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Dynamic Coast - National Coastal Change Assessment: Cell 6 - Mull of Kintyre to the Mull of Galloway

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National Coastal Change Assessment Steering Committee

Executive Summary

- Cell 6 extends from the Mull of Kintyre south to the Mull of Galloway including the Firth of Clyde.
- In Cell 6 Mean High Water Springs extends to 1,405 km which makes up around 7% of the Scottish coastline (excluding tidal inlets). Of this length, 63% (884 km) has been categorised as hard and mixed, 27% (376 km) as soft and 10% (145 km) as artificial.
- Within the historical period of 1890 to 1970 (74 years) a little more than half of the soft shoreline by length has not changed significantly (56%), 29% has advanced seawards (accretion)and 16% has retreated landwards (erosion).
- The period from the 1970s to modern spans 37 years, so the historical period data has been normalised to 37 years to allow comparisons with the modern period. When this adjustment has been applied the extent of erosion has remained at 7%, the amount of accretion has fallen from 14% historically to 10% recently and the proportion of soft coast remaining stable has increased from 79% historically to 82% recently.
- Both the average rates of accretion and retreat has increased from the historical to the recent period. The rate of erosion has increased from 0.3 m/yr to 0.7 m/yr, accretion from 0.3 m/yr to 0.8 m/yr.
- An increase in coasts with no or insignificant change is consistent with a move from accretion (which is reducing), through a transitional condition of no change (which is increasing), although, paradoxically, erosion has remained stable.
- This suggests there may have been a shift in the status of soft coast of Cell 6 in the modern period from a bias of accretion toward an erosional bias.

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 retreated landwards (erosion), 11% has advanced seawards (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.

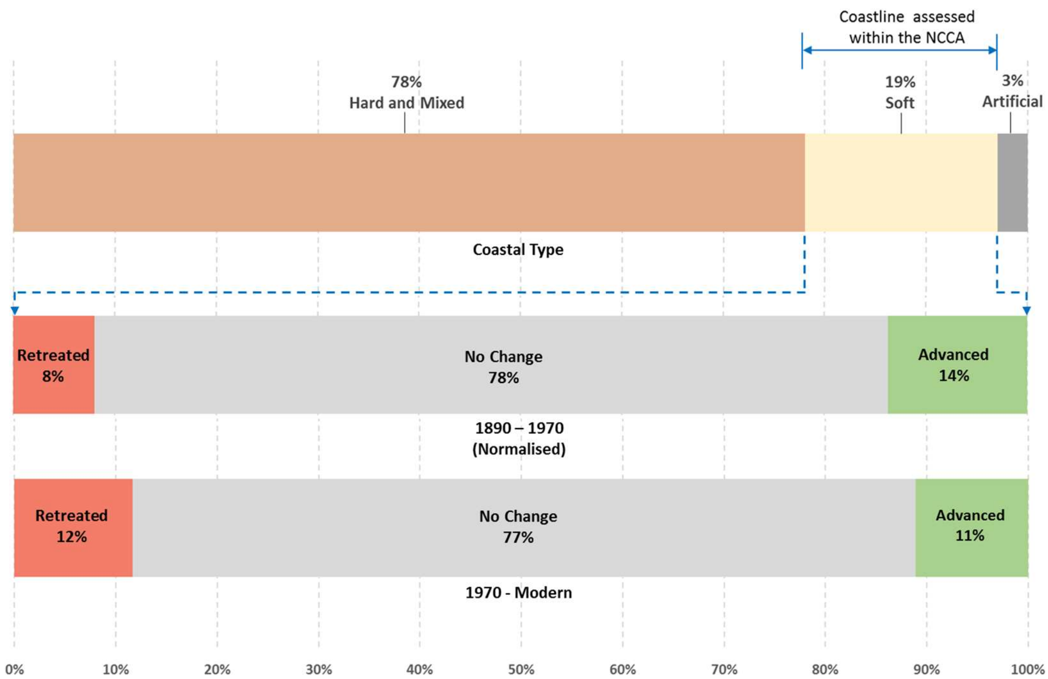

Figure 1: National coastal change results showing the proportion of soft coast retreating, stable and advancing within each change category in the historical (ca. 1890-1970 normalised for time period) and recent (ca. 1970-Present) time periods.

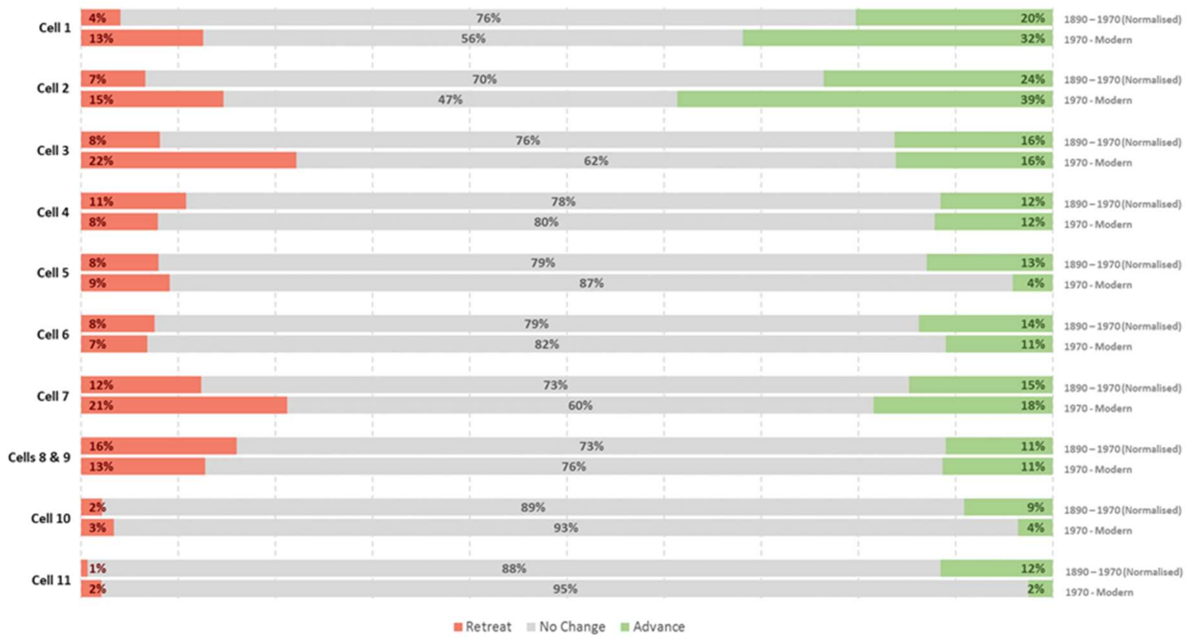

Figure 2: National coastal change results showing historical (ca. 1890-1970, normalised for time period) and recent (ca. 1970 Present.) % of coastal cell showing retreat (red), stability (grey) and advance (green) for soft coast within each cell.

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 this promotes sediment losses 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 6 - Mull of Kintyre to the Mull of Galloway

Cell 6 extends from the Mull of Kintyre south to the Mull of Galloway including the Firth of Clyde and consists of four sub-cells (Figure 6.1). Further contextual information about the processes operating in Cell 6 can be found in Ramsay & Brampton (2000).

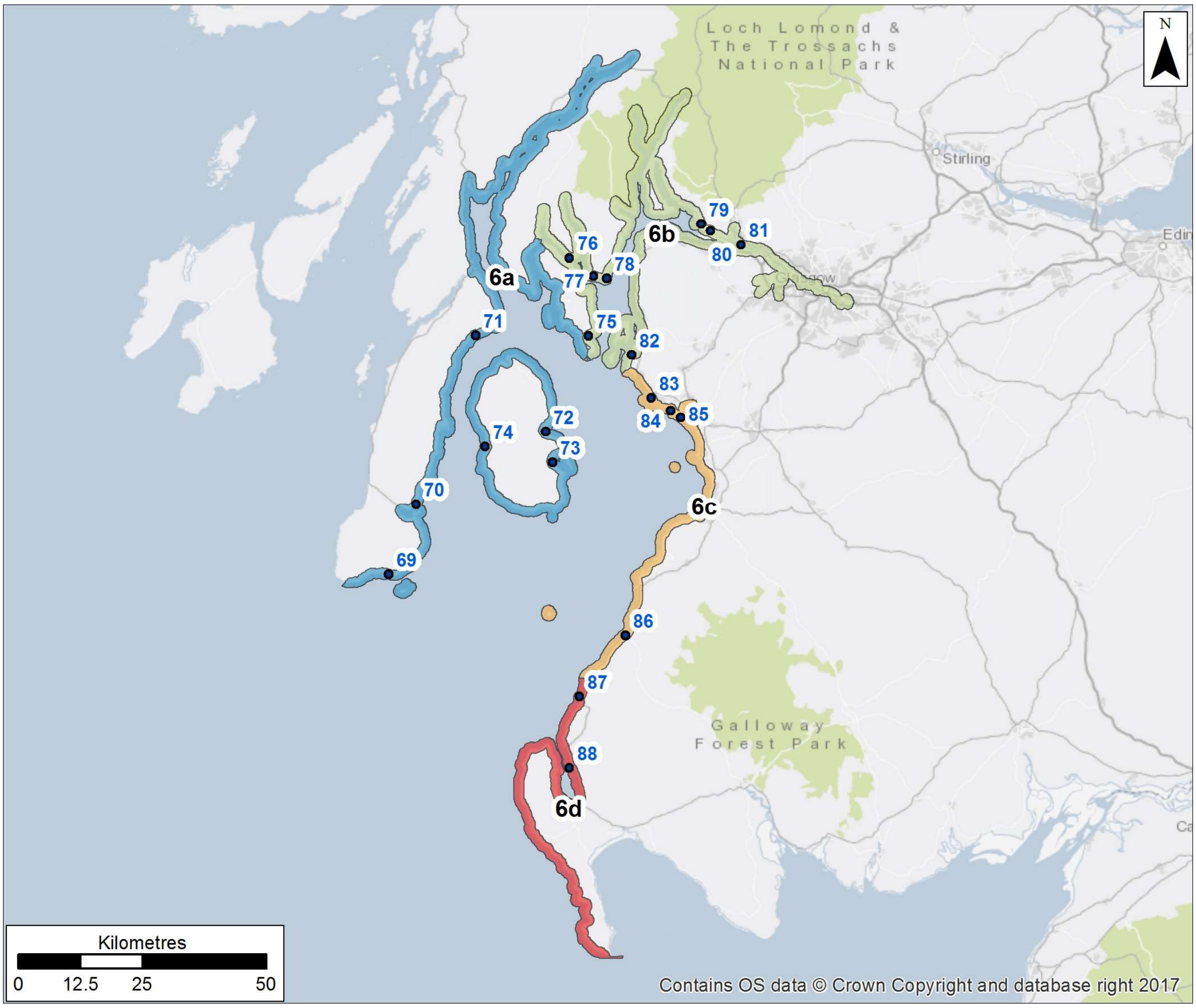

Figure 6.1: The sub-cell boundaries of Cell 6 and locations of sites discussed in this report (blue numbers).

Physical Overview

In Cell 6 Mean High Water Springs (MHWS) extends to 1,405 km which makes up around 7% of the Scottish coastline (excluding tidal inlets). Of this length, 63% (884 km) has been categorised as hard and mixed, 27% (376 km) as soft and 10% (145 km) as artificial (Table 6.1). Within the historical period a little more than half of the soft shoreline has not changed significantly (56%), accretion has occurred along 29% of soft coasts with erosion occurring along 16% (Figure 6.2). The period from the 1970s to modern spans 37 years, so the historical period data has been normalised to 37 years to allow comparisons with the modern period.

When this adjustment is applied the extent of erosion has remained at 7%, the extent of stability has reduced from 79% to 82% and the extent of accretion has fallen from 14% to 10% (Figure 6.2). In addition to the changes in extents in Cell 6, there has been an increase in the rate of change with erosion increasing from 0.3 m/yr to 0.7 m/yr and accretion increasing from 0.3 m/yr to 0.8 m/yr (Figure 5.2). Further statistics for Cell 6 can be found in Table 6.2 and Table 6.3 at the end of this report.

Table 6.1: Proportion of each coastal type within Cell 6.

Modern Coastal Type	Length	
	km	%
Soft	376.1	27%
Artificial	145.2	10%
Hard and Mixed	883.9	63%
Total Length (excluding tidally influenced inlets)	1405.1	100%

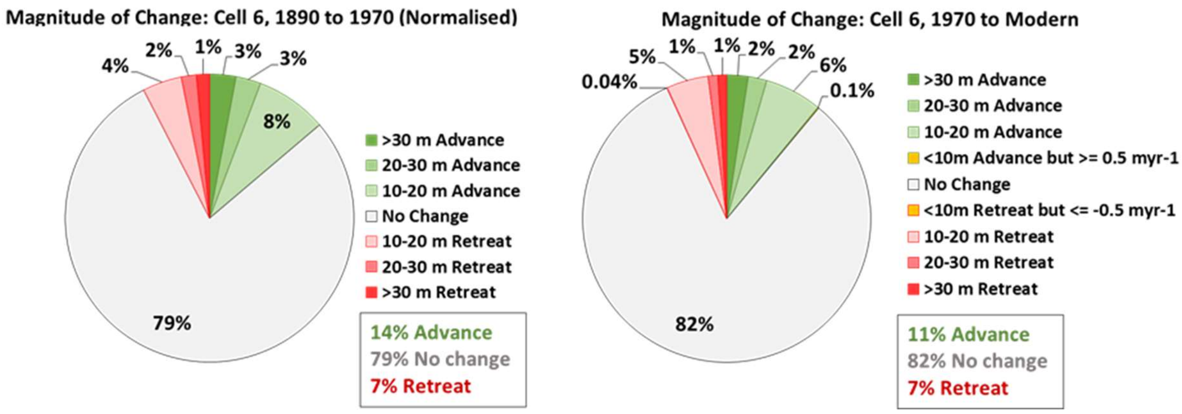

Figure 6.2: Coastal change results for Cell 6 showing the proportional amount of change in the historical (ca. 1890-1970 normalised) and recent (ca. 1970-Present) time periods. Rounding errors may produce small % differences between Figure 2 and Figure 6.2.

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 6 a total land area of 15.4Ha, which supports various assets, is anticipated to be lost by 2050, this include one non-residential property. When areas that erosion may influence are included then a further non-residential property is anticipated to be affected. For a full summary of vulnerable assets see Table 6.4 at the end of this report.

Sub-cell Summaries

Subcell 6a - Mull of Kintyre to the Inner Firth of Clyde

6a.1 Brunerican Bay (Site 69)

Historic Change: Brunerican Bay is a 1 km long sand beach backed by sand dunes, lying at the south end of the Mull of Kintyre. Unlike the bay to the west, the 1897 MHWS line lies landward of the 1978 line which suggests accretion of up to 20 m along the west and central sections but erosion in the east (Figure 6.3) of about the same amount (the bay to the west show 13 m of erosion between 1997 and modern). However, the OS modern MHWS line in Brunerican Bay is depicted as lying a further 20 m seaward of the 1978 line and is likely to be unreliable. Given that the vegetation edge shown here on the photography is cliffed, erosional and some 30 m landward of the 1978 line, then this location is likely to be eroding.

Figure 6.3: MHWS position in 1890, 1970s, and Modern datasets at Brunerican Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: As the past historic rate shows no evidence of erosion the future vulnerability Brunerican Bay has not been assessed since, although it is likely to be eroding, there are no fixed assets to the rear of the beach.

6a.2 North Headland at Campbeltown Bay (Site 70)

Historic Change: This headland is a rocky based shore where the 1890 MHWS hugs the upper part of the intertidal, despite this MHWS appears to have changed during the assessed time periods. The 1978 line lies up to 25 m seaward of the 1890 line with the modern LiDAR line lying up to 15 m landward of the 1978 (Figure 6.4). This change is likely to be inaccurate given the rocky nature of the shore and the probable mislocation of the 1978 line which appears to lie very close to the water's edge and is thus likely to be unreliable.

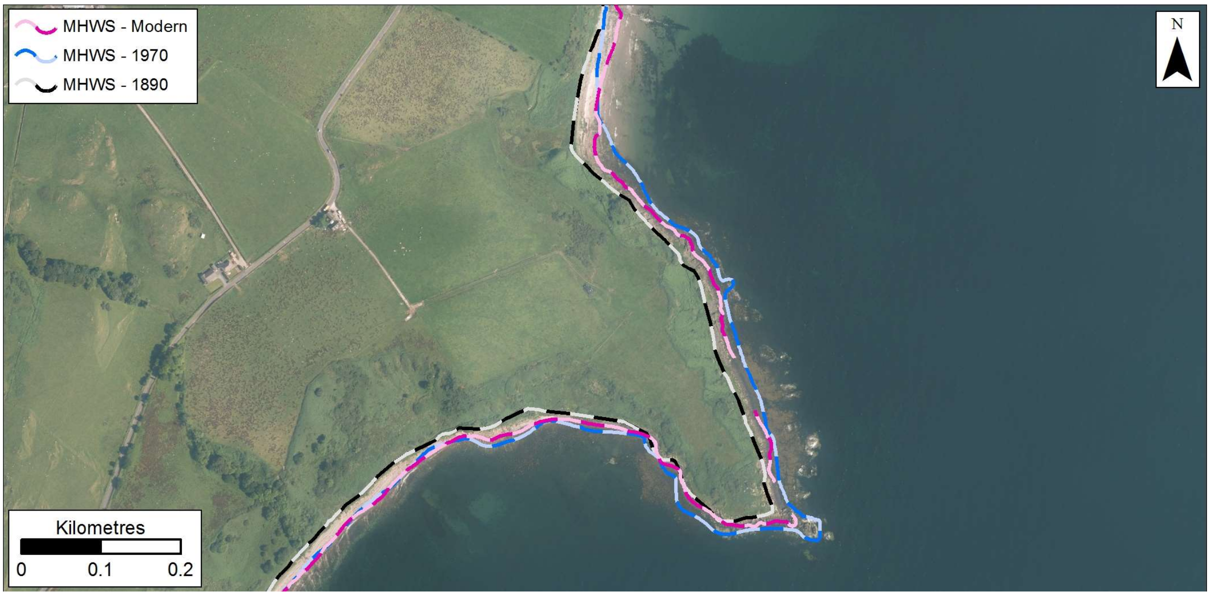

Figure 6.4: MHWS position in 1890, 1970s, and Modern datasets at the North Headland of Campbeltown Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Due to the observed erosion within the data, this location is identified as an area of concern for the future (Figure 6.5). These figures however, are likely to be inaccurate given the rocky nature of the shore and the probable mislocation of the 1978. This area falls within the Campbeltown Potentially Vulnerable Area.

Figure 6.5: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at the North Headland of Campbelton Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6a.3 Claonaig Bay (Site 71)

Historic Change: The 450 m long beach at Claonaig shows the 1890 MHWS to coincide with the 1977 line over much of the small bay except in the west at the river exit, where there has been accretion of up to 30 m over this period (Figure 6.6). This has been followed by landward movement of 14 m to 2014 as depicted by the OS Digital Surface Model. To the east of the beach, outcrops of rock serve to restrict the rate of erosion before the jetty is reached that services the seasonal ferry to Lochranza on Arran.

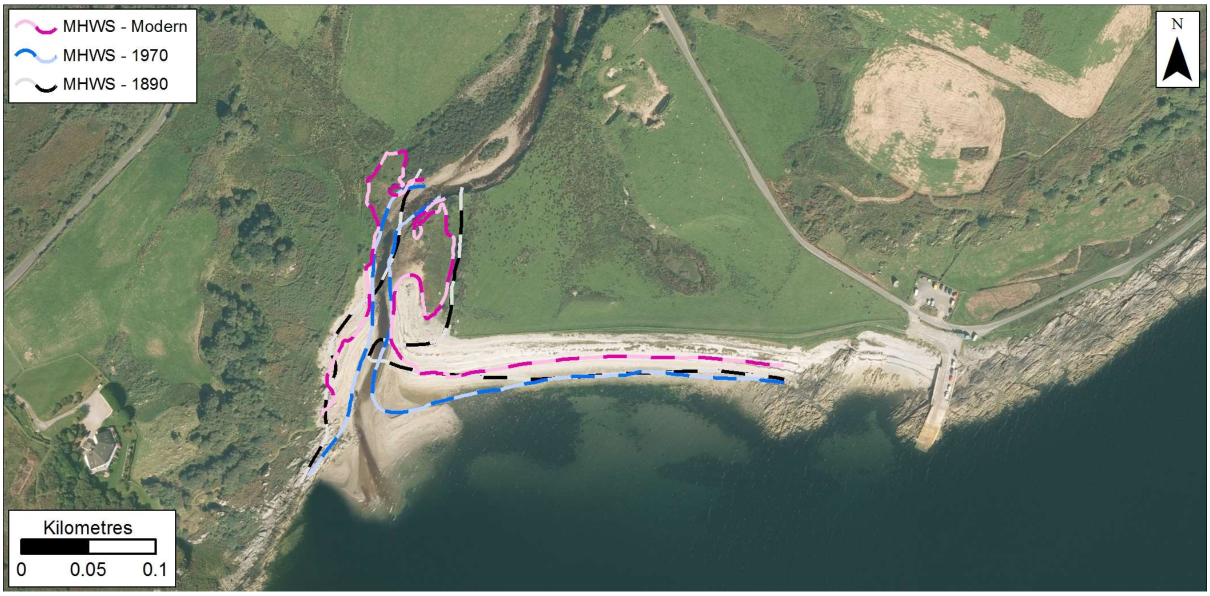

Figure 6.6: MHWS position in 1890, 1970s, and Modern datasets at Claonaig Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The projected erosion to 2050 at Claonaig does not directly affect any assets other than a minor access track along the rear of the beach (Figure 6.7). The erosion vicinity zone comes close to the only access road to the ferry car park and jetty as well as the access road to residential properties at Skipness. Thus, whilst the ferry jetty and car park are sited on rock and thus relatively secure, the access road to the landward may be a cause for concern in the future, if erosion begins to threaten the softer and unconsolidated emerged beach deposits that lie to the seaward and upon which it likely rests.

Figure 6.7: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Claonaig Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6a.4 Brodick Bay, Arran (Site 72)

Historic Change: Brodick Bay is approximately 1.5 km long and bisected by the river that exits from Glen Rosa. Behind the sandy beach lies open ground supporting a golf course, and in the south, an access road, car park and playing fields. Almost along its full length, the 1890 MHWS line lies well seaward of the current position; up to 70 m in the south of the bay (Figure 6.8). In 1890 the beach was fronted by a long spit that extended north across the river exit but by 1978 this had retreated landward by 30 m. By 2014 the LiDAR line is a further 20 m landward so that some 70 m has been lost since 1890 in the south. In the north some 30 m of recession occurred between 1890 and 1978 and a further 10 m to 2014 adds up to 40 m of loss 1890-2014. The losses continue in the south with the artificial addition of sand dredged from the replacement pier and fed to the beach in 2016. This sand has subsequently been lost to the north of the river exit which is now accreting as a result. The erosion of Brodick beach is directly attributable to the ill-advised removal of sand from this beach in the 1970s and 1980s. Artificial sand bags have been placed at the back of the beach in 2015 as well as a short stubby rock groyne to slow the rate of erosion, to little avail. There are now plans to protect the shore by the insertion of boulder rip rap and groynes. Brodick is notified as a Potentially Vulnerable Area.

Figure 6.8: MHWS position in 1890, 1970s, and Modern datasets at Brodick Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Using the rates of erosion 1978 to 2014 and projecting them forward to 2050 reveal a substantial length of Brodick Bay to be of concern with 600 m of the beach in the north expected to recede by up to 20 m (Figure 6.9). In the south almost 200 m may erode inland by up to 15 m. The beach in the north is backed by sand dune and the northern part of the golf course, with no buildings under threat. In the south, the beach is backed by the southern part of the golf course as well as a pathway, recreational areas, car park and buildings that will be cause for concern in the future. At the river exit the projected recession of MHWS by 2050 is some 100 m inland but this is generated by the fluctuations in the exit of the river and may well be an overestimate that will change over time.

Figure 6.9: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Brodick Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6a.5 Lamlash, Arran (Site 73)

Historic Change: At Lamlash, the 1895 MHWS coincides with the 1978 position showing no real change over that time period. Since 1978 and 2014 however, there has been up to 15 m (0.4 m/yr) of recession over the 200 m central section of shore that lies between the two river exits (Figure 6.10). Lamlash Bay is notified as a Potentially Vulnerable Area.

Figure 6.10: MHWS position in 1890, 1970s, and Modern datasets at Lamlash. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Although the erosion along the Lamlash shore largely affects dune and recreational land, the projected erosion influenced area does affect two buildings in the extreme south, with several additional buildings and 130 m of the A841 road falling within the erosion vicinity zone (Figure 6.11).

Figure 6.11: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Lamlash. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6a.6 Machrie, Arran (Site 74)

Historic Change: Two areas at Machrie have shown recession since 1895. In the south, where the river exits, the shore has receded by 25 m from 1895 to 1979 and a further 25 m to 2014 LiDAR (Figure 6.12). In the north, at the Machrie golf course, the MHWS has retreated by 40 m between 1895 and 1979 and then by 10 m to 2014 over 400 m. This is despite coarse gravels being placed on the upper shore at the toe of the vegetated erosional scarp.

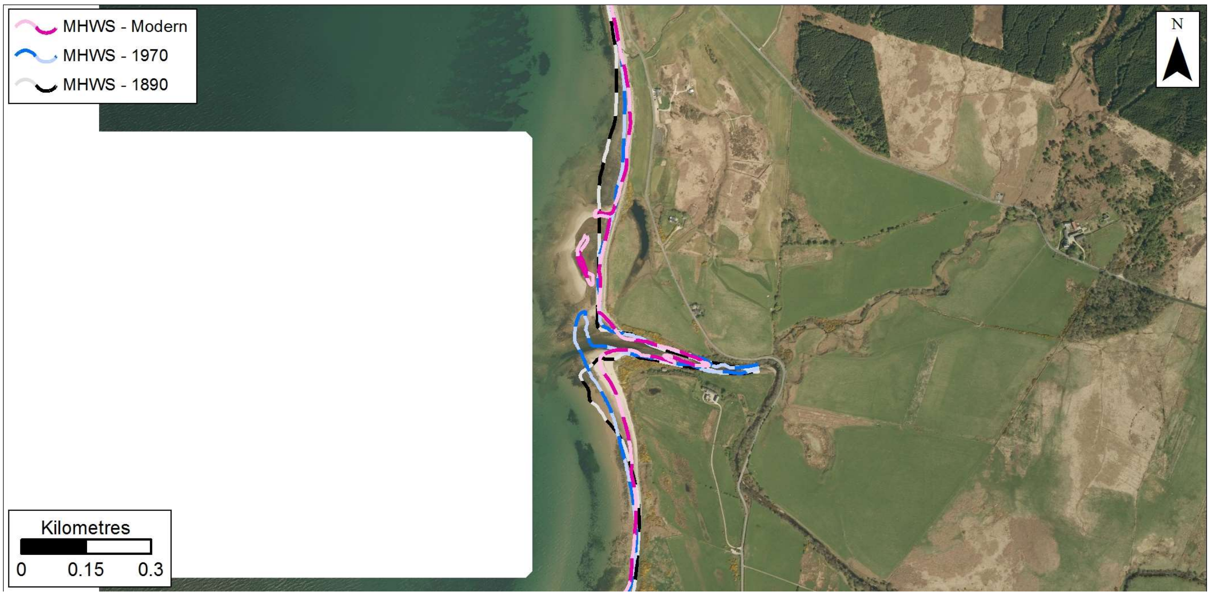

Figure 6.12: MHWS position in 1890, 1970s, and Modern datasets at Machrie. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 6.13: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Machrie. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: In the south, there are no assets under threat at the stream exit. In the north at the Machrie golf course, the projected loss by 2050 over 120 m of coast is 16 m, with the erosion influenced zone extending over 140 m and the erosion vicinity to over 240 m and 80 m inland. The erosion influenced zone includes golf course buildings (Figure 6.13). Crucially, the only perimeter access road along the west coast of Arran is unprotected, very close to MHWS, and is of potential concern in the future should rates of erosion change.

Subcell 6b - Inner Firth of Clyde to Farland Head

6b.1 Kilchattan Bay, Bute (Site 75)

Historic Change: Kilchattan Bay lies on the south-east corner of Bute with a sand beach of approximately 1.6 km in length. In general terms, accretion dominated the entire beach between 1890 and the 1970s but since then the north has shown some erosion of up to 8m. The southern part of the beach has accreted by up to 13m over a 500m stretch in front of the houses and roadway. At the extreme south end, the position of MHWS has remained stable over the time periods. Beyond this the shore becomes rocky and is protected by a sea wall fronting the coastal access road and several houses.

Figure 6.14: MHWS position in 1890, 1970s, and Modern datasets at Kilchattan Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Since the central part of the bay is accreting, the houses and road at this section offer no cause for concern. Similarly, at the rocky south end of the bay, even though the road runs close to MHWS, the road and the backing houses sit on rock and there has been little past movement of MHWS. Vulnerability issues are not anticipated.

6b.2 Bargehouse Point & South Hall shore, Kyles of Bute (Site 76)

Historic Change: Over a 1.1 km stretch of the north shore of the Kyles of Bute to the south of Colintraive and east of Strone Point, the current shoreline lies some 20 m landward of the shore as depicted in 1890 and 1978. There is no evidence to suggest that it is inaccurate (Figure 6.15).

Figure 6.15: MHWS position in 1890, 1970s, and Modern datasets at Bargehouse Point and South Hall shore. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: This shore is relatively undeveloped, however, one farmhouse and some 1 km of the coastal access road lies within the zone of erosion anticipated by 2050 (Figure 6.16).

Figure 6.16: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Bargehouse Point and South Hall shore. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6b.3 Toward Point to Toward Quay, Cowal Peninsula (Site 77)

Historic Change: Along several parts of the shore between Toward Point and Toward Quay the 1898 MWHS position lies some 25 m seaward of the 1964 line suggesting accretion, followed by 7 m of landward erosion by 2011, although in some places this reached 20 m of erosion over this time period (Figure 6.17). To the east of this section and west of Toward Point, the 1890 line lies landward of both the 1964 and 2011 line suggesting accretion to 1964 followed by erosion to 2011. The coastal road (A815) runs along the shoreline and is often very close to MHWS. Castle Toward's gardens are notified as a Garden of Designed Landscape.

Figure 6.17: MHWS position in 1890, 1970s, and Modern datasets. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The shore between Toward Point and Toward Quay supports the main road A815 extension to Loch Striven. The road closely parallels a largely unprotected shore. In the west some 200 m of this roadway lies within the projected erosion zone that may extend inland by 12 m by 2050 (Figure 6.18). In the east, a further 1km of road is directly affected by the projected erosion zone, together with three properties.

Figure 6.18: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data between Toward Point and Toward Quay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6b.4 Toward (Site 78)

Historic Change: Much of the shoreline north of Toward is artificially defended by seawalls along which the A815 runs. However, at Toward itself the shore is undefended and although was subject to accretion between 1890 and 1964, it has subsequently undergone recession to 2011 by up to 25 m (Figure 6.19). This has reduced the extent of the gardens that lie to the seaward of the long line of residential properties that parallel the road, which at this point lies some 130 m inland. Two other smaller areas of recent recession affect farm buildings to the west of the point.

Figure 6.19: MHWS position in 1890, 1970s, and Modern datasets at Toward. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Some 500 m of shore is projected to be eroding by 2050 and although the affected zone mainly comprises residential gardens, the erosion affected zone is more extensive (Figure 6.20). The erosion vicinity extends 80 m inland over 500 m of coast length, with 18 residential properties falling within the zone.

Figure 6.20: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Toward. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6b.5 East of Ardmore Point (Site 79)

Historic Change: The shore to the east of Ardmore Point has built out 25 m since 1980 but then eroded landward by 10 m between 1990 and 2011 (Figure 6.21). Although undeveloped and undefended, the main West Highland rail line north of Glasgow lies close to the shore. This shoreline is part of a Potentially Vulnerable Area, Inner Clyde Special Protection Area and Site of Special Scientific Interest.

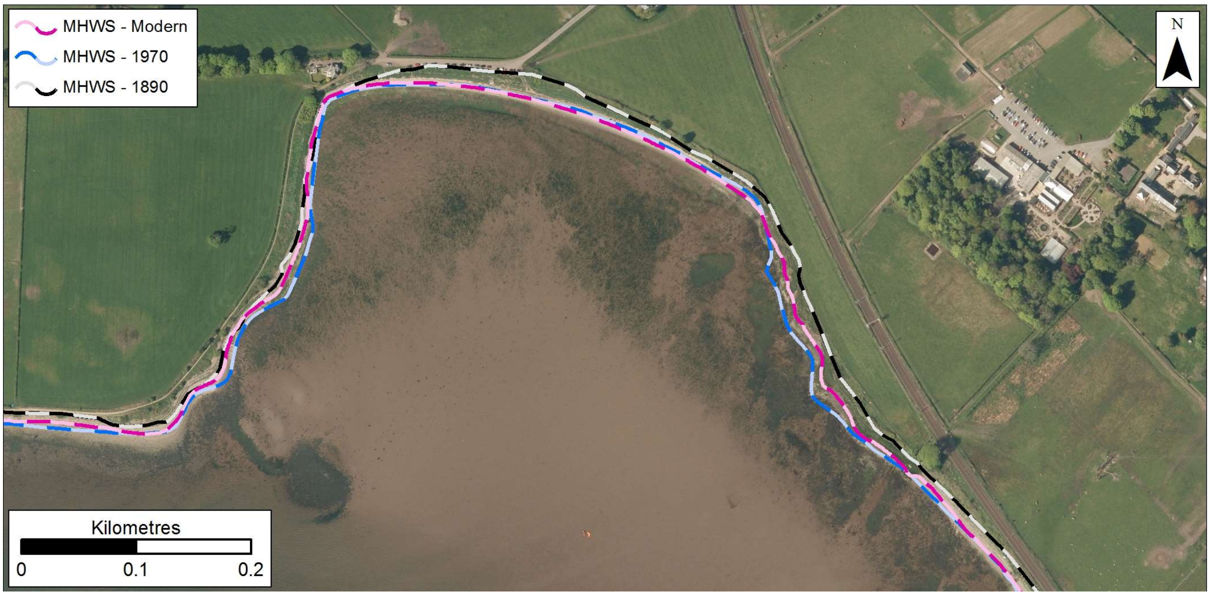

Figure 6.21: MHWS position in 1890, 1970s, and Modern datasets east of Ardmore Point. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: For over 250 m of shore length, the projected erosion vicinity zone extends 50 m inland and overlaps the rail line (Figure 6.22). This section remains unprotected and although the rail line to the east lies closer to the shore and is protected artificially, the entire stretch of shore is a cause for future concern.

Figure 6.22: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data east of Ardmore Point. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6b.6 Cardross (Site 80)

Historic Change: The beach fronting the town of Cardross has undergone substantial change since the survey of 1896, particularly where the small stream exits. Here the 1896 line lies 40 m seaward of the 2012 shore suggesting rapid erosion so that by 1970 the shore was within 17 m of the modern 2012 shore, with 170 m of urban frontage shore eroding over the recent period at 0.7 m/yr.

This shoreline is part of a Potentially Vulnerable Area, Inner Clyde Special Protection Area and a Site of Special Scientific Interest.

Figure 6.23: MHWS position in 1890, 1970s, and Modern datasets at Cardross. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The shoreline here is undefended. The direct erosional area is currently impacting mainly recreational land and access tracks. Nevertheless, the erosion affected area overprints onto 40 m of rail track whilst the erosion vicinity area (80 m inland and 250 long) captures 250 m of rail track and 13 residential homes as well as two railway bridges.

Figure 6.24: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Cardross. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6b.7 Dumbarton Castle Bay (Site 81)

Historic Change: The saltmarsh coastline to the east of Dumbarton Rock has undergone variable amounts of erosion since 1896 of up to 80m in one area to 1963. In places, further recession of 20 m has occurred 1963-2012, but this is variable along the shore in common with many saltmarsh fringing shores (Figure 6.25). This shoreline is part of a Potentially Vulnerable Area, and Inner Clyde Special Protection Area and Site of Special Scientific Interest.

Figure 6.25: MHWS position in 1890, 1970s, and Modern datasets at Dumbarton Castle Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Although the erosion zone here affects undefended saltmarsh, the erosion vicinity captures some 100 m of mainline rail track that lies 70 m landward and is a cause for concern in the future (Figure 6.26). This section of shore has been the subject of more detailed study commissioned by the Firth of Clyde Forum and conducted by ARUP and Glasgow University (SNH, 2016).

Figure 6.26: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Dumbarton Castle Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6b.8 Hunterston B Nuclear Power Station access road (Site 82)

Historic Change: Over a short stretch of 250m of shore just south of the main jetty and north of Hunterston B Nuclear Power station, the 1895 MHWS at Hunterston lies some 26 m seaward of the 1965 position and a further 15 m seaward of the 2012 LiDAR position (Figure 6.27). Although this area is relatively sheltered, the recent rates of migration of MHWS have averaged 0.4 m/yr along the unprotected shore. Oilrig Road, the main access to the power station, lies within 17 m of the 2012 shore at this point. The substantial rectilinear-framed areas are where artificial land claim has occurred. This shoreline is part of a Potentially Vulnerable Area and Southannan Sands Site of Special Scientific Interest.

Figure 6.27: MHWS position in 1890, 1970s, and Modern datasets at Hunterston B Nuclear Power Station. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Projected forward to 2050, 160 m of this unprotected stretch of shore is anticipated to be eroding by 21 m inland and impacting 70 m of the only access road to the nuclear power station (Figure 6.28). This extends to 300 m of roadway lying within the erosion vicinity. This renders the road directly vulnerable and in need of management attention.

Figure 6.28: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Hunterston B Nuclear Power Station. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Subcell 6c - Farland Head to Bennane Head

6c.1 Ardrossan (Site 83)

Historic Change: North of Ardrossan harbour, a small promontory juts seaward onto an area of submerged bedrock outcrop. The beach deposits that sit on this outcrop and comprise the promontory have undergone continuous recession since 1895 when the MHWS lay 40 m to seaward (Figure 6.29). Between 1895 and 1963 the shore receded 25 m and then another 15 m to 2012 over a 100 m length of shoreface.

Figure 6.29: MHWS position in 1890, 1970s, and Modern datasets north of Ardrossan. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Although the projected erosion area in 2050 extends 30 m inland, the area affected is recreational land with no built assets. The erosion vicinity however, extends 90 m inland where it just impinges on the A738 main coast road (Figure 6.30).

Figure 6.30: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data north of Adrossan. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6c.2 Saltcoats (Site 84)

Historic Change: The coastline to the south of Saltcoats caravan park and at the north end of Ardeer is dominated by a sand beach backed by dunes and truncated in the south by an artificial jetty built of slag, to service an ironworks at Stevenson at the Ardeer foreshore. Over a 2 km length of coast south from Saltcoats, the shore has receded by an average of 80 m to 1963 and a further 15 m to 2012 (Figure 6.31). Artificial protection has been built in the north part of the bay but the southern part continues to erode, especially rapidly where a small stream exits close to the abandoned jetty promontory. The shoreline is part of a Potentially Vulnerable Area.

Figure 6.31: MHWS position in 1890, 1970s, and Modern datasets at Saltcoats. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Although the coast is undeveloped and supports no built assets, the projected 2050 shore would lie some 60 m landward of the present one extending over a 900 m length of beach (Figure 6.32).

Figure 6.32: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Saltcoats. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6c.3 Ardeer (Site 85)

Historic Change: South of Saltcoats, the linear stretch of sand that fronts the largely disused explosives factory site at Ardeer has been eroding since 1895 as shown by the position of the MHWS line of that date which lies up to 30 m seaward of the present 2012 line. The 1963 line however mirrors the 2012 line and suggests that the shore has been artificially protected at some stage post 1895 but pre 2012. Ground observations confirm a range of dilapidated and patched defences that extend south from the disused jetty to the north. At about 1.5 km south of the jetty these defences no longer exist and the shore has begun to erode again, as evidenced by recession of the MHWS line and large erosional bights cutting up to 25 m into the backing sand dune ridgeline and which taper and narrow to the south (Figure 6.33). Just north of this point the 1895 line lies 21 m seaward of the 1963 line which itself lies 13 m seaward of the 2012 line.

Figure 6.33: MHWS position in 1890, 1970s, and Modern datasets at Ardeer. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: Although now apparently backed by a sand dune area, the entire Ardeer peninsula was originally an island. Later its extensive sand dune system became the site of an explosive factory which was a global supplier of explosives to the mining and quarrying industries and a major player in the design and development of products for the chemical and defence industries (ICI site) during the 20th century. As the site has been used in the past as essentially a munitions facility (it is still covered by explosives legislation) it is likely to contain buried remnants of pollutants and toxins that today would be strictly controlled but were not in the past. Thus, any potential erosion of the coastal edge at any point along this coast runs the risk of reintroducing buried materials from the past into the present beach environment. So, although the 2050 projection suggests erosion of greater than 20 m over only 100 m of shore length, the importance of this on any acceleration of erosion in the bights to the south are considerable as is the possibility of the release of any dangerous materials contained within the backing dune systems.

Figure 6.34: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Ardeer. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

6c.4 A77 to the south of Girvan (Site 86)

Historic Change: Some 1.5 km south of the roundabout at the south end of Girvan the A77 comes very close to the shore so that eventually, just opposite some industrial buildings, the road is supported by boulder rip rap as coast protection. This protection stops approximately 200 m northeast of where the road turns inland and away from the shore at a small slipway. At this point, the 1895 position of MHWS coincides with that in 1963 but since then has eroded to 2012 by up to 15 m (Figure 6.35). Since the 2012 position to the north of this lies seaward of the 1963 position, the accreting coast is likely due to sediment moving north from the eroding section. This suggests the northward movement of erosion into an area where no protection is offered to the A77. This shoreline is classed as a Potentially Vulnerable Area and has been notified as part of the Girvan to Ballantrae Site of Special Scientific Interest.

Figure 6.35: MHWS position in 1890, 1970s, and Modern datasets at Woodland Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The projected 2050 position of MHWS over 60 m of shore lies 20 m inland and impinges directly on the A77. The erosion vicinity covers a greater 150 m length of the roadway (Figure 6.36). It seems inevitable that the protection offered to the southern part of the road will soon require to be extended north to address potential future vulnerability.

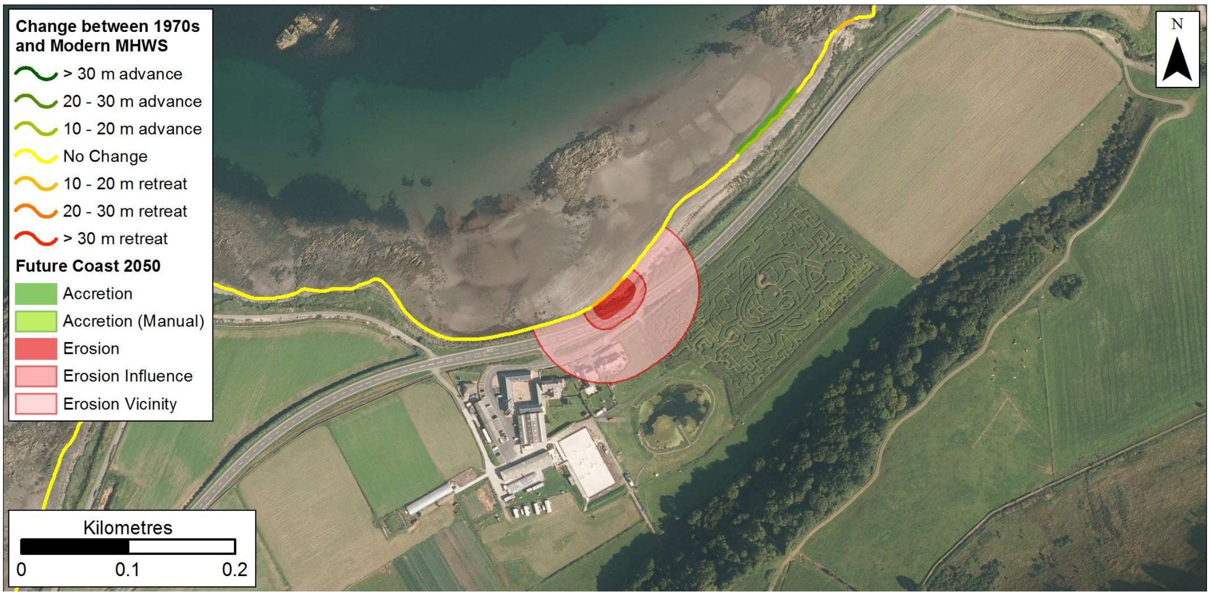

Figure 6.36: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Woodland Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Subcell 6d - Bennane Head to the Mull of Galloway

6d.1 Ballantrae (Site 87)

Historic Change: 500m north of the jetty at Ballantrae the position of MHWS in 1894 has been re-occupied by the 2012 position over about a 700 m stretch of the unprotected shore (Figure 6.37). In some places the 1971 gravel shore lies 20 m seaward of the 2012 shore. A smaller, but similar, section of eroding shore lies at the north end of Ballantrae itself, fronting recreational ground, but is protected by a boulder revetment.

Figure 6.37: MHWS position in 1890, 1970s, and Modern datasets at Ballantrae. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 6.38: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Ballantra . Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: This section of shore is composed of gravels backed by low gravel ridges which extend as far as an abandoned cliff inland. The A77 lies some 70 m inland from the 2012 coast position. The projected 2050 coast lies some 20 m inland with the directly affected coast length being 500 m (Figure 6.38). The land affected is agricultural and there are no built assets in the areas of vulnerability, however, the erosion vicinity zone captures some 500 m of the A77 carriageway.

6d.2 Cairnryan Old Pier (Site 88)

Historic Change: Although likely to comprise a fair amount of made ground, the promontory at Cairnryan accreted seaward between 1893 and 1968 by up to 30 m before eroding inland by up to 36 m to its modern 2011 position (Figure 6.39). This recent rate of erosion (1968-2011) reached 0.9 m/yr. and gives rise for concern since only one industrial building appears to have boulder protection with the rest of the promontory having no formal protection.

Figure 6.39: MHWS position in 1890, 1970s, and Modern datasets at Cairnryan Old Pier. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 6.40: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Cairnryan Old Pier. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Future Vulnerability: The projected erosion by 2050 is for 26 m of inland movement over 140 m of shore in the directly impacted area, with the erosion vicinity extending 90 m inland over 200 m of shore (Figure 6.40). The assets affected appear to be abandoned industrial remains apart from one building close to the shore and two warehouses inland. However, during World War II, the Cairnryan promontory was a No.2 Military Port, with three harbour piers, only one of which remains and in a state of disrepair and is fenced off. The port promontory has been variously used as a construction site (for D Day Mulberry harbours), a loading point for WW2 ordnance disposal at sea, including the U-boat Atlantic fleet, and a breakers yard in the 1960s and 1990s. The promontory is thus likely to contain polluted materials from that era. As a result, any projected erosion may give cause for concern. It is worth noting that the internal sediments of the promontory are unknown and if they are composed of coarse materials, such as concrete foundations etc. there may be less cause for concern in the future from a coastal stability perspective.

Coastal Change Statistics for Cell 6

Within the soft sections of Cell 6, **29%** has been **advancing** between **1890 and 1970**; compared with **11%** between **1970 and modern data**.
Within the soft sections of Cell 6, **16%** has been **retreating** between **1890 and 1970**; compared with **7%** between **1970 and modern data**.
Within the soft sections of Cell 6, 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 6, the **average rate of retreat** is **-0.3 m/yr** between **1890 and 1970**, and **-0.7 m/yr** between **1970 and modern data**.
Within the soft sections of Cell 6, **56%** has **not changed** significantly between **1890 and 1970**; compared with **82%** between **1970 and the modern data**.

Table 6.2: A summary of the average rates, average change distances, and lengths of advance, retreat, and no change within sub-cells of Cell 6.

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 6a	5.7	0.07	157.0	21.7	0.27	49.2	-22.2	-0.27	14.3	1.6	0.02	93.5
Sub-cell 6b	5.7	0.07	109.1	25.3	0.30	34.1	-28.9	-0.35	12.0	1.7	0.02	63.1
Sub-cell 6c	-3.5	-0.03	70.9	41.0	0.54	12.6	-25.7	-0.30	28.3	-1.1	-0.01	30.0
Sub-cell 6d	5.0	0.06	37.0	22.6	0.27	11.5	-19.7	-0.23	4.3	0.4	0.01	21.2
Cell 6	3.9	0.05	374.0	25.2	0.31	107.4	-25.1	-0.30	58.8	1.1	0.01	207.8
	-	-	-	-	-	28.7%	-	-	15.7%	-	-	55.6%

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 1970 to Modern Soft Coast Insignificant Change (m)	Average 1970 to Modern Retreat Rate on Soft Coast (m/year)	Length of Soft Insignificant Change (km)
Sub-cell 6a	1.1	0.03	157.1	26.0	0.77	11.6	-18.7	-0.55	7.9	0.1	0.00	137.7
Sub-cell 6b	-1.4	-0.05	112.1	35.3	1.01	5.2	-21.2	-0.65	11.1	-1.2	-0.04	95.7
Sub-cell 6c	5.5	0.20	70.4	23.5	0.82	20.1	-26.8	-0.96	3.5	0.3	0.02	46.8
Sub-cell 6d	-0.1	0.01	36.5	23.4	0.78	4.5	-22.3	-0.62	3.2	-1.3	-0.03	28.8
Cell 6	1.1	0.04	376.1	25.5	0.83	41.4	-21.3	-0.66	25.6	-0.4	-0.01	309.0
	-	-	-	-	-	11.0%	-	-	6.8%	-	-	82.2%

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 6.3: 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 6.

1890-1970	Cell 6		Sub-cell 6a		Sub-cell 6b		Sub-cell 6c		Sub-cell 6d	
	Length (km)	Length (%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
>30 m Advance	22.9	6%	7.7	2%	7.6	2%	5.7	2%	2.0	1%
20-30 m Advance	21.9	6%	9.0	2%	6.9	2%	3.2	1%	2.8	1%
10-20 m Advance	62.6	17%	32.5	9%	19.6	5%	3.8	1%	6.8	2%
No Change	207.8	56%	93.5	25%	63.1	17%	30.0	8%	21.2	6%
10-20 m Retreat	34.3	9%	9.2	2%	8.0	2%	13.9	4%	3.2	1%
20-30 m Retreat	13.2	4%	2.8	1%	2.0	1%	7.8	2%	0.6	0%
>30 m Retreat	11.4	3%	2.2	1%	2.0	1%	6.7	2%	0.5	0%
Total length	**374.0**	**100%**	**157.0**	**42%**	**109.1**	**29%**	**70.9**	**19%**	**37.0**	**10%**

Max advance (m)	192	Irvine	156	142	192	129
Average change (m)	3.9		5.7	5.0	37.0	0.3
Max retreat (m)	-293	Holy Loch	-205	-293	-135	-84

1970-Modern	Cell 6		Sub-cell 6a		Sub-cell 6b		Sub-cell 6c		Sub-cell 6d	
	Length (km)	Length (%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
>30 m Advance	9.0	2%	2.4	1%	1.9	1%	3.6	1%	1.1	0%
20-30 m Advance	7.9	2%	1.9	0%	0.4	0%	4.6	1%	1.0	0%
10-20 m Advance	24.2	6%	7.3	2%	2.8	1%	11.8	3%	2.3	1%
<10m Advance but >= 0.5 myr^{-1}	0.4	0%	0.0	0%	0.1	0%	0.2	0%	0.2	0%
No Change	308.9	82%	137.7	37%	95.7	25%	46.8	12%	28.8	8%
<10m Retreat but <= -0.5 myr^{-1}	0.1	0%	0.0	0%	0.1	0%	0.0	0%	0.0	0%
10-20 m Retreat	17.7	5%	5.6	1%	8.5	2%	1.9	0%	1.8	0%
20-30 m Retreat	4.1	1%	1.5	0%	1.1	0%	0.7	0%	0.8	0%
>30 m Retreat	3.7	1%	0.8	0%	1.4	0%	0.9	0%	0.6	0%
Total length	**376.0**	**100%**	**157.1**	**42%**	**112.1**	**30%**	**70.4**	**19%**	**36.5**	**10%**

Max advance (m)	259	Campbell Town Loch	259	108	112	68
Average change (m)	1.1		1.1	-1.4	5.5	-0.1
Max retreat (m)	-114	Portavadie	-78	-85	-114	-66

Asset Vulnerability Statistics for Cell 6

Table 6.4: 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 6.

Cell 6	Units	Modern to 2050				2050+			
		Erosion	Erosion Influence	Erosion Vicinity	Total	Erosion	Erosion Influence	Erosion Vicinity	Total
Community Services	Number	-	-	-	-	-	-	-	-
Non Residential Property		1	1	14	16	1	4	13	18
Residential Property		-	-	51	51	2	12	65	79
Septic Water Tanks		-	-	1	1	-	-	2	2
Utilities		1	-	-	1	1	-	-	1
Rail	Length (km)	-	0.0	0.7	0.7	0.0	0.1	0.7	0.8
Roads (SEPA)		1.1	0.8	2.4	4.3	1.8	0.4	2.6	4.8
Roads (OS)		0.1	0.1	0.4	0.6	0.2	0.1	0.7	0.9
Clean Water Network		0.2	0.6	2.5	3.3	0.8	0.3	3.1	4.2
Total Anticipated Erosion	Area (hectares)	15.4	10.6	75.1	101.0	33.5	16.1	79.4	129.0
Runways		-	-	-	-	-	-	-	-
Cultural Heritage		0.1	0.6	7.5	8.2	1.7	1.3	8.7	11.6
Environment		0.6	0.3	1.5	2.3	0.7	0.3	1.3	2.4
Flooding (200 year envelope)		11.8	5.5	26.1	43.4	18.9	8.0	22.7	49.5
Flooding (1000 year envelope)		12.7	6.4	30.5	49.6	20.8	8.7	27.3	56.9
Erosion within PVAs		9.7	6.3	43.9	59.9	19.5	7.8	49.5	76.9
Erosion outwith of PVAs		5.7	4.3	31.2	41.2	13.9	8.3	29.9	52.1
Battlefields		-	-	-	-	-	-	-	-
Gardens and Designed Landscapes		0.1	0.6	7.5	8.3	1.7	1.3	8.7	11.7
Properties in Care		-	-	-	-	-	-	-	-
Scheduled Monuments		-	-	-	-	-	-	-	-
Nature Conservation Marine Protected Areas		0.0	0.0	0.0	0.0	-	-	-	-
National Nature Reserves (NNR)		-	-	-	-	-	-	-	-
Special Areas of Conservation (SAC)		-	-	-	-	-	-	-	-
Special Protection Areas (SPAs)		0.3	0.2	1.0	1.5	0.4	0.2	0.9	1.5
Sites of Special Scientific Interest (SSSI)		0.4	0.2	1.3	1.8	0.5	0.2	1.2	1.9

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