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Dynamic Coast - National Coastal Change Assessment: Cell 2 - Fife Ness to Cairnbulg Point

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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 2 extends from the Fife Ness northwards to Cairnbulg Point near Fraserburgh and includes the Firth of Tay.
- In Cell 2 Mean High Water Springs extends to 546 km which makes up around 3% of the Scottish coastline. Of this length, 51% (278 km) is categorised as hard and mixed, 15% (80 km) as artificial and 34% (188 km) as soft coast.
- Within the historical period of 1890-1970s (74 years) almost 41% of the soft shoreline experienced no significant change, 46% has advanced seawards (accretion) , with 12% retreating 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 comparison with the modern period. When this adjustment has been applied the extent of erosion has increased from 6% historical period to 14% post 1970s, the extent of stability has reduced from 70% to 47% and the extent of accretion has increased from 24% to 38%.
- Cell 2 has seen a large increase in dynamism, where the proportion of soft coast moving more than 10m has increased from 36% before the 1970s to 53% after. Whilst the proportion experiencing erosion has more than doubled to 14%, the extent of advance has increased from around a quarter to a more than a third.

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 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.

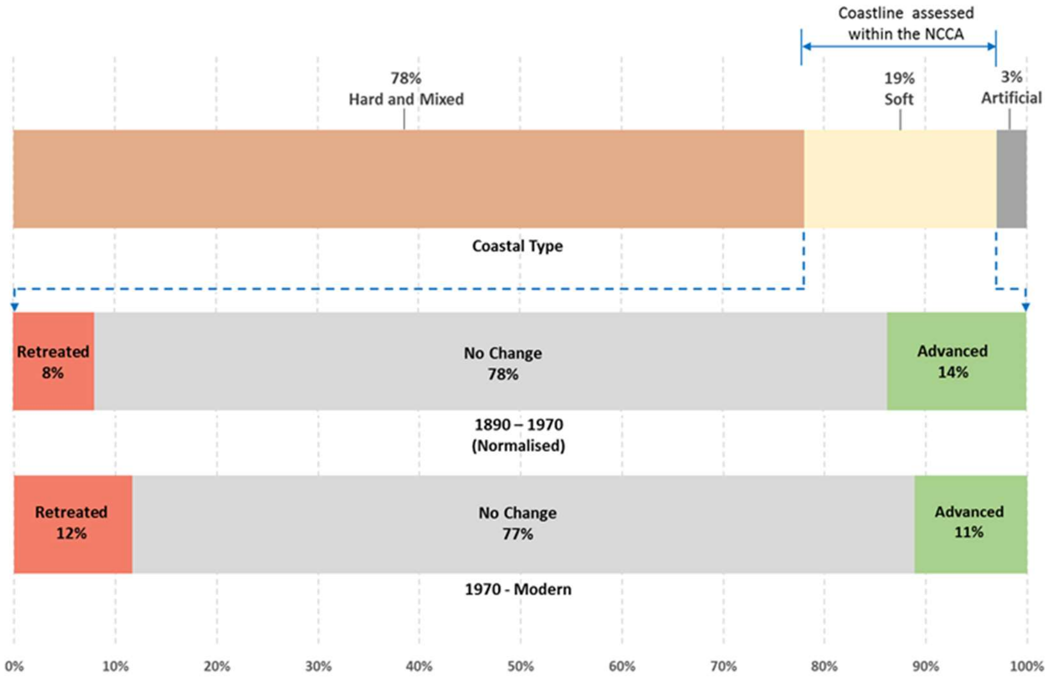

Figure 1: National coastal change results showing the proportion of soft coast retreating, stable and advancing within each change category in the historical (ca. 1890-1970 normalised for time period) and recent (ca. 1970-Present) time periods.

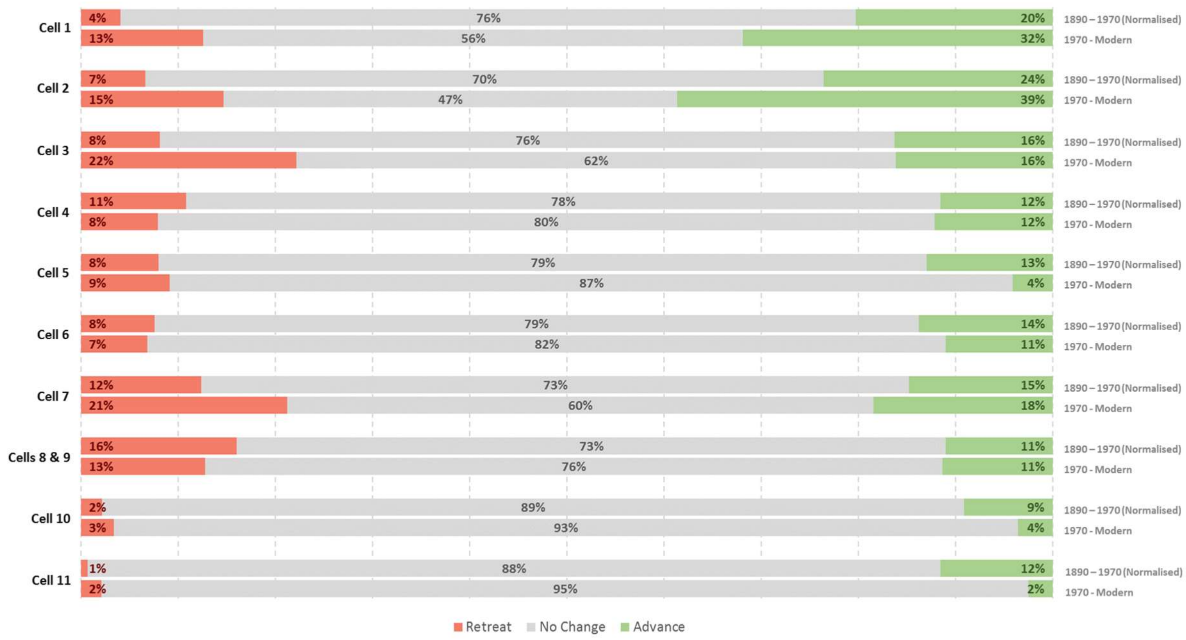

Figure 2: National coastal change results showing historical (ca. 1890-1970, normalised for time period) and recent (ca. 1970 Present.) % of coastal cell showing retreat (red), stability (grey) and advance (green) for soft coast within each cell. Small differences between this figure and Figure 2.2

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 2 - Fife Ness to Cairnbulg Point

Cell 2 extends from the Fife Ness northwards to Cairnulg Point near Fraserburgh and includes the Firth of Tay. The sub-cell boundaries are shown in Figure 2.1. For further contextual information about the processes operating in Cell 2 see Ramsay & Brampton (2000).

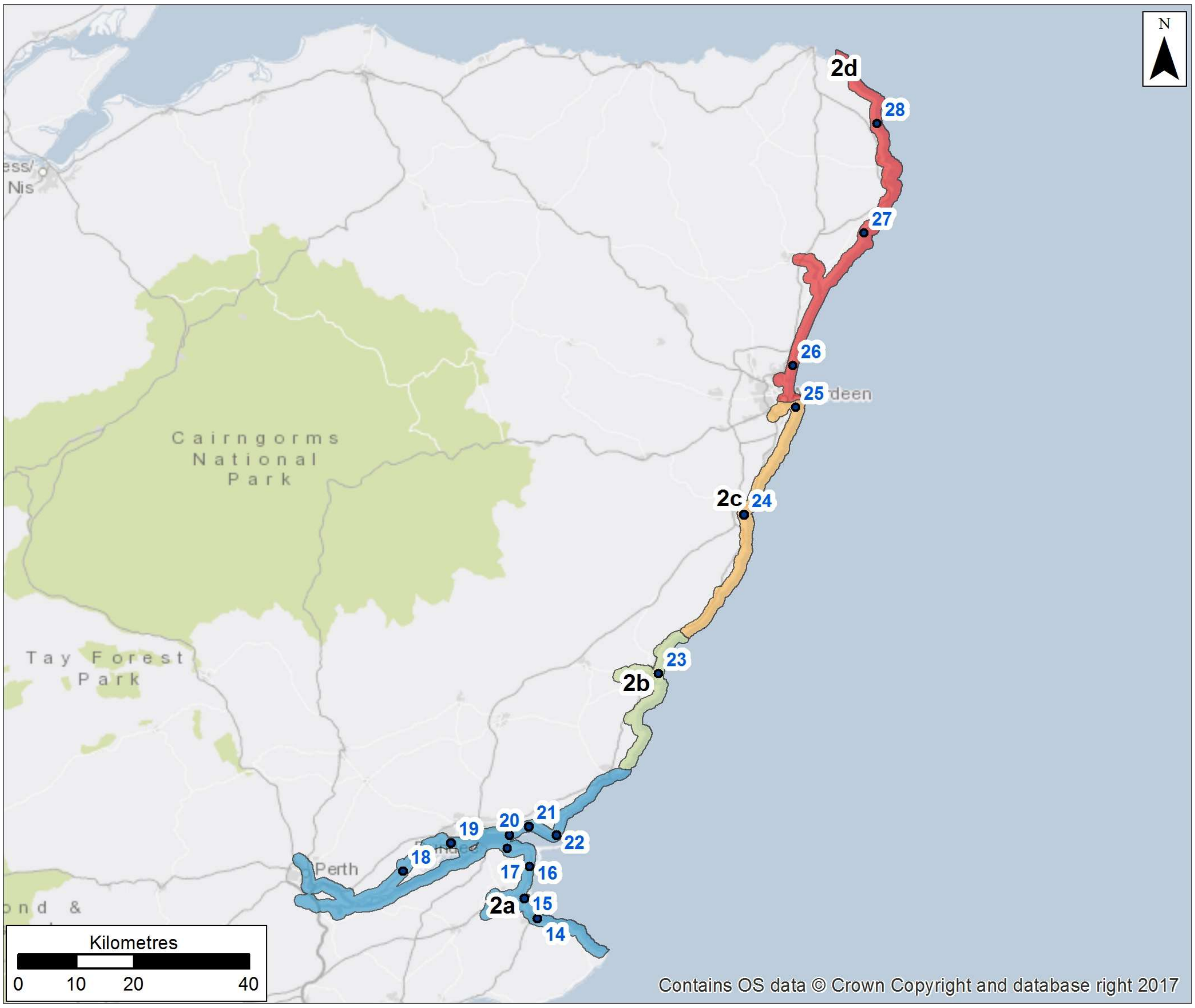

Figure 2.1: The sub-cell boundaries of Cell 2 and locations of sites discussed in this report (blue numbers).

Physical Overview

In Cell 2 Mean High Water Springs (MHWS) extends to 546 km which makes up around 3% of the Scottish coastline. Of this length, 51% (278 km) is categorised as hard and mixed, 15% (80 km) as artificial and 34% (188 km) as soft coast (Table 2.1). Within the historical period of 1890-1970s almost 41% of the length of soft shoreline did not experience significant change, accretion dominated 46% of the area, with 12% of the coastal length retreating (Figure 2.2). 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 increased from 6% historically to 14% post 1970s, the extent of stability has reduced from 70% to 47% and the extent of accretion has increased from 24% to 39%. In addition to the increases in the extents of erosion and accretion in Cell 2, there has been an increase in the rate of change with erosion increasing from 0.7m/yr to 1.4m/yr and accretion increasing from 0.7m/yr to 2.8m/yr (Figure 2.2).

This trend is consistent with an increase in the dynamism where before the 1970s only 30% of the shoreline moved more than 10 m, since the 1970s this has increased to 53%. At the same time areas of stability have reduced from 70% before the 1970s to 47% since. Further statistics for Cell 2 can be found in Table 2.2 and Table 2.3 at the end of this report.

Table 2.1: Proportion of each coastal type within Cell 2.

Modern Coastal Type	Length	
	km	%
Soft	187.9	34%
Artificial	80.2	15%
Hard and Mixed	277.9	51%
Total Length (excluding tidally influenced inlets)	545.9	100%

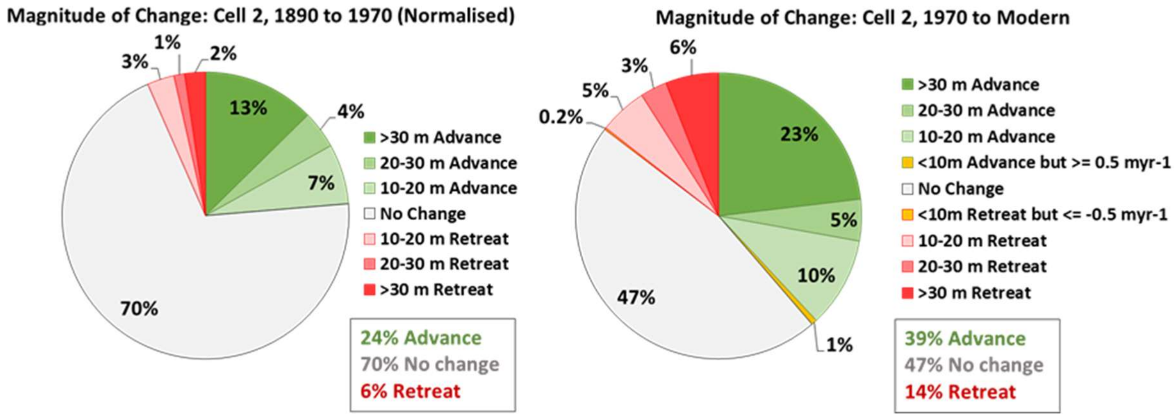

Figure 2.2: Coastal change results for Cell 2 showing the proportional amount of change in the historical (ca. 1890-1970 normalised) and recent (ca. 1970-Present) time periods. Rounding errors may produce small % differences between Figure 2 and Figure 2.2.

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 2 there are anticipated to be no residential and non-residential properties within the areas expected to be eroded by 2050. A further 79.0Ha of land supporting various types of assets is anticipated to be lost by 2050. When the erosion influenced areas are included then eight residential and non-residential properties are anticipated to be affected. For a full summary of vulnerable assets see Table 2.4 at the end of this report.

Sub-cell Summaries

Subcell 2a - Fife Ness to Deil's Head

2a.1 St Andrews East Sands (Site 14)

Historic Change: The beach at St Andrews East Sands lies to the south of the Kinnes Burn and extends 700 m from the breakwater to the rocky foreshore outcrops at the south end of the beach. The beach changed little between 1893 and 1993, with only very modest fluctuations plotted along its length. Between 1993 and 2009 whilst the northern part of the beach retreated small amounts or remained largely stable, the southern part retreated by up 10 m (0.6 m/yr) over this time period (Figure 2.3).

Figure 2.3: MHWS position in 1890, 1970s, and Modern datasets at St. Andrews East Sands. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: East Sands has artificial defences in place and therefore erosion at this location is not expected to continue into the future.

2a.2 St Andrews West Sands (Site 15)

Historic Change: St Andrews West Sands lie to the north of the town and encloses the Eden Estuary to the west. In 1896, the links were around 180 hectares, however by the early 1990s an additional 50 hectares had been gained and by 2009 a further seven hectares, all through natural processes (Figure 2.4). The additional area since 1896 has provided sufficient land for almost half of the Jubilee Course, the access road and several car parks. At the southern end of West Sands, the beach accreted some 150m in the intervening century, and towards the northern limit, Out Head had advanced seawards by over 250 m (2 m/yr). The eastward movement of Out Head has occurred in conjunction with erosion of its western edge, where some 60 m of retreat occurred over the same period. Along the Eden estuary coast some apparent accretion of the salt marshes as the shoreline turns towards the west is observed with MHWS advancing seawards some 50 m (0.5 m/yr).

Figure 2.4: MHWS position in 1890, 1970s, and Modern datasets at St. Andrews West Sands. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Since the early 1990s a similar pattern of accretion has continued, although at half the rate. The southern end of the West Sands has advanced almost 20 m between 1993 and 2009 but again towards Out Head, the dunes had advanced eastward by up to 100m (approaching 3 m/yr) (Figure 2.4). The area of erosion just south of Out Head on the Eden coast continues within the recent change analysis. This is likely related to the increased effect of short westerly waves at high tide, this part of Out Head being increasingly the most exposed to such effects, although movement of the main channel of the River Eden cannot be ruled out. The last few decades have also seen some beach and dune erosion along the Eden Estuary coast of the Jubilee Course (managed by sloped gabion baskets and a now repeated beach feeding programme) and several blow outs have occurred along the dune cordon of West Sands. Despite the seaward movement of MHWS at the Swilcan Burn (at the southern end of West Sands), some dune reinstatement and dune grass planting has been carried out nonetheless. These works may reflect the considerable visitor pressure in this area alongside natural fluctuation and processes.

MHWS along the southern shore of the Eden Estuary, adjacent to the Old Course, moved seawards in the twentieth century; however this trend has reversed in the last few decades. MHWS in 1982 largely followed the vegetation edge of the current salt marsh, although today MHWS is located more than 20 m inland halfway up the marsh surface (Figure 2.5). In some areas of Scotland, the vegetation edge is plotted, in error, as coincident with MHWS. However, the 1982 mapping here depicts saltmarsh plants on both sides of the MHWS line suggesting the landward movement is correct.

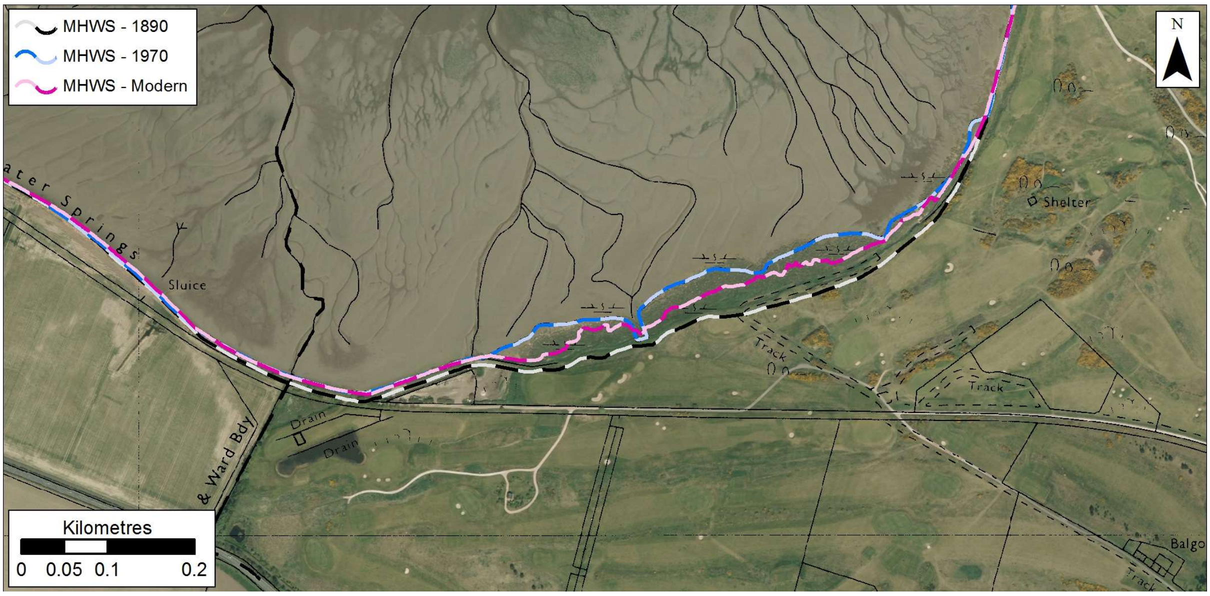

Figure 2.5: Position of MHWS in the 1890s, 1970s and Modern datasets at in the Eden Estuary, with the 1970s OS 1:10,000 map overlain the aerial photography. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

St Andrews links are part of a Potentially Vulnerable Area, a Garden of Designed Landscape and is notified as a part of the Firth of Tay and Eden Estuary Special Protection Area and Eden Estuary Site of Special Scientific Interest.

Figure 2.6: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at St. Andrews West Sands. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. Within the dunes at St Andrews there are two areas where there has been significant erosion and/or landward migration of MHWS, firstly to the northern Eden Estuary coast and secondly to the south within the area of the salt marsh (Figure 2.6). If the past rates continue then the MHWS of 2050 is anticipated to move up to 40 m inland and will overlap onto areas of the golf course in the south. In the north, any anticipated erosional footprint is some 20 m away from any golf course assets. Both the West Sands and Eden Estuary are designated for their natural heritage interests and the erosion does occur within known areas of flood risk (200yr extent).

2a.3 Tentsmuir (Site 16)

Historic Change: Tentsmuir is an extensive and largely afforested sand dune system which stretches some 7.5 km between the Eden Estuary and the River Tay to the north. Although its overall form has remained largely unchanged between 1893 and 1988, the two corners on the southeast and north east limits of the dunes have undergone substantial change (Figure 2.7 and Figure 2.8). At the mouth of the Eden estuary at Reres Wood between 1893 and 1988, MHWS moved landward more than 500 m (5.9 m/yr) which is the fastest rate of erosion in Scotland over this time period. The dunes at Tentsmuir Point in the north experienced comparable rates of seaward advance under accretion, advancing 530 m (6.2 m/yr).

Between 1988 and 2009 the main east-facing coast of Tentsmuir advanced up to 280 m (9.8 m/yr). Further south, some of the earlier spectacular losses on the Eden Estuary coast have been partially mitigated and a 500 m spit (Shelly Spit) has developed since 1988 (Figure 2.8). To the north at Tentsmuir Point a spit has also formed since 1980 (Figure 2.7), fuelled (in part) by erosion of adjacent sections of beach. Within this area 80 ha have been gained between 1890 and 1980; reducing to 56 ha by 2009. This shoreline contains the Tentsmuir Coastal Defences Scheduled Monument, a National Nature Reserve, Special Area of Conservation, Special Protection Area and Site of Special Scientific Interest.

Figure 2.7: MHWS position in 1890, 1970s, and Modern datasets at North Tentsmuir. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The anticipated position of the 2050 MHWS at Reres Wood is some 100 m inland from its current position, affecting some designated habitats and potentially influencing the area of flood risk (Figure 2.9). Whilst the modern MHWS has advanced a distance seaward over the recent period, this has partly been offset by the losses experienced since the 1890s. The recent rates are unlikely to continue since the northward extension of Out Head will likely result in northward deflection of the Eden main channel giving rise to a future erosional trend at Reres Wood. This effect is plotted on the vulnerability map.

Figure 2.8: MHWS position in 1890, 1970s, and Modern datasets at South Tentsmuir. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 2.9: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at South Tentsmuir. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Further north, at Tentsmuir Point the narrowing and extension of the northernmost spit is expected to occur, with the distinct possibility that the spit may become detached as an island, although there is some uncertainty in this scenario (Figure 2.10). Since any northward extension of the spit impinges on, and is limited by, the deepwater channel of the Tay then the future coast (2050) shows the recently formed spit to continue to curve anticlockwise to the west. Two more spatially limited areas of erosion are anticipated toward Tayport on the western shore of Tentsmuir. The eastern most will affect forested dune but the western most affects some salt marsh and has the potential to impact upon derelict buildings and the western access road to Tentsmuir reserve.

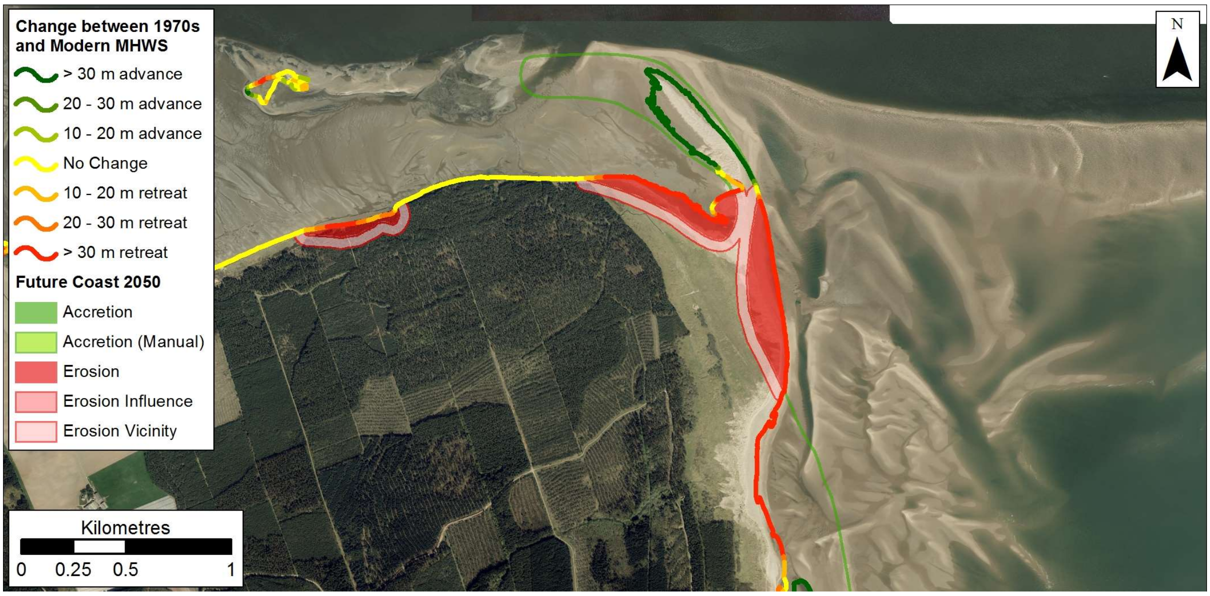

Figure 2.10: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at North Tentsmuir. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

2a.4 Tayport Caravan Site (Site 17)

Historic Change: A comparison of the coastal changes at the Tayport Links caravan park (to the east of Tayport) shows that much of the park is located on claimed land. Since the 1980s the recreational ground is defended and although the defences at the caravan site appear to be less formal, they have moved the MHWS seawards around 5m between 1980 and 2009 (Figure 2.11).

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact on areas of increased risk by 2050. Given the modest advance at the caravan park prior to 2009 and the defences in place, there is no recent trend of erosion and so any assessment of future vulnerability is not warranted.

Figure 2.11: MHWS position in 1890, 1970s, and Modern datasets at Tayport. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

2a.5 Carse of Gowrie (Site 18)

Historic Change: Whilst the southern shore of the Tay to the west of Tayport is backed by a rocky and generally steep hinterland that show close coincidence of MHWS over the time steps used here, much of the northern side of the Tay between Port Allen and Templehall Farm has seen remarkable changes since 1894 (Figure 2.12). The reed beds flanking the shore have extended into the Tay and seawards/eastwards over the 81 years in a pattern that continues to this day. The consistent pattern is remarkable with MHWS moving south towards the channel peaking at over 300 m prior to 1975. The accretion extends some 5km down the north bank of the Tay from Daleally to south of Inchture village but is at its greatest upriver. This historic accretion continues and has accelerated between 1975 and 2011. Some 51 ha of land has been formed between 1894 and 1975, and a further 189 ha up to 2011. At 5.25 ha/yr, these rates of accretion are amongst the fastest in Scotland.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. Given the accretion in this area, a vulnerability assessment is not necessary.

Figure 2.12: MHWS position in 1890, 1970s, and Modern datasets at Carse of Gowrie. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

2a.6 Dundee Airport (Site 19)

Historic Change: The shoreline west of Dundee ran alongside the railway line in 1900, but large areas of Invergowrie Bay were claimed long before the 1991 map which largely still reflects the current position of the defended shoreline (Figure 2.13). The claimed area was the site of the municipal refuse which resulted in migration west into the bay. The main phase of land claim has slowed and the area now supports playing fields and Dundee airport. Further land claim has occurred between 1990 and 2014 at the western end of the runway.

Figure 2.13: MHWS position in 1890, 1970s, and Modern datasets at Dundee Airport. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. Given the defended/ artificial character of this shore, an anticipated 2050 shoreline was not developed.

2a.7 Broughty Ferry (Site 20)

Historic Change: The shoreline along the western side of Broughty Ferry as far as the castle rock has remained largely stable since the 1890s, despite some minor movements of MHWS (Figure 2.14). Given the proximity of dense housing, the shore has been defended for a long time. Immediately east of the castle rock a short section of seawall gives way to dunes that have undergone substantial reconstruction over the recent past, and the modern MHWS has migrated a short distance landward over a short section of shore. To the east, a small foreland along the esplanade has developed since 1890s at what is locally called the "grassy beach" where some 30m has been lost between 1994 and 2012. This section of shoreline is part of the Dundee and Broughty Ferry Potentially Vulnerable Area. Broughty Castle is a property in care and a scheduled monument. To the east of the castle the foreshore is part of the Firth of Tay and Eden Estuary Special Protection Area and the Monifieth Bay SSSI.

Figure 2.14: MHWS position in 1890, 1970s, and Modern datasets at Broughty Ferry. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. Much of the Broughty Ferry shoreline is defended, and the dune-backed shore east of castle rock is relatively stable although the dunes are known to cap a low concrete wall that supports a path and fronts the roadway. Further east toward the Dighty Burn exit at the "grassy beach", some 200 m of shore lies within the future erosion area and a non-residential building lies within the erosion influenced zone (Figure 2.15).

Figure 2.15: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Broughty Ferry. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

2a.8 Monifieth (Site 21)

Historic Change: The shoreline east of the Dighty Burn to Monifieth shows a combination of accretion and land claim since 1901, the largest of which lies to the east of the caravan park and was a former refuse site for Tayside Region (Figure 2.16). Between the Dighty Burn and the caravan park is a short section of boulder defences protecting the railway line, beyond which is a dune area defended by a linear wooden palisade (and groynes) that is currently (2017) undermined and overtopped. This gives way to the former refuse site to the east. Largely infilled by 1994, the MHWS has moved landward to the extent that boulder defences were inserted over several years between the 1970s to 1990s as far as the edge of the Barry Buddon Range and its extensive dune systems. Monifieth is part of the Dundee, Broughty Ferry Potentially Vulnerable Area and Firth of Tay and Eden Special Area of Conservation.

Figure 2.16: MHWS position in 1890, 1970s, and Modern datasets at Minifieth. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. Erosion along the caravan and playing field section at Monifieth has been arrested by the progressive insertion of boulder defences to beyond the outfall of a small stream and the unprotected foreshore at the start of the Barry Buddon dune system.

2a.9 Barry Links and Buddon Ness (Site 22)

Historic Change: Barry Links is a large triangular sand dune system at the mouth of the Tay Estuary which extends over 1,000 ha. It has formed over the last six thousand years or so by the recycling of marine and river-borne sediments. The general pattern of development is summarised by May and Hansom (2003) and more recent detailed changes in the coastal edge were established by Hansom et al. (2004). Between 1901 and 1995 (Figure 2.17), the eastern edge of Barry Links eroded and moved consistently westwards. Over this time sediments were likely carried around Buddon Ness itself and repositioning it 400m further west. Whilst some sections of the western-facing shore have experienced erosion, other areas have advanced. East of the Buddon Burn MHWS advanced over 120 m in the twentieth century.

Between 1995 and 2014 erosion has affected all areas except an 800m stretch just west of the Ness (Figure 2.17). During this period, a large 2.5 km long rock armour sea wall was built to protect the Ministry of Defence owned dunes and training facilities on the east shore. Any minor seaward advances along the eastern-facing shore are associated with these. At the southern end of the defences a large erosional bight occurs that has been enlarging since the supply of sediment from dune erosion to the north has been cut off. Parts of Barry Links lie within the Monifieth Potentially

Vulnerable Area and the Firth of Tay and Eden Special Area of Conservation. Barry Links is a Site of Special Scientific Interest.

Figure 2.17: MHWS position in 1890, 1970s, and Modern datasets at Barry Links. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. The rates of erosion along both flanks of Buddon Ness have given rise to substantial areas of projected erosion zones, the largest of which extends 170 m inland from the Ness over a length of 1.8 km. The likely reason for such erosion is the extent of defenced shore to the east along the MoD –owned land and in the west at Monifieth, all of which have drastically reduced the supply of sediment to both sides of the Buddon Ness foreland.

Figure 2.18: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Barry Links. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Subcell 2b - Deil's Head to Milton Ness

2b.1 Montrose (Site 23)

Historic Change: Montrose Bay extends from Scurdie Ness in the south to St Cyrus in the north. The River South Esk flows into the Montrose basin, past the harbour and exits at the southern limit of the Bay at Montrose Harbour. In the northern part of the Bay, the River North Esk enters and deposits its sediment along the northern section. When the position of the MHWS line in 1903 and 1984 are compared, the central section of Kinnaber Links and the golf course frontage appear to have experienced erosion (up to 20 m or 0.3 m/yr); which has occurred whilst both the north and south ends of the bay have advanced (Figure 2.19). This suggests, along with the orientation of the River North Esk that sediment has been transported both north and south from the central section of the bay (this is termed a drift-divide). The industrial development at Montrose Harbour has led to the coastline being hardened and defences extended onto the open coast and northwards over the later part of the twentieth century. Towards the north of Traill Drive the shoreline advanced up until 1982 and has then been cut back aggressively, losing 50 m by 2014 (1.6 m/yr). It is unclear to what extent these changes result from natural changes to sediment supply or human induced changes, including harbour dredging and the construction of coastal defences. It is clear that erosion has increased markedly at the northern end of the town defences between 1982 and 2011 reaching 52 m just beyond the northern end of the two short rock groynes that were inserted in the 1990s to arrest the rate of recession. The local authority has plans to remove the northern most groyne to allow the coast to realign northwards. They are proposing to re-use the rock armour to the south, maintaining the access from Traill Drive.

The northern half of the bay is dominated by accretion as sediments are moved from the south to the north and augmented by sediment from the North Esk. Hansom et al. (2004) have documented recent changes to this section of coast. The 1903 map shows two exits for the River North Esk which reflect the cyclical movement of the river's mouth. Before 1903, sediment from the south deflected the North Esk northwards, until a point when the river breached and regained its southerly position. The former channel silted up and is still evident within air photography. Whilst this has led to cyclic changes at the North Esk, it has in-filled the northern part of the bay, resulting in substantial seaward migration of 50 m in the north and 130 m at the river exit. The links at Montrose are within the Montrose Basin Potentially Vulnerable Area and the northern half of Montrose Bay contains a Site of Special Scientific Interest.

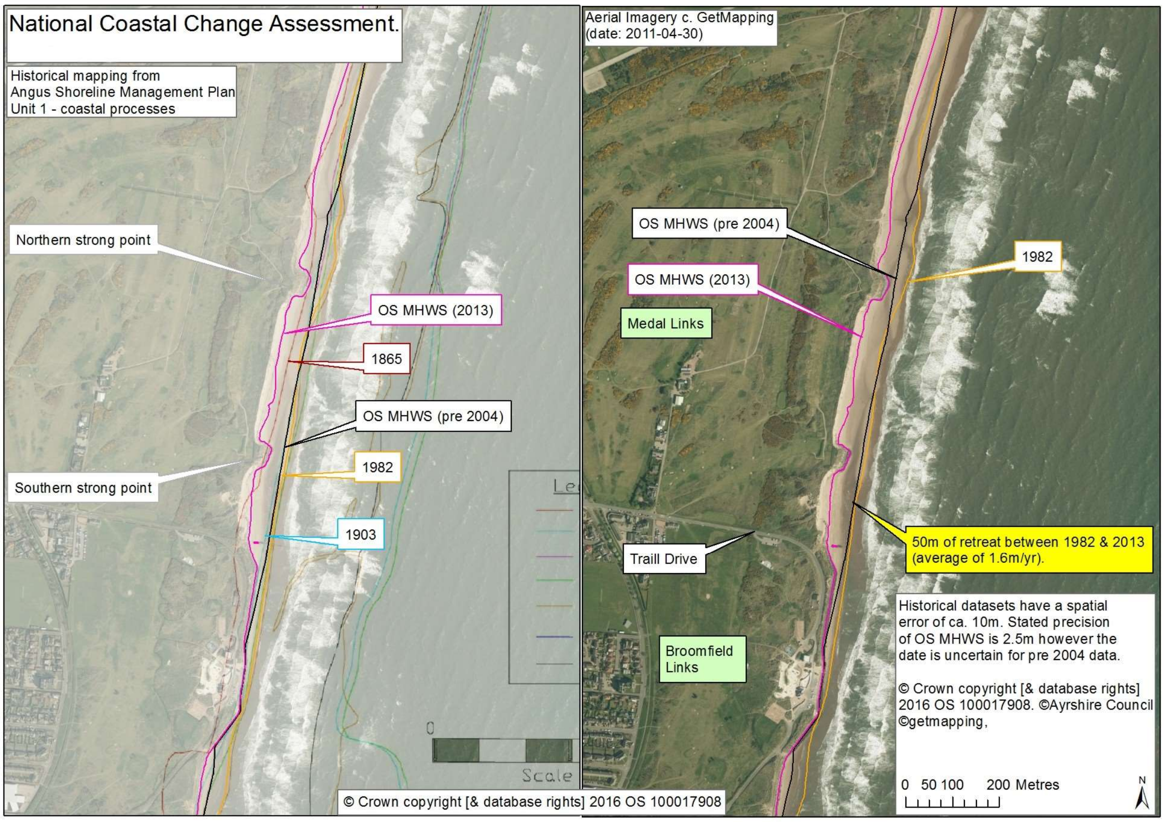

Figure 2.19: Analysis of the coastal change at Montrose combining Shoreline Management Plan data and NCCA data.

Figure 2.20: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Montrose. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. Whilst there are faster areas of retreat elsewhere in Scotland, few exist along such a lengthy stretch of soft and susceptible shore as along the Montrose golf course fronting the northern part of the town itself (Figure 2.20). Close to the end of the seawall the future erosion zone reaches a maximum of 80m inland although this zone narrows to the north as the recent erosion rate drops off. The assets that are potentially affected are restricted to the golf course frontage, although the access road to the play park behind the seawall lies within the erosion vicinity zone. Crucially, the main areas of golf course fronting the suburban areas are low lying and protected from erosion and inundation by an ever-narrowing cordon of high dunes along the Montrose Bay frontage.

Subcell 2c - Milton Ness to Girdle Ness

2c.1 Stonehaven (Site 24)

Historic Change: The shoreline at Stonehaven has retreated almost across its entire length between 1902 and 1988 in some cases by over 40 m (0.5 m/yr). The greatest losses are located at the mouth of the Cowie Water that enters the bay at its midpoint. To the north, losses have occurred but at a much lower rate. Between 1988 and 2013 the position of MHWS has changed less than 10 m in most cases across the entire bay (Figure 2.21). Stonehaven Bay is mostly protected by sea defences, but some sections remain vulnerable to flooding and some defences extend inland along the channels of the Cowie Water and Carron Water that exit into the bay.

Figure 2.21: MHWS position in 1890, 1970s, and Modern datasets at Stonehaven. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. The future coast in 2050 has not been projected for Stonehaven beach, as the recent changes are not greater than 10 m and therefore not statistically significant.

2c.2 Nigg Bay, Aberdeen (Site 25)

Historic Change: Nigg Bay lies to the south of Girdle Ness, the headland at the southern edge of Aberdeen Bay at the southern bank of the River Dee. It is a simple bay-head beach (i.e. a crescent shaped bay stretched between two headlands). Between 1902 and 1974 the changes have been modest and largely insignificant, other than the current area of the car park in the north, where there had been 17 m of erosion (0.2 m/yr), and an area that is now protected by defences (Figure 2.22). The modern published mapping seems to have changed little since 1974, despite the recent aerial photographs showing considerable earlier advance and retreat of the coastal edge in the southern end of the bay. This is likely due to delays in updating the currency of the modern line, deeming it out of date. No recent LiDAR is available which might be used to update it. Nigg Bay is notified as a Site of Special Scientific Interest.

Figure 2.22: MHWS position in 1890, 1970s, and Modern datasets at Nigg Bay (Aberdeen). Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Vulnerability Assessment: The vulnerability assessment projects the erosion rate that has occurred on the soft coast since the 1970s forward to 2050. Since the currency of the modern MHWS cannot be assured then there is no basis from which to produce a future look.

Subcell 2d - Girdle Ness to Cairnbulg Point

2d.1 Aberdeen Bay (Site 26)

Historic Change: Aberdeen Bay stretches 21km from the mouth of the Dee in the south to the headland just south of Collieston, north of the River Ythan. Between the Rivers Dee and Don the shoreline fronting Aberdeen City has been defended for many decades and the position of MHWS in 1970s is similar to that in 1889. Loss of sediment and undermining of the extensive sea wall and groynes at Aberdeen City over recent years resulted in a series of rock fishtail groynes being inserted along the urban section together with a substantial beach feeding programme between the new groynes (Figure 2.23). However, the unprotected area at the mouth of the Don has moved over 200 m landwards in the intervening one hundred years and continues to do so, in response to losses resulting from the northerly movement of sediment which dominates all but the very southern part of the bay (Figure 2.24). This shore at the Don mouth is classified as a Potentially Vulnerable Area.

Figure 2.23: MHWS position in 1890, 1970s, and Modern datasets at Aberdeen City and the fish tail groynes. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Continuing northwards the coastal edge at Royal Aberdeen and Murchar golf courses experienced reasonable accretion in the period leading up to the 1970s. This pattern continued northwards with areas of accretion (often 30 m or 0.4 m/yr) interrupting occasional areas of stability. At the mouth of the Ythan, the open coast of the Sands of Forvie experienced erosion (30 m or 0.5 m/yr) up to the 1970s. The pockets of erosion that have occurred are often located at burn mouths as they adjust to the northerly movement of sediment.

Over the more recent period since the 1970s beyond the exit of the Don, greater than 10 m of retreat has affected Royal Aberdeen, Murchar Golf course and Blackdog links (Figure 2.24). The dunes at Blackdog protect a disused landfill site, which has oil leachate problems related to its dilute and disperse design, lowering beach levels and the undercutting of the frontal dunes by a burn exit. Some remedial work has taken place here in the last 10 years, canalising the burn. North of this, erosion has caused some undercutting of the dunes at Balmedie Country Park where the Balmedie Burn has moved northwards. During the last few decades the central section of the dunes at Balmedie and Menie have benefitted from northward moving sediment that has produced a moving zone of accretion (Figure 2.25). This has resulted in northward deflection of the burns that exit onto this coast and, despite warnings of erosion on the northern sides of these exits before construction of the Trump Golf Course, the northerly deflection of the Menie Burn has resulted in two phases of damage to the third green since the course opened in 2012. The result has been 200 m of boulder protection retrofitted along the frontage of the third green that will likely cause future, but as yet undetected, erosion of downdrift areas along the northern part of the course. North of the Sand End Burn at the northern limit of the golf course, erosion dominates and continues for 2.5 km along the Foveran Links frontage where over 40 m have been lost in places (0.8 m/yr) before the mouth of the Ythan is reached (Figure 2.26 and Figure 2.27)

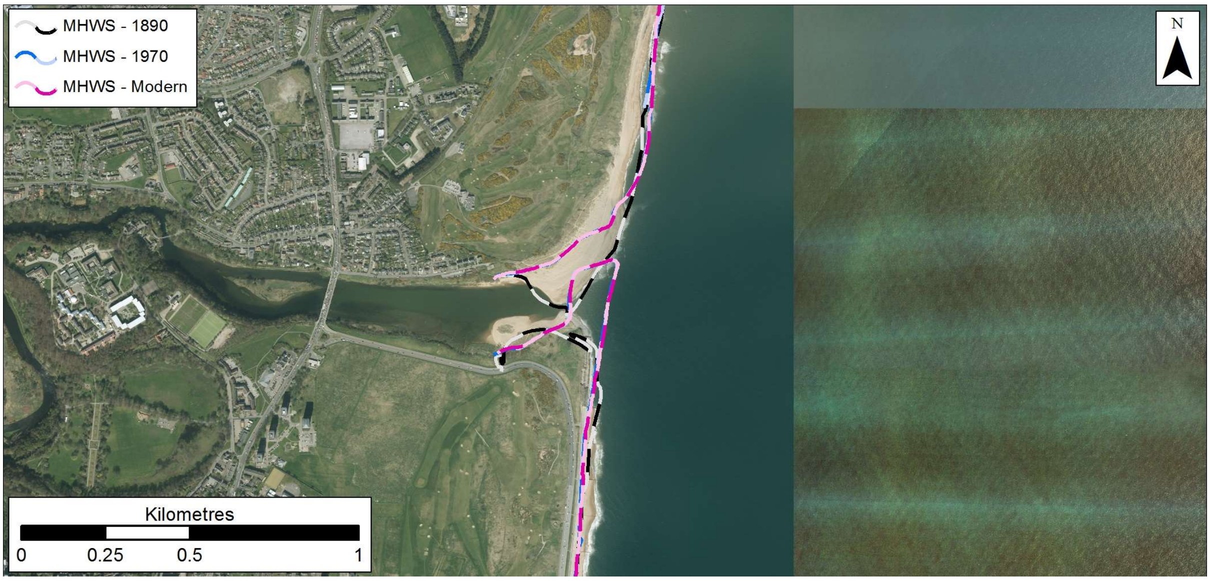

Figure 2.24: MHWS position in 1890, 1970s, and Modern datasets at the River Don. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

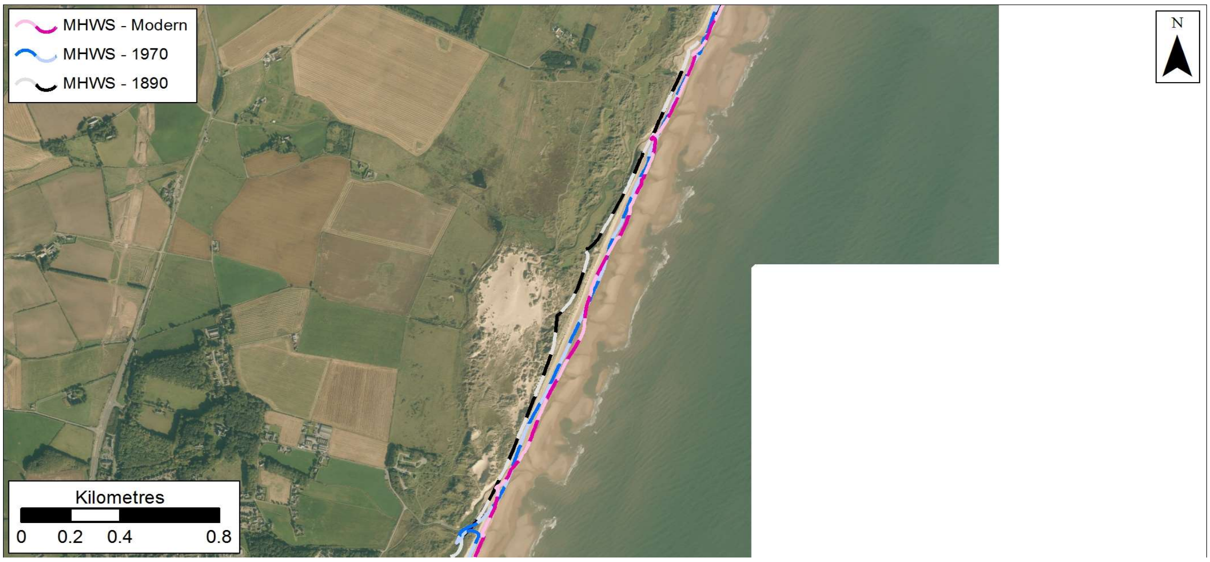

Figure 2.25: MHWS position in 1890, 1970s, and Modern datasets at Menie. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 2.26: MHWS position in 1890, 1970s, and Modern datasets south of the River Ythan mouth. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 2.27: MHWS position in 1890, 1970s, and Modern datasets at the mouth of the River Ythan. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

The foreshore at this part of Aberdeen Bay is part of the Ythan Estuary Special Protection Area and there are Sites of Special Scientific Interest at Foveran Links and Forvie as well as a National Nature Reserve.

Vulnerability Assessment: The vulnerability assessment projects the erosion rate that has occurred on the soft coast since the 1970s forward to 2050. It anticipates around 20 m erosion by 2050 within sections of the Royal Aberdeen Golf Course and up to 80 m of erosion at Murchar Golf Course (Figure 2.28). Some of these anticipated erosion areas are already causing concern.

Figure 2.28: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Royal Aberdeen and Murchar Golf Courses. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Whilst these areas of anticipated erosion do overlap coastal flood boundaries; it is not clear if there is an increased risk of breaching. Future erosion is also anticipated at two locations at Blackdog where the burn flows close to the beach before turning northwards, but also further downstream. Here up to 20 m of erosion is expected by 2050. There is uncertainty over the timing of recent remediation work related to past erosion and oil leachate from the landfill site and if the modern mapping takes this fully into account.

Further north at Balmedie (Figure 2.29), small pockets of erosion are anticipated along the dune edge of the planned (2017) Trump golf course extension south from Menie. If this materialises then there may be a need for defences in the future, that on an open coast dominated by longshore sediment movement, will have damaging impacts to the north.

Towards the mouth of the Ythan, Forveran Links to the north of Menie are expected to experience future erosion along the coastal edge (Figure 2.30). This is likely to promote instability within the coastal edge blow outs that may extend into the interior of the dune system. However, given the generally increasing stability of these dunes, in common with many Scottish dune systems, this would potentially increase the scientific interest of the system, and help partially off-set some of the features that were stabilised and destroyed by the 2012 construction of the Trump Golf course at Menie Links and will be repeated at the 2017 course at Balmedie.

Figure 2.29: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data at Balmedie. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 2.30: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data south of the River Ythan mouth. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

2d.2 Cruden Bay (Site 27)

Historic Change: The shoreline at Cruden Bay has undergone moderate recession between the 1890s and 1972 along its entire length and up to 30 m of accretion between 1972 and 2013 (Figure 2.31). The backing dune system is both high and healthy and although some trimming of the dune toe occurs during storms to reveal high and unstable sand faces, this has not resulted in any substantial migration of MHWS. These same storms, in conjunction with higher than normal discharge of the stream has resulted in undermining of the piers and landfall steps of the historic Ladies' Bridge that connects the village to the recreational beach.

Vulnerability Assessment: The vulnerability assessment projects the past rates into the future to give a sense of the potential impact in areas of increased risk by 2050. Past rates of accretion at Cruden Bay over the period up until 2013 are such that assessment of future vulnerability is not required. However, it is known that minor erosion of less than 10 m affects Ladies' Bridge such that the access steps have been undermined, preventing access to the beach and remedial works are required to reinstate it. There are proposals to replace the bridge subject to funding being secured.

Figure 2.31: MHWS position in 1890, 1970s, and Modern datasets at Cruden Bay. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

2d.3 St Fergus & Rattray head (Site 28)

Historic Change: Accretion has dominated the shoreline at St Fergus between 1900 and 1971. To the north of the burn some areas advanced up to 70 m, whilst most advanced around 20-40m over this period. To the south of the burn, a small area of erosion has occurred where 35m was lost over the same period. Between the 1970s and 1980s the St Fergus Gas Terminal was constructed and several pipelines made landfall and were installed underneath the dunes which were successfully reinstated several times over that period. Since 1971, the dominance of accretion has reduced and erosion is more common, with greater than 20 m of retreat occurring since the 1970s (Figure 2.32). The modern shoreline here has not been updated since 1974 and so the true migration of MHWS is problematic. Nevertheless, the position of the dune toe shown on the aerial photography suggests that MHWS has migrated landward to reoccupy its 1890s position. The pattern of change is not uniform but fluctuates along the shoreline, perhaps reflecting the instability caused during the removal and replacement of the dunes following the repeated pipeline installations. To the north end of St Fergus Bay the modern position of MHWS lies landward and up to 40m of erosion has occurred into the backing dune field. This section of coast contains the Peterhead Potentially Vulnerable Area and Loch of Strathbeg Site of Special Scientific Interest and Ramsar site.

Vulnerability Assessment: The vulnerability assessment projects the erosion rate that has occurred on the soft coast since the 1970s forward to 2050. Whilst much of the shoreline has remained within 10 m since 1974, the dunes along the northern half of the St Fergus gas terminal have retreated up to 28 m (0.5 m/yr). When this is propagated forward to 2050 the anticipated position of MHWS is around 20 m inland (Figure 2.33). Whilst this does overlap with an area of coastal flood risk, at its recent rate it is not anticipated to cause a breach within the main dune ridge either here or at the northern end of the bay where although the rate of erosion is greater, the baking dune cordon is higher, wider and thus more robust. Nevertheless, given the strategic importance of the gas installations at St Fergus and its long and successful tradition of beach and dune management, then any future erosional threat is likely to be dealt with rapidly, likely by beach feeding and further dune stabilisation

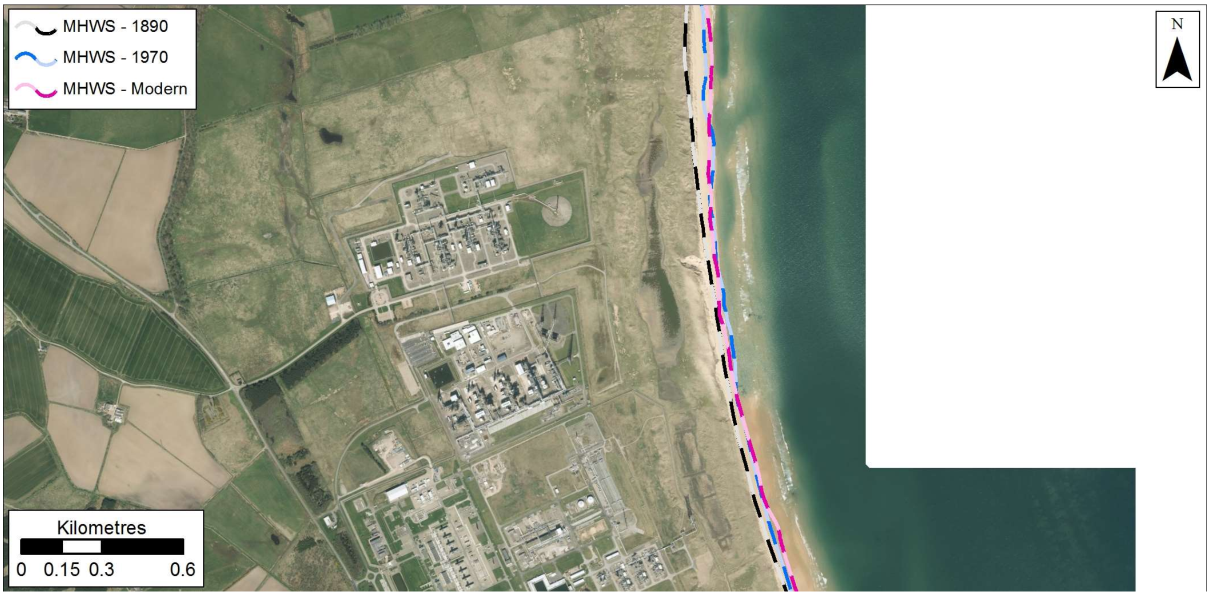

Figure 2.32: MHWS position in 1890, 1970s, and Modern datasets at the St. Fergus Gas Terminal. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Figure 2.33: Possible future coastline position in 2050 based on rates between 1970 and Modern MHWS data with the SEPA 1000 year flood envelope at St. Fergus Gas Terminal. Getmapping are our current providers of Scotland-wide digital aerial imagery© Getmapping plc.

Coastal Change Statistics for Cell 2

Within the soft sections of Cell 2, **49% has been advancing** between **1890 and 1970**; compared with **39%** between **1970 and modern data.**

Within the soft sections of Cell 2, **14% has been retreating** between **1890 and 1970**; compared with **15%** between **1970 and modern data.**

Within the soft sections of Cell 2, the **average rate of advance** is **0.7 m/yr** between **1890 and 1970**, and **2.8 m/yr** between **1970 and modern data.**

Within the soft sections of Cell 2, the **average rate of retreat** is -**0.7 m/yr** between **1890 and 1970**, and **-1.3 m/yr** between **1970 and modern data.**

Within the soft sections of Cell 2, **37%** has **not changed** significantly between **1890 and 1970**; compared with **47%** between **1970 and the modern data.**

Table 2.2: A summary of the average rates, average change distances, and lengths of advance, retreat, and no change within sub-cells of Cell 2.

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 2a	28.5	0.34	73.8	89.9	1.03	36.4	-105.0	-1.22	11.4	1.5	0.02	26.1
Suc-cell 2b	18.2	0.21	37.5	39.4	0.54	18.0	-19.7	-0.24	3.0	1.9	0.03	16.4
Sub-cell 2c	4.0	0.06	18.1	17.9	0.23	5.3	-19.8	-0.23	2.1	1.9	0.03	10.7
Sub-cell 2d	19.1	0.24	56.5	40.9	0.52	32.0	-27.5	-0.37	9.1	1.1	0.01	15.4
Cell 2	21.2	0.26	185.8	58.7	0.71	91.7	-60.5	-0.67	25.6	1.5	0.02	68.6
	-	-	-	-	-	49.3%	-	-	13.8%	-	-	36.9%

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 2a	47.8	1.80	83.9	114.0	4.31	40.9	-49.8	-1.94	12.9	-0.3	-0.01	30.1
Suc-cell 2b	-0.2	0.02	33.5	36.9	0.97	4.5	-27.9	-0.82	5.7	-0.6	-0.02	23.3
Sub-cell 2c	1.9	0.11	16.8	15.1	0.57	3.4	-49.1	-1.27	0.8	1.5	0.07	12.6
Sub-cell 2d	9.6	0.30	53.9	29.8	0.93	24.0	-25.1	-0.80	8.2	0.4	0.01	21.8
Cell 2	24.2	0.89	188.1	76.9	2.81	72.7	-37.9	-1.35	27.6	0.1	0.00	87.8
	-	-	-	-	-	38.7%	-	-	14.7%	-	-	46.7%

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 2.3: 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 2.

1890-1970	Cell 2		Sub-cell 2a		Sub-cell 2b		Sub-cell 2c		Sub-cell 2d	
	Length (km)	Length (%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
>30 m Advance	48.9	26%	24.2	13%	8.5	5%	0.3	0%	16.0	9%
20-30 m Advance	16.5	9%	4.6	2%	2.9	2%	1.1	1%	7.9	4%
10-20 m Advance	26.2	14%	7.6	4%	6.7	4%	3.8	2%	8.1	4%
No Change	68.6	37%	26.1	14%	16.4	9%	10.7	6%	15.4	8%
10-20 m Retreat	11.8	6%	3.7	2%	2.0	1%	1.3	1%	4.8	3%
20-30 m Retreat	4.7	3%	1.8	1%	0.6	0%	0.5	0%	1.8	1%
>30 m Retreat	9.1	5%	5.9	3%	0.4	0%	0.3	0%	2.5	1%
Total length	**185.8**	**100%**	**73.8**	**40%**	**37.5**	**20%**	**18.1**	**10%**	**56.5**	**30%**

Max advance (m)	537.3	North Tentsmuir	537	192	84	277
Average change (m)	21.2		28.5	18.2	4.0	19.1
Max retreat (m)	-556	South Tentsmuir	-556	-58	-47	-169

1970-Modern	Cell 2		Sub-cell 2a		Sub-cell 2b		Sub-cell 2c		Sub-cell 2d	
	Length (km)	Length (%)	(km)	(%)	(km)	(%)	(km)	(%)	(km)	(%)
>30 m Advance	43.5	23%	32.0	17%	2.3	1%	0.1	0%	9.1	5%
20-30 m Advance	8.8	5%	1.8	1%	1.0	1%	0.3	0%	5.8	3%
10-20 m Advance	19.2	10%	6.4	3%	1.2	1%	2.6	1%	9.0	5%
<10m Advance but >= 0.5 myr^{-1}	1.2	1%	0.8	0%	0.0	0%	0.4	0%	0.1	0%
No Change	87.8	47%	30.1	16%	23.3	12%	12.6	7%	21.8	12%
<10m Retreat but <= -0.5 myr^{-1}	0.4	0.2%	0.3	0%	0.0	0%	0.0	0%	0.1	0%
10-20 m Retreat	10.2	5%	3.5	2%	2.6	1%	0.4	0%	3.8	2%
20-30 m Retreat	5.7	3%	2.4	1%	1.4	1%	0.1	0%	1.8	1%
>30 m Retreat	11.3	6%	6.8	4%	1.7	1%	0.3	0%	2.5	1%
Total length	**188.1**	**100%**	**83.9**	**45%**	**33.5**	**18%**	**16.8**	**9%**	**53.9**	**29%**

Max advance (m)	386	North Tentsmuir	386	131	46	97
Average change (m)	24.2		47.8	-0.2	1.9	9.6
Max retreat (m)	-196	North Tentsmuir	-196	-111	-172	-103

Asset Vulnerability Statistics for Cell 2

Table 2.4: 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 2.

Cell 2	Units	Modern to 2050				2050+			
		Erosion	Erosion Influence	Erosion Vicinity	Total	Erosion	Erosion Influence	Erosion Vicinity	Total
Community Services	Number	-	-	-	-	-	-	-	-
Non Residential Property		-	3	14	17	5	5	9	19
Residential Property		-	5	69	74	12	3	111	126
Septic Water Tanks		-	-	-	-	-	-	-	-
Utilities		-	-	-	-	-	-	1	1
Rail	Length (km)	-	-	0.2	0.2	0.0	0.1	0.1	0.2
Roads (SEPA)		-	-	0.2	0.2	-	0.0	0.6	0.7
Roads (OS)		0.1	0.1	0.5	0.7	0.2	0.1	0.6	0.9
Clean Water Network		0.1	0.1	0.6	0.8	0.2	0.1	0.8	1.1
Total Anticipated Erosion	Area (hectares)	79.0	20.7	123.0	222.7	151.8	23.1	131.8	306.6
Runways		-	-	-	-	-	-	-	-
Cultural Heritage		16.1	2.9	16.1	35.1	13.3	2.2	12.4	27.9
Environment		54.9	12.0	62.1	129.0	97.0	11.6	59.1	167.7
Flooding (200 year envelope)		38.8	7.6	32.3	78.7	48.9	5.4	26.8	81.1
Flooding (1000 year envelope)		41.0	8.2	36.2	85.4	53.4	6.1	31.9	91.3
Erosion within PVAs		20.7	6.8	39.1	66.6	45.6	8.0	42.9	96.5
Erosion outwith of PVAs		58.8	14.1	85.6	156.1	107.2	15.4	90.9	210.2
Battlefields		-	-	-	-	-	-	-	-
Gardens and Designed Landscapes		0.4	0.3	2.6	3.3	1.0	0.5	2.9	4.3
Properties in Care		-	-	0.084	0.084	-	-	0.126	0.126
Scheduled Monuments		16.0	2.6	14.8	33.4	14.5	2.3	13.0	29.8
Nature Conservation Marine Protected Areas		-	-	-	-	-	-	-	-
National Nature Reserves (NNR)		14.6	2.0	10.5	27.2	9.3	1.0	5.1	15.5
Special Areas of Conservation (SAC)		47.5	7.8	38.7	94.1	82.8	7.8	37.1	127.7
Special Protection Areas (SPAs)		23.1	3.9	19.6	46.5	25.1	3.0	14.7	42.8
Sites of Special Scientific Interest (SSSI)		60.7	12.8	54.1	127.6	108.9	12.5	53.0	174.4

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