%)**
>30 m Advance	9.1	3%	2.9	1%	1.5	0%	0.3	0%	4.4	1%
20-30 m Advance	11.8	3%	2.7	1%	0.8	0%	0.6	0%	7.6	2%
10-20 m Advance	47.9	13%	8.1	2%	5.3	1%	4.1	1%	30.5	8%
No Change	276.4	76%	42.3	12%	63.0	17%	34.0	9%	137.0	38%
10-20 m Retreat	12.2	3%	3.4	1%	2.0	1%	2.2	1%	4.6	1%
20-30 m Retreat	2.8	1%	1.0	0%	0.2	0%	0.8	0%	0.9	0%
>30 m Retreat	1.1	0%	0.3	0%	0.1	0%	0.3	0%	0.5	0%
Total length	**361.3**	**100%**	**60.7**	**17%**	**72.9**	**20%**	**42.1**	**12%**	**185.6**	**51%**

Max advance (m)	158	Ayre of Cara	158	150	59	99
Average change (m)	4.2		4.6	2.6	1.7	5.2
Max retreat (m)	-66	Bay of Tressness	-66	-54	-46	-66

1970-Modern	**Cell 10**		**Sub-cell 10a**		**Sub-cell 10b**		**Sub-cell 10c**		**Sub-cell 10d**	
	Length (km)	**Length (%)**	**(km)**	**(%)**	**(km)**	**(%)**	**(km)**	**(%)**	**(km)**	**(%)**
>30 m Advance	2.9	1%	1.2	0%	0.1	0%	0.4	0%	1.1	0%
20-30 m Advance	1.8	0%	0.5	0%	0.4	0%	0.3	0%	0.7	0%
10-20 m Advance	8.6	2%	1.4	0%	1.9	1%	0.4	0%	5.0	1%
<10m Advance but >= 0.5 myr^{-1}	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
No Change	346.2	93%	56.4	15%	71.6	19%	41.4	11%	176.9	48%
<10m Retreat but <= -0.5 myr^{-1}	0.0	0%	0.0	0%	0.0	0%	0.0	0%	0.0	0%
10-20 m Retreat	10.5	3%	2.0	1%	0.3	0%	0.5	0%	7.7	2%
20-30 m Retreat	1.8	0%	1.0	0%	0.0	0%	0.1	0%	0.7	0%
>30 m Retreat	0.2	0%	0.2	0%	0.0	0%	0.0	0%	0.0	0%
Total length	**372.0**	**100%**	**62.6**	**17%**	**74.3**	**20%**	**43.0**	**12%**	**192.1**	**52%**

Max advance (m)	190	Chruchill Barrier 4	190	50	53	186
Average change (m)	0.2		0.3	0.3	-0.8	0.4
Max retreat (m)	-37	Grimness	-37	-15	-27	-31

Asset Vulnerability Statistics for Cell 10

Table 10.4: A summary of the number, length, or area of assets within the erosion, erosion influence, and erosion vicinity buffers of the future coastline projections for Cell 10.

Cell 10	Units	Modern to 2050				2050+			
		Erosion	Erosion Influence	Erosion Vicinity	Total	Erosion	Erosion Influence	Erosion Vicinity	Total
Community Services	Number	-	-	-	-	-	-	-	-
Non Residential Property	Number	-	-	-	-	-	-	1	1
Residential Property	Number	-	1	3	4	-	1	3	4
Septic Water Tanks	Number	1	-	2	3	1	-	2	3
Utilities	Number	-	-	-	-	-	-	-	-
Rail	Length (km)	-	-	-	-	-	-	-	-
Roads (SEPA)	Length (km)	0.1	0.1	1.5	1.7	0.2	0.2	1.3	1.8
Roads (OS)	Length (km)	-	-	-	-	-	-	-	-
Clean Water Network	Length (km)	-	-	1.5	1.5	0.0	0.1	1.5	1.7
Total Anticipated Erosion	Area (hectares)	12.2	10.5	74.7	97.4	27.3	12.3	80.4	120.0
Runways	Area (hectares)	-	-	-	-	-	-	-	-
Cultural Heritage	Area (hectares)	0.6	0.7	4.1	5.3	1.2	0.7	4.2	6.1
Environment	Area (hectares)	7.2	5.8	22.6	35.5	14.4	4.9	19.8	39.1
Flooding (200 year envelope)	Area (hectares)	9.7	6.0	31.6	47.3	16.1	5.2	35.0	56.3
Flooding (1000 year envelope)	Area (hectares)	10.0	6.4	34.8	51.3	17.3	5.6	38.7	61.6
Erosion within PVAs	Area (hectares)	10.1	9.2	65.3	84.6	22.5	10.9	68.6	102.1
Erosion outwith of PVAs	Area (hectares)	2.1	1.3	9.4	12.8	4.8	1.4	11.8	17.9
Battlefields	Area (hectares)	-	-	-	-	-	-	-	-
Gardens and Designed Landscapes	Area (hectares)	-	-	-	-	-	-	-	-
Properties in Care	Area (hectares)	-	-	-	-	-	-	-	-
Scheduled Monuments	Area (hectares)	0.6	0.7	4.1	5.4	1.2	0.7	4.2	6.1
Nature Conservation Marine Protected Areas	Area (hectares)	-	-	-	-	-	-	-	-
National Nature Reserves (NNR)	Area (hectares)	-	-	-	-	-	-	-	-
Special Areas of Conservation (SAC)	Area (hectares)	-	-	0.0	0.0	-	-	0.0	0.0
Special Protection Areas (SPAs)	Area (hectares)	7.2	5.8	21.4	34.3	13.9	4.7	18.1	36.7
Sites of Special Scientific Interest (SSSI)	Area (hectares)	5.6	4.9	13.8	24.3	10.0	3.9	12.5	26.3

References

Hall, A.M., Hansom, J.D., and Jarvis J., (2008). Processes, patterns and rates of erosion by storm waves on hard rock headlands: The Grind of the Navir, Shetland, Scotland. Marine Geology. 248, 28-46.
doi: 10.1016/j.margeo.2007.10.007

Hansom, J.D., Lees, G., McGlashan, D.J. and John, S., (2004). Shoreline Management Plans and coastal sediment cells in Scotland: Coastal Management, 32, 227-242. doi: 10.1080/08920750490448505.

Ramsay, D.L. and Brampton, A.H. (2000) Coastal Cells in Scotland: Cell 10 - Orkney. Scottish Natural Heritage Research, Survey and Monitoring, Report No 151.

Rennie, A. F. (2006) The role of sediment supply and sea-level changes on a submerging coast, past changes and future management implications. Unpublished PhD Thesis, University of Glasgow.

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