SLODDEN TO BINBANE HEAD CERM STUDY

FINAL REPORT

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1 INTRODUCTION

1.1 Background

RPS were commissioned by Donegal County Council to develop a Coastal Erosion Risk Management (CERM) plan for the Donegal coastline between Slodden Port and Binbane Head on the western side of the Inishowen peninsula. Five individual sites located on this peninsula, Rockstown Harbour, Tullagh Bay, Pollen Strand, Five Finger Strand and the Binbane Coast road were identified for inclusion in this CERM study. Given the high amenity values associated with the Five Finger Strand and also Ballyliffin Golf Club which is located in the hinterland of the Pollen Strand, at least two of the five study sites could be considered of high local importance.

During the severe winter of 2013/2014 when a number of significant offshore wave events coincided with high spring tides and storm surges, regions of the Inishowen peninsula were subjected to notable coastal erosion. More recently in January 2016, coastal erosion driven primarily by heavy winds and rain resulted in the loss of a small carpark at the popular Lagg Beach (Five Finger Strand). This episode of coastal erosion rendered the popular tourist amenity inaccessible and dangerous to pedestrians.

In addition to the concerns about ongoing erosion pressures, Donegal County Council is committed to maintaining the integrity and extent of the premier, high amenity areas and beaches across each of the five individual study sites. As such, Donegal County Council appointed RPS to undertake a Coastal Erosion Risk Management (CERM) study with the aim of investigating the threat posed by coastal erosion to the various sites in order to develop an appropriate plan to best the various shorelines in a sustainable and holistic manner.

Upon completion, this report will address the 11 study requirements outlined in Schedule A.1 of the CFERM guidance published by the Office of Public Works (OPW). These objectives are to:

- Review and assess existing information;
- Identify information gaps & arrange for necessary field;
- Address surveys of existing coastal protection structure and other surveys;
- Undertake an assessment of existing coastal processes and coastline evolution;
- Prepare detailed current and future coastal change maps;
- Prepare a detailed risk assessment;
- Undertake a preliminary environmental assessment;
- Undertake an Options & Feasibility assessment
- Prepare a coastal flood and erosion risk management plan
- Produce an economic assessment of benefits and costs; and
- Produce and submit a final report.

1.2 Site Description

The Inishowen peninsula in County Donegal is well recognised for the highly indented contemporary configuration of the coastline which has resulted in the formation of numerous small embayment beaches and estuary mouth systems (Carter, 1988). Included in these embayment beaches and estuary mouth systems are the five individual study sites that have been identified for inclusion in this CERM study; these sites are listed below and illustrated in Figure 1.1. It should be noted that owing to the extremely sheltered nature of Trawbreaga Bay, no areas within the bay where identified at being at risk from coastal erosion and hence this area was not considered as part of this erosion assessment.

- Rockstown Harbour (Bay 1)
- Tullagh Bay (Bay 2)
- Pollan Strand (Bay 3)
- Five Finger Strand (otherwise known as Lagg beach)(Bay 4)
- Binbane Coast Road (Bay 5)

Many of these embayment beaches are flanked by rocky headlands that preclude longshore sediment inputs indicating a lack of offshore sand on the inner shelf (Cooper *et al*., 2007). In regard to the wider sediment transport regime it has been established that the contemporary supply of modern continental-shelf or fluvial sediment to the coastal system is negligible (Cooper *et al.,* 2007).

Given its geographic location, the Inishowen peninsula is regularly exposed to high energy swell waves from the west and south westerly sectors. However, owing to the complex bathymetry and highly indented nature of the coastline much of this wave energy is highly refracted and diffracted before it reaches the majority of these beaches (Carter, 1988).

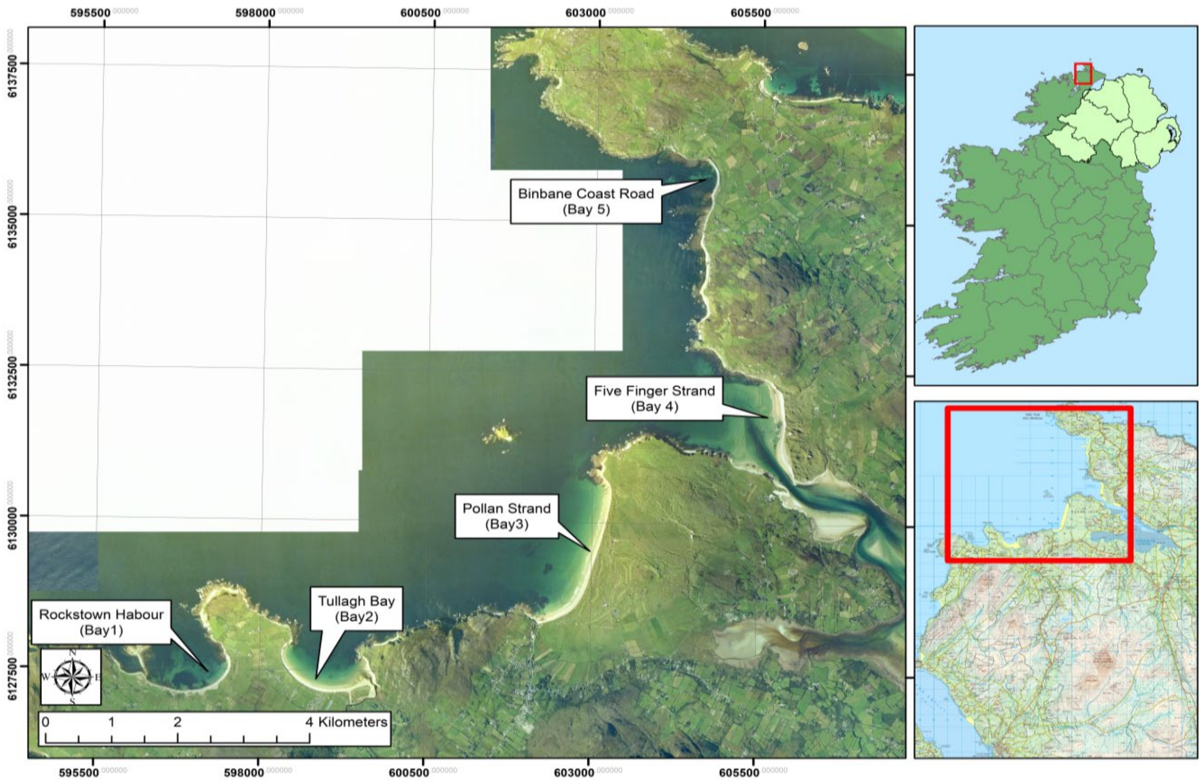

Figure 1.1 Areas of interest within Donegal Bay, Ireland

1.2.1 Rockstown Harbour and Tullagh Bay

Both Rockstown Harbour and Tullagh Bay are classic horseshoe embayment beaches flanked by rocky headlands that limit the longshore transport of sediment.

The beach at Rockstown Harbour is approximately 2.2km in length and is comprised primarily of sand and shingle material. The shingle material found on the backshore would to some extent provide natural protection against coastal erosion by "capping" the finer sand material and thus limiting sediment transport in storm conditions. As can be seen in Figure 1.2 the nearshore area at Rockstown harbour is also characterised by numerous rocky outcrops of hard bed rock around the fringes of the bay. These features cause waves to shoal and break before they reach the shoreline thus providing a notable degree of natural protection against coastal erosion.

In respect to the built environment at Rockstown harbour it can be seen from Figure 1.2 that aside from a few buildings (i.e. <10), a minor road and a small pier, there are no significant assets within 100m of the existing vegetation line.

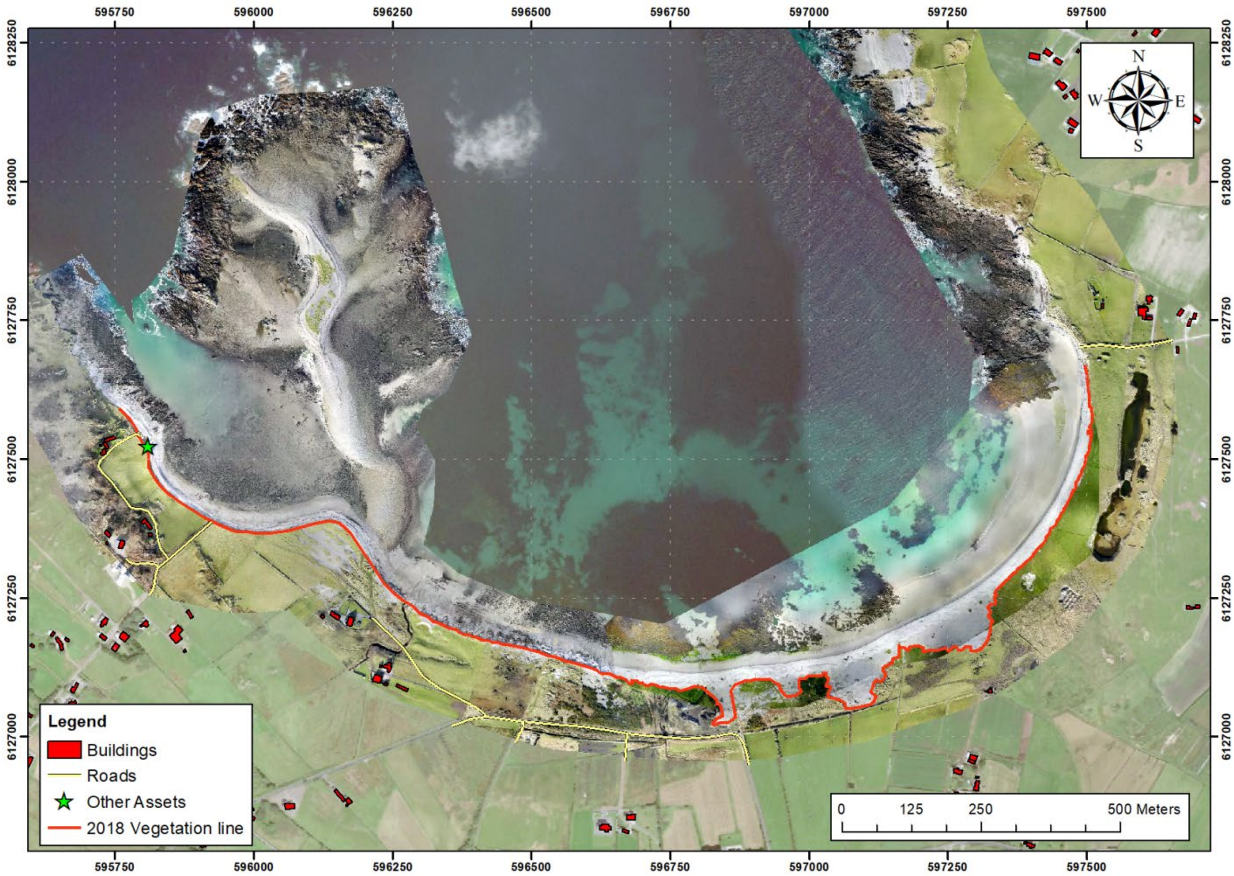

Figure 1.2: Buildings and roads at Rockstown harbour relative to the 2018 vegetation line

The beach at Tullagh Bay is also just over 2km in length but is orientated towards the north east which means that incident waves from the dominant sectors (i.e. north west & west) are highly diffracted and refracted before reaching the shoreline. The beach in this embayment is comprised primarily of a medium sand material.

As can be seen in Figure 1.3, there are *c.*20 buildings, a minor road and a caravan park within 180m of the existing vegetation line.

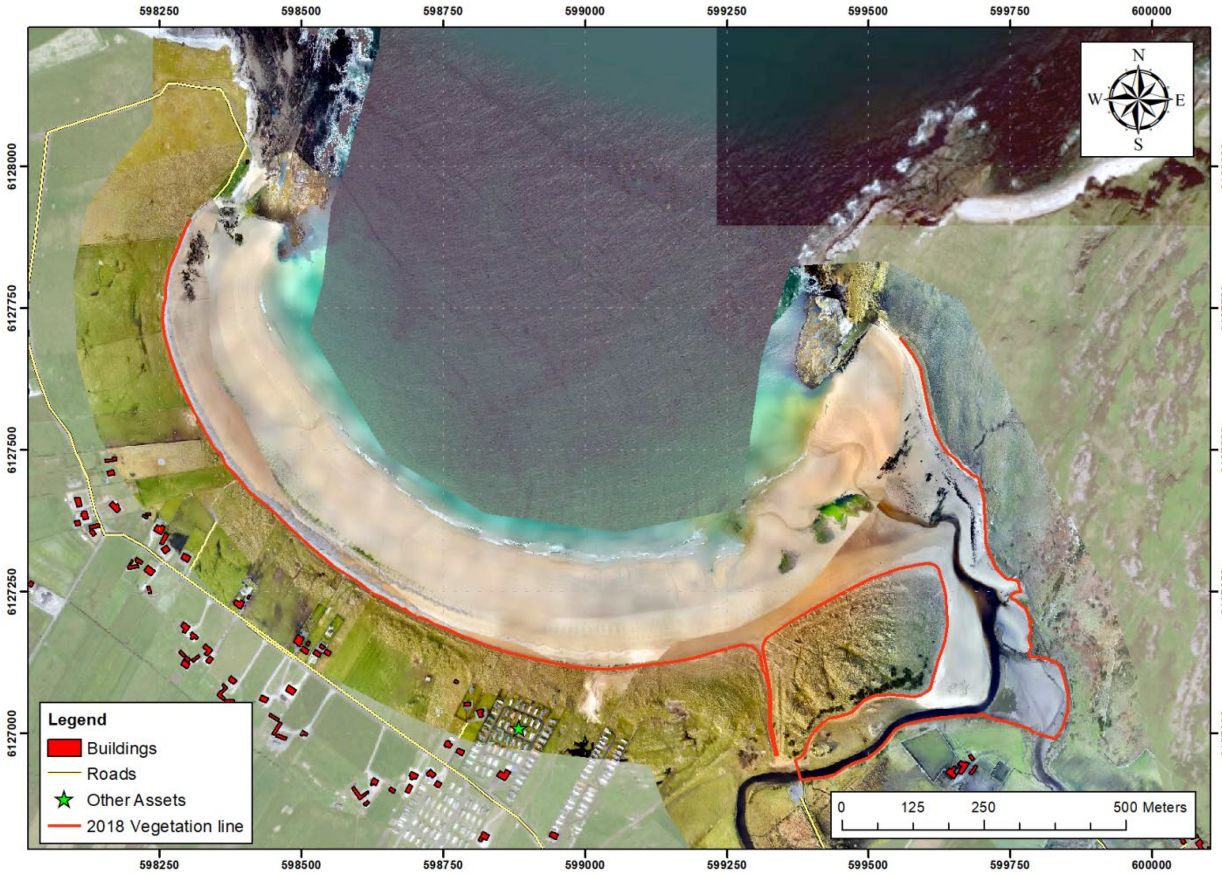

Figure 1.3: Buildings and roads at Tullagh Bay relative to the 2018 vegetation line

1.2.2 Pollan Strand

Pollan Strand is *c*.3.0km of moderately exposed littoral coast characterised by a narrow beach and shore face with the shoreline consisting of a notable dune system. The beach in this region is generally dominated by a medium sand material capped across the backshore by gravel and shingle material as illustrated in Figure 1.4. Over time the orientation of Pollan strand has naturally adjusted to be perpendicular to dominant wave direction in this area (i.e. from the north west and westerly sectors).

To the south of Pollan Strand there is a small carpark for beach visitors and a number of residential buildings (see Figure 1.5). Based on geological information obtained from Geological Survey Ireland (GIS) the substratum below these buildings is comprised of bedrock whilst the substrata below the carpark area is comprised of marine sands and gravels.

The beach at Pollan Strand is of particular local importance as Ballyliffin Golf Club which consists of two links courses offering 36 holes of golf is situated within the immediate hinterland. Ballyliffin Golf Club has hosted several major championships; most recently it hosted the Irish Open in 2018 which saw crowds of just below 95,000 people visit the north-west region.

Aside from a few localised sections of the coastline that are fronted by relatively ineffective rock armouring, the majority of Pollan Strand lacks any form of significant hard engineering defences. However, the naturally formed layer of shingle material along the backshore which can be seen in Figure 1.6 will limit sediment transport during storm conditions and thus provide a degree of natural protection against erosion of the beach and dune.

Figure 1.4: Residential buildings and the gravel & shingle backshore to the south of Pollan Strand

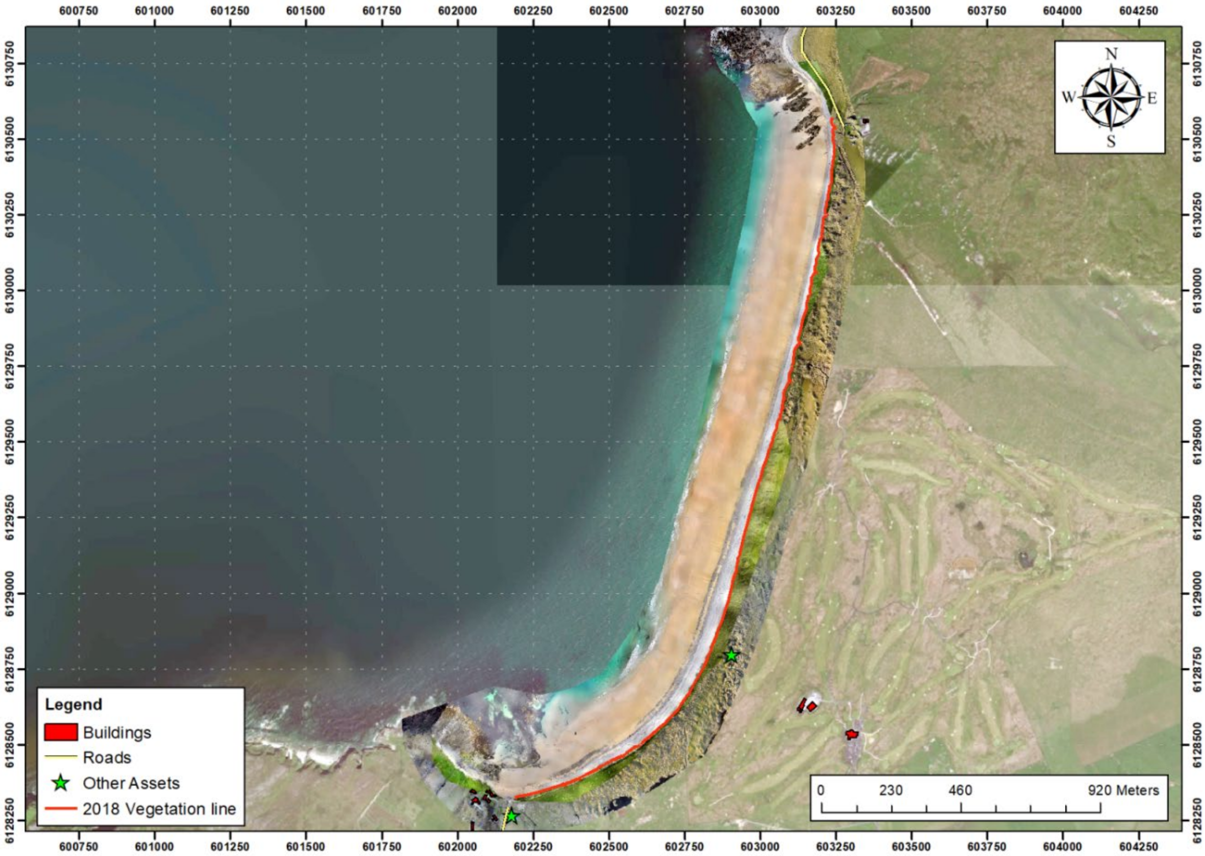

Figure 1.5: Buildings and roads at Pollan Strand relative to the 2018 vegetation line

Figure 1.6: Ballyliffin Golf Club situated in the immediate hinterland of Pollan Strand. (**Image: North & West coast links golf Ireland**)

1.2.3 Five Finger Strand (i.e. Lagg beach)

The Five Finger Strand, also known as Lagg beach (as referred to in this report), extends for *c.* 1.7 km between Five Finger rock in the north and Lagg point to the south (see Figure 1.9). The beach is comprised primarily of a medium sand material that overlies a lower cobble layer which is geologically constrained between the two rock headlands.

One of the most prominent features of Lagg beach is the extensive vegetated dune system that fronts the majority of shoreline. The primary access to Lagg beach is via a small minor road to the north, which prior to 2015 extended right to the beach. However, following storm Desmond in December of 2015 a significant portion of this road was lost to erosion (see Section 2). This point of access to Lagg beach before and after storm Desmond can be seen in Figure 1.7 and Figure 1.8 respectively.

The other notable feature of this area is the ebb delta at the tidal channel into Trawbreaga Bay. It is well established through numerous scientific studies that the position of this ebb delta changes constantly and that there is a complex exchange of sediment between the estuary, the beach and dunes, and the ebb delta (O'Connor *et al*., 2011). Analysis of historical patterns of behaviour of this system (Cooper *et al*., 2007) indicates that periodic switches in position of the ebb channel at a multi-decadal timescale are the main driver of long-term coastal morphology in this area.

Extensive studies of this area have established that the position of the tidal inlet tends to shift over time, causing a re-formation of a tidal delta. The sediment contained within the old delta is then re-worked by wave action (Jackson *et al*., 2007, Cooper *et al*., 2007; O'Connor *et al*., 2011). More recent work (Jackson *et al*., 2016) found that wave forcing is the main driver of changes in bar migration patterns at the site, helping to accelerate (low energy conditions) and decelerate (high energy) the rate of onshore migration.

Aside from the minor road providing access to Lagg beach there are no notable built assets within the immediate vicinity of the shoreline as illustrated in Figure 1.9. There are a number of defences within the actual bay, however these have minimal impact on coastal processes as the wave climate within the bay in dominated by short period, low energy wind waves generated over the short fetches within the bay.

Figure 1.7: Access to Lagg beach on 25th February 2015 with drainage shown in red (Image: Peter Homer)

Figure 1.8: Access to Lagg beach on 08th January 2018 (Image: Peter Homer)

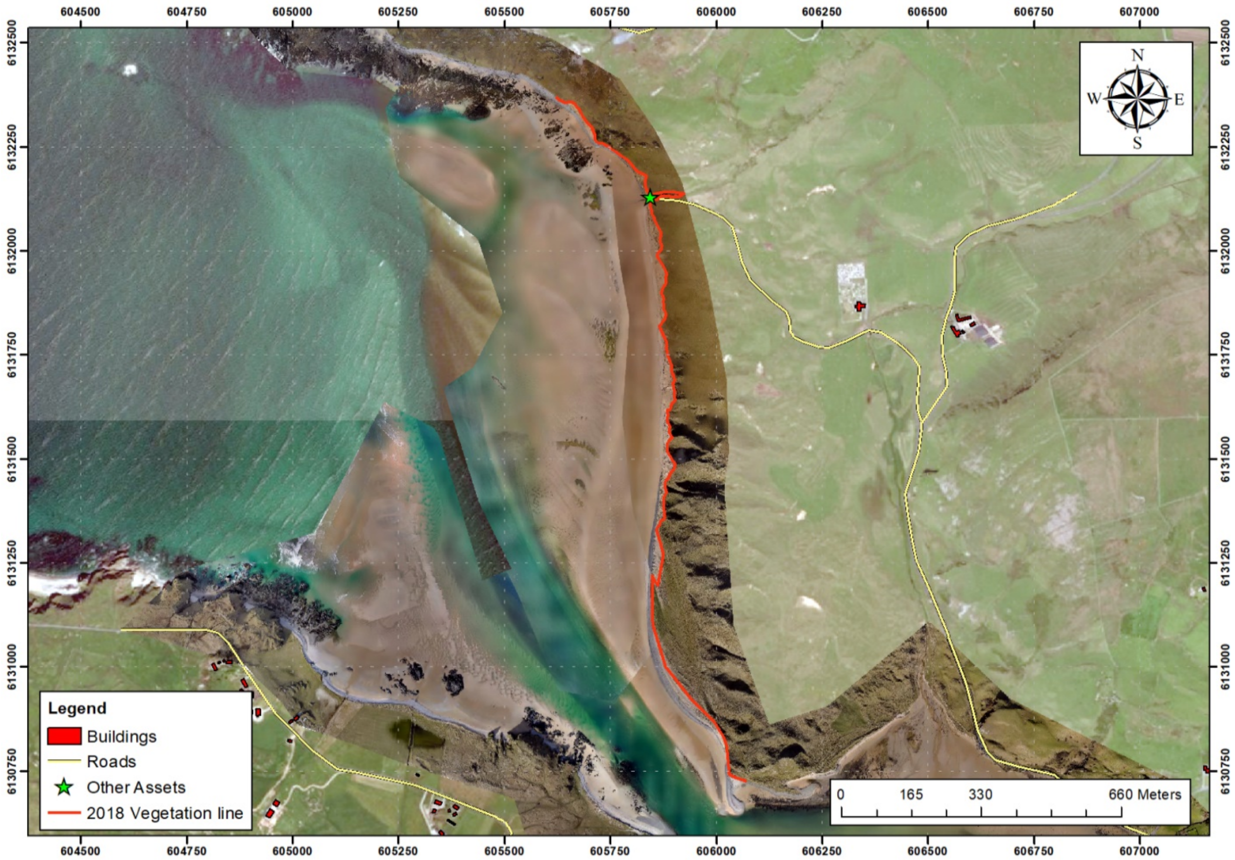

Figure 1.9: Buildings and roads at Lagg beach relative to the 2018 vegetation line

1.2.4 Binbane Coast

Binbane coast is located several kilometres to the north of Lagg beach and extends north to south for *c.*1.0km. The coastline at Binbane is characterised by numerous rocky outcrops, hard bedrock and very little sand. The backshore region is dominated by coarse shingle and gravel material (see Figure 1.10).

As can be seen in Figure 1.11 below, the only built asset in close proximity to the shoreline is a minor road that runs parallel to the coastline for approximately 500m. Rock filled gabion baskets have been installed along the seaward edge of this section of the road (see Figure 1.12).

Given that the majority of the coastline in this area is comprised of hard bedrock this area is unlikely to be affected by the same pressure of coastal erosion as experienced at the other sites. However the shingle and cobble material is likely to be mobilised during high energy wave events and potentially projected landward. Under certain conditions this could temporarily limit access along the 500m section of road illustrated in Figure 1.11.

It should be noted that there is also a sports pitch located within 100m of the coastline at Binbane, however as can be seen in Figure 1.11 this facility is fronted by a significant rocky outcrop. This rocky outcrop would reduce wave energy at the coastline by breaking waves in the nearshore region.

Figure 1.10: Shingle and gravel material along the backshore region of the Binbane coast

Figure 1.11: Buildings and roads at Binbane coast relative to the 2018 vegetation line

Figure 1.12: Partially buried gabion baskets along the Binbane coast

2 HISTORICAL REVIEW

2.1 Historical retreat

In order to better understand the coastal processes across the study areas, a review was undertaken of historical maps and orthophotography acquired from Ordnance Survey Ireland. This data comprised mapping from 1903, 1995, 2000, 2000, 2013 and most recently 2018 and provided a degree of insight into the evolution of the beaches over the past 100 years.

Each dataset was accurately geo referenced using ArcGIS and the vegetation line (i.e. the boundary of where visible vegetation growth was observed on the upper beach) was digitised. Figure 2.1 to Figure 2.5 illustrate the historical retreat of the shoreline across the five study areas between 1903 and 2018. In these Figures the position of past vegetation lines are projected onto orthophotographs that were collected in late 2018 and thus illustrate the recent coastal alignment of each area.

The historical analysis of coastal change at Rockstown harbour indicated that between 1995 and 2018 there was very little movement of the shoreline. Based on this assessment this shoreline can be classified as dynamically stable, fluctuating about a mean position in response to specific storm events.

Similarly having observed virtually no change in the general position of the vegetation line, Tullagh Bay, Pollan Strand and Binbane are also considered to be dynamically stable. It should be noted that the eastern extent of Tullagh Bay actually demonstrated notable signs of accretion between 1995 and 2018 with the formation of new embryo dunes.

Figure 2.4 shows Lagg beach as the only site that has experienced any significant coastal change between 1903 and 2018. The historical analysis of this site found that the northern extent of Lagg beach has been retreating landward since 1995, with a maximum rate of retreat of 1.03m per year between 2000 and 2004. Conversely, the southern extent of Lagg beach, near the tidal inlet, has experienced significant accretion over the same period. These changes reflect the complex exchange of sediment between the estuary, the beach and dunes, and the ebb delta as reported by O'Connor *et al*., 2011.

During the winter of 2015 storm Desmond resulted in highly localised erosion at the point of access to Lagg beach. This resulted in the partial loss of a minor road and access to the beach, however, as described in Section 2.2 the primary factor behind this event was in fact heavy rainfall.

A summary of the historic shoreline erosion/accretion at the five study areas between 1903 and 2018 is presented in Table 2.1

Table 2.1: Summary of the historical erosion rates at the five study area between 1903 and 2018

Area	1903 – 1995	1995 – 2000	2000 – 2004	2004 – 2016	2013 - 2018	1903-2018	1995-2018
	Coastal Change (m/yr) (erosion = negative, accretion = positive)						
Rockstown Harbour	-0.284	0.048	0.362	0.087	-0.215	0.215	-0.061
Tullagh Bay	0.037	0.295	1.521	0.444	-0.319	-0.117	-0.433
Pollan Strand	-0.059	1.048	-0.282	0.128	-0.209	0.011	-0.184
Lagg Beach	-0.120	-3.774	-4.118	0.945	-1.973	0.415	1.596
Binbane Coast	-0.059	0.23	0.023	0.256	-0.372	0.032	-0.073

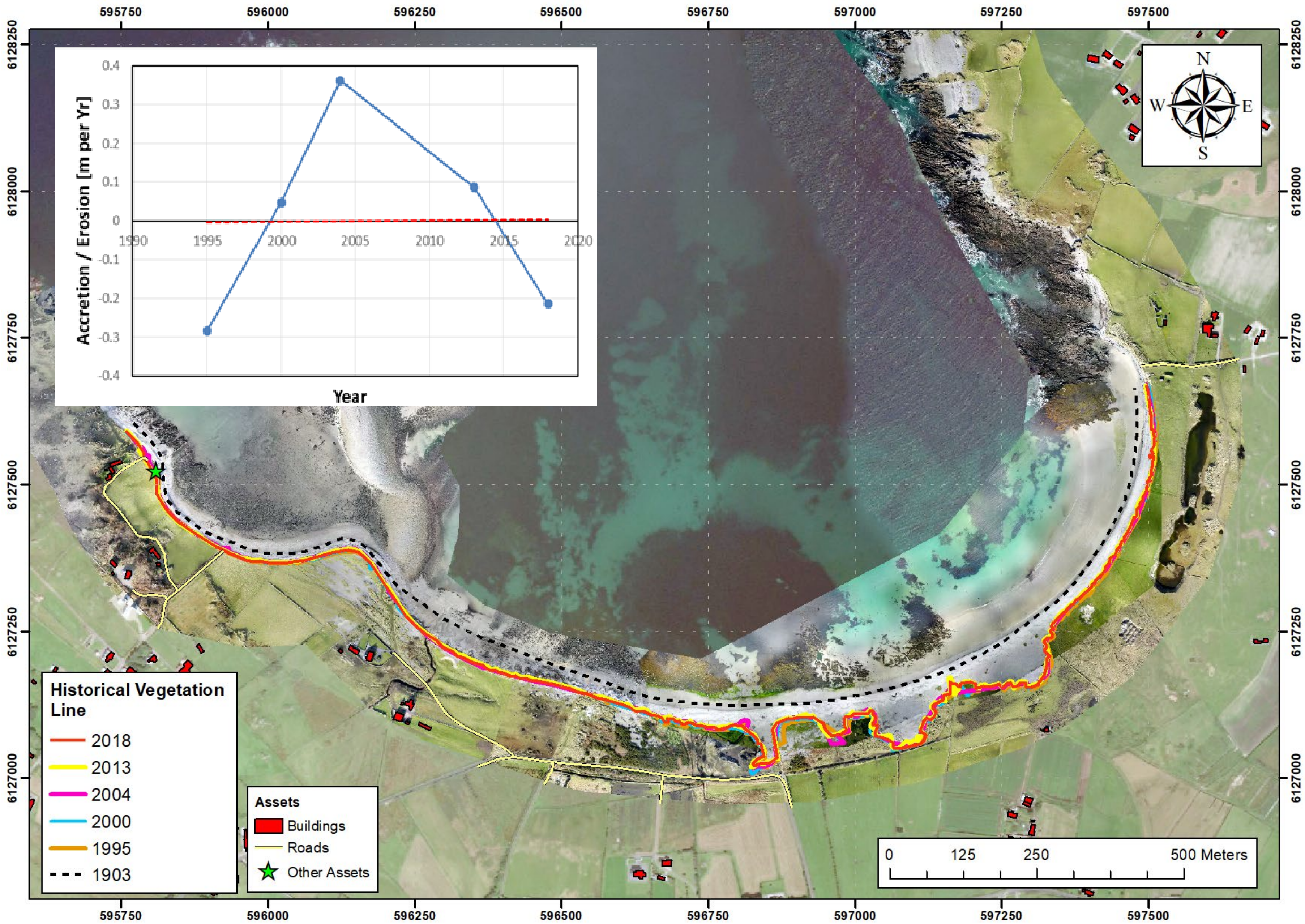

Figure 2.1: Historical retreat at Rockstown harbour between 1903 and 2018 with mean erosion/accretion summary inlay (based on digitised shoreline extent)

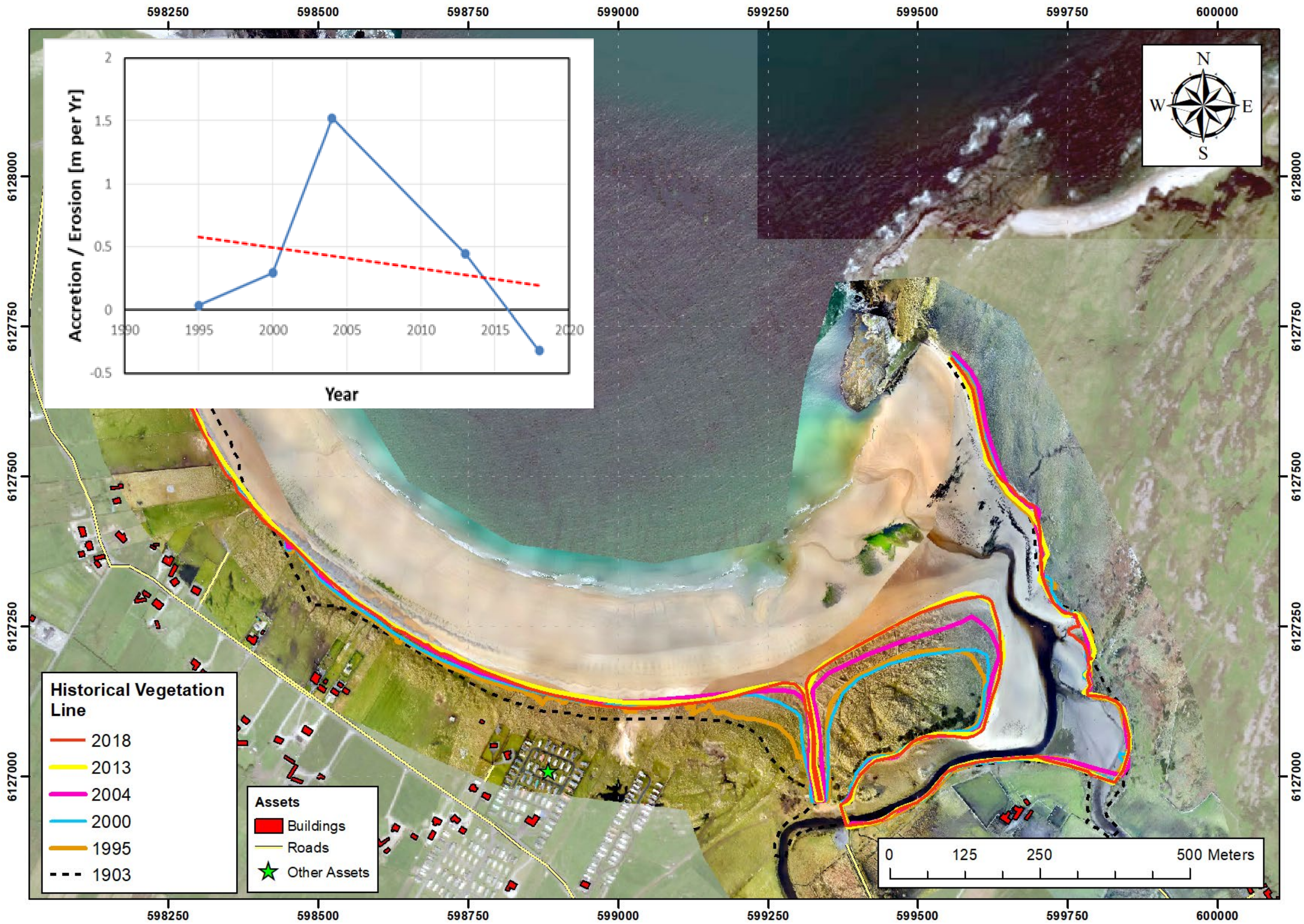

Figure 2.2: Historical retreat at Tullagh Bay between 1903 and 2018 with mean erosion/accretion summary inlay (based on digitised shoreline extent)

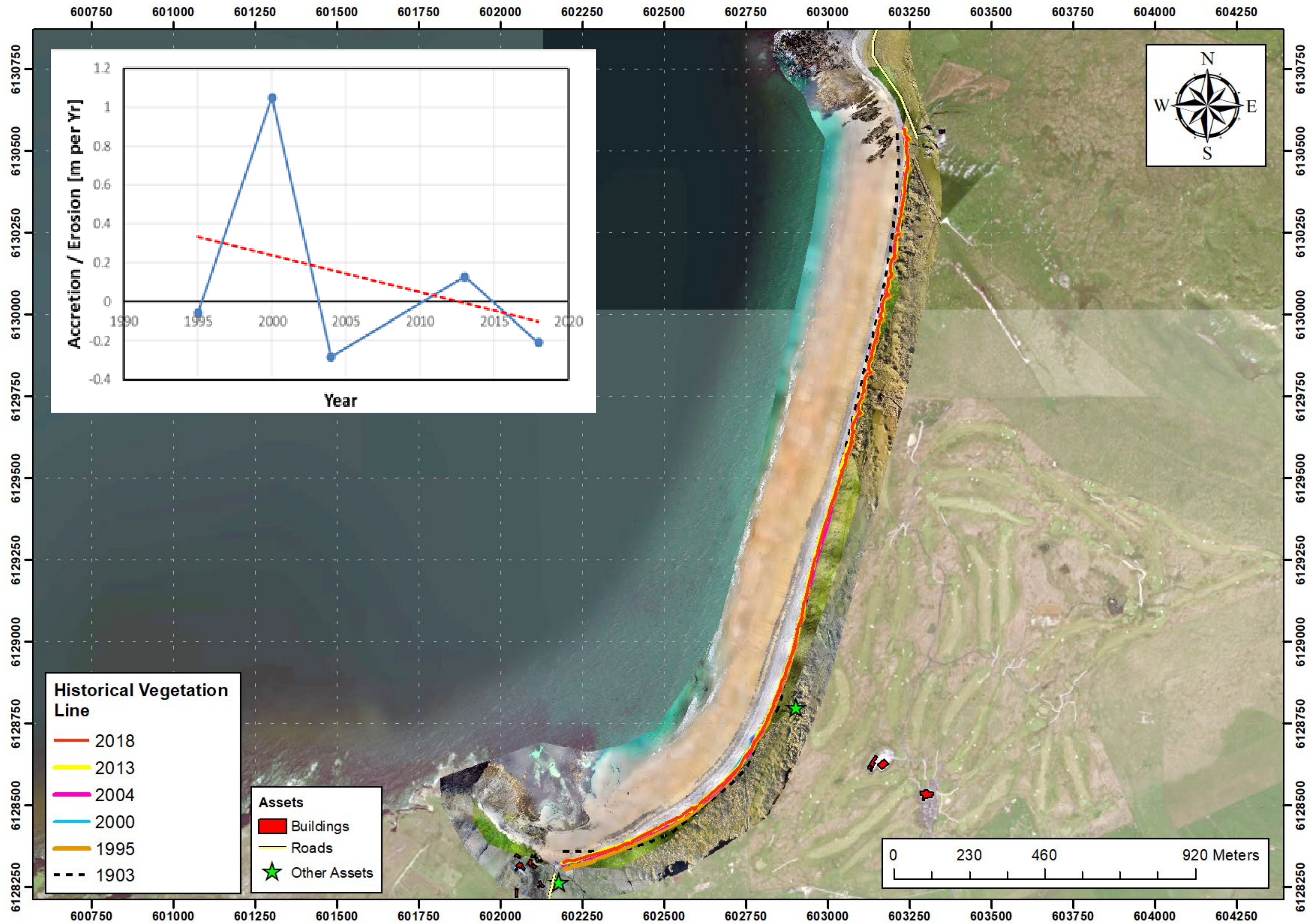

Figure 2.3: Historical retreat at Pollan strand between 1903 and 2018 with mean erosion/accretion summary inlay (based on digitised shoreline extent)

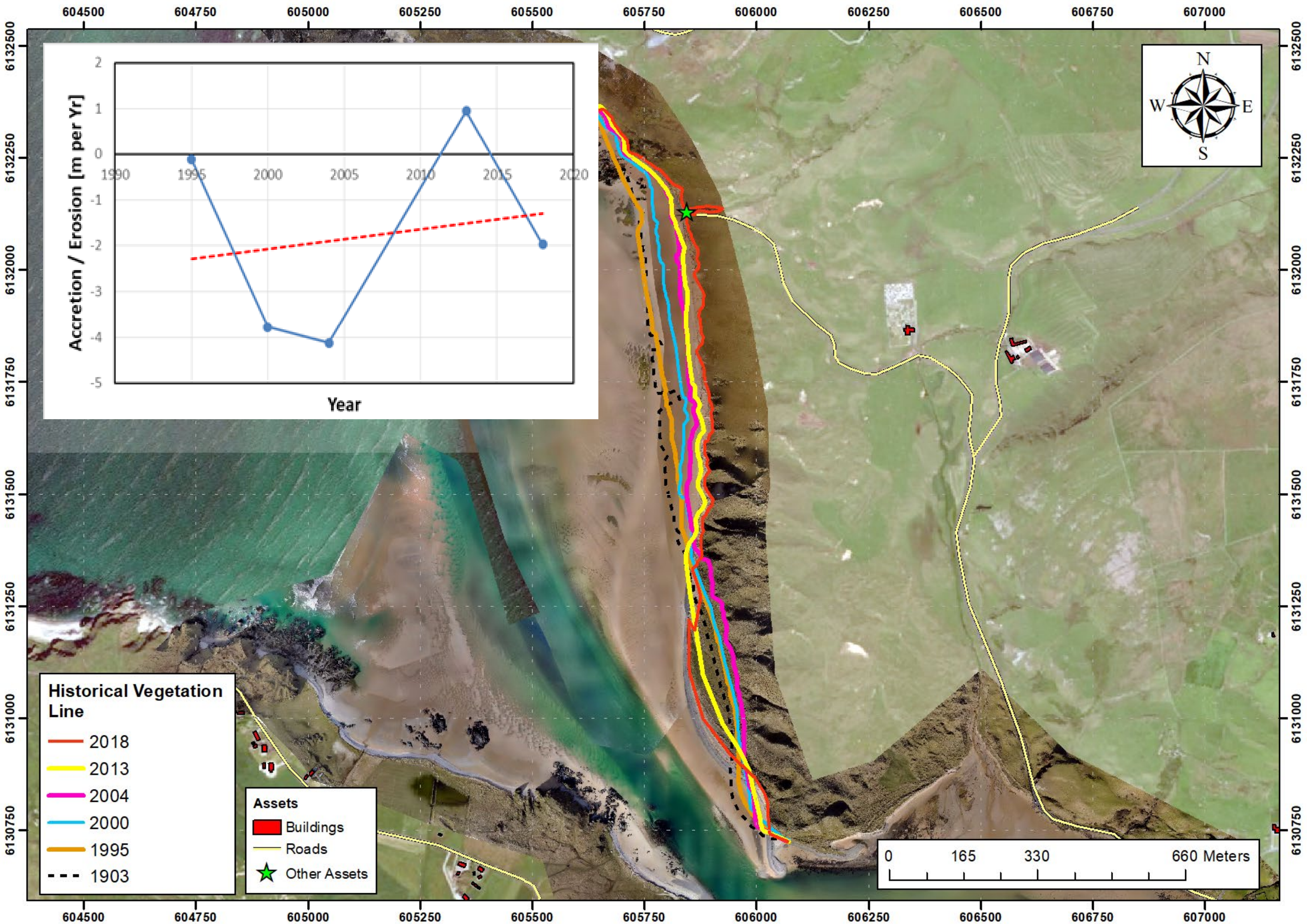

Figure 2.4: Historical retreat at Lagg beach between 1903 and 2018 with mean erosion/accretion summary inlay (based on digitised shoreline extent)

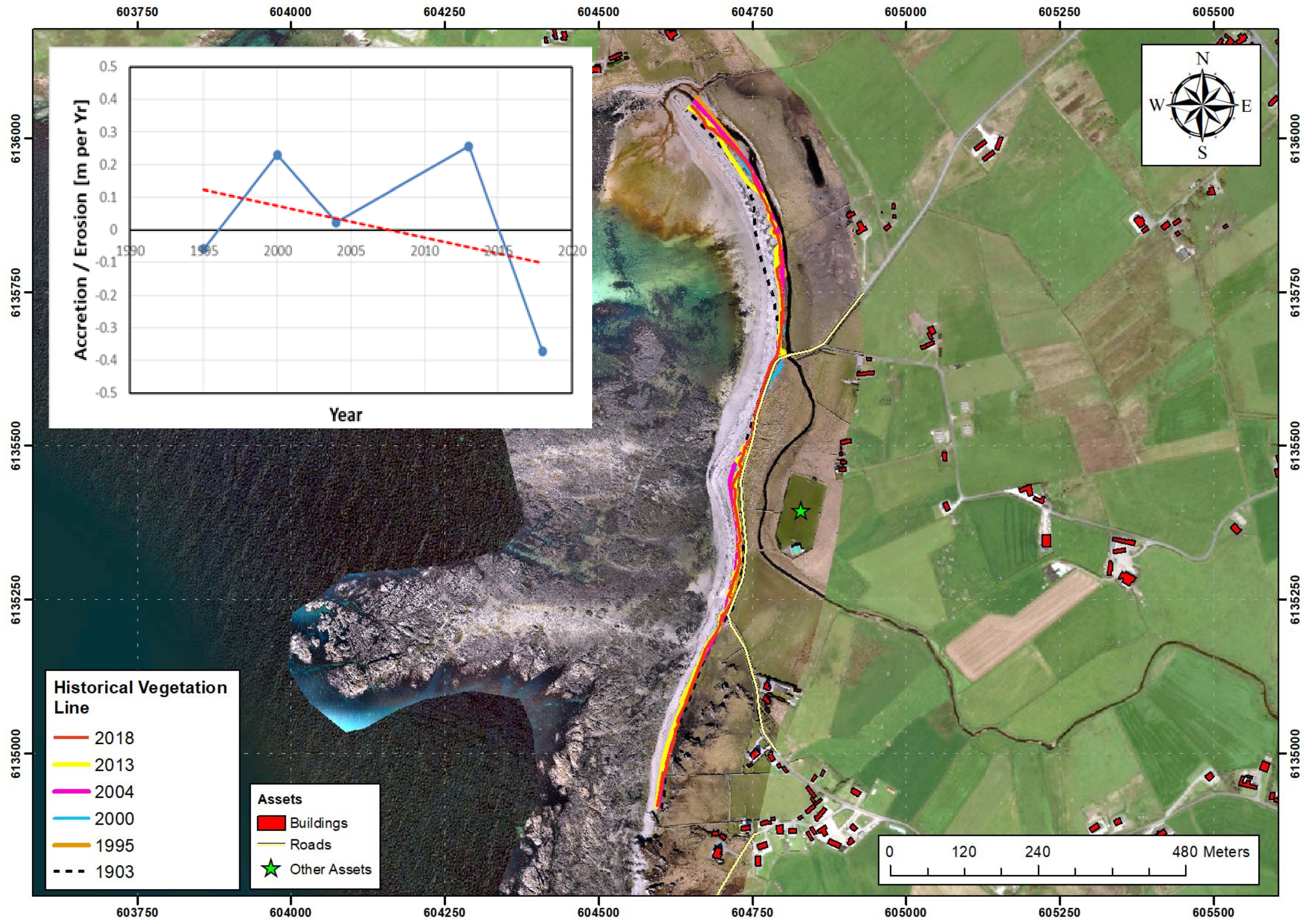

Figure 2.5: Historical retreat at Binbane coast between 1903 and 2018 with mean erosion/accretion summary inlay (based on digitised shoreline extent)

2.2 Erosion at Lagg beach during the winter of 2015

Contrary to local reports, the erosion that resulted in the partial loss of a minor road and access to Lagg beach in the winter period of 2015 appears to have actually been primarily caused by heavy rainfall and not exceptionally stormy offshore conditions.

Storm Desmond, the fourth named storm of the season, brought widespread heavy rain and storm force winds to across much of Ireland and the UK. Met Éireann described this storm event as “highly abnormal” owing to the exceptional level of rainfall and resultant flooding. During this period Malin Head reported its wettest December since 1885 (see Figure 2.6).

This heavy rainfall overwhelmed the drainage infrastructure running parallel to the minor road shown in Figure 1.7 resulting in the erosion illustrated in Figure 1.8. As can be seen in Figure 2.7 the inshore wave climate experienced during the winter of 2015 was no more arduous than any other winter period and therefore highly unlikely to have been the primary cause of the erosion observed during 2015.

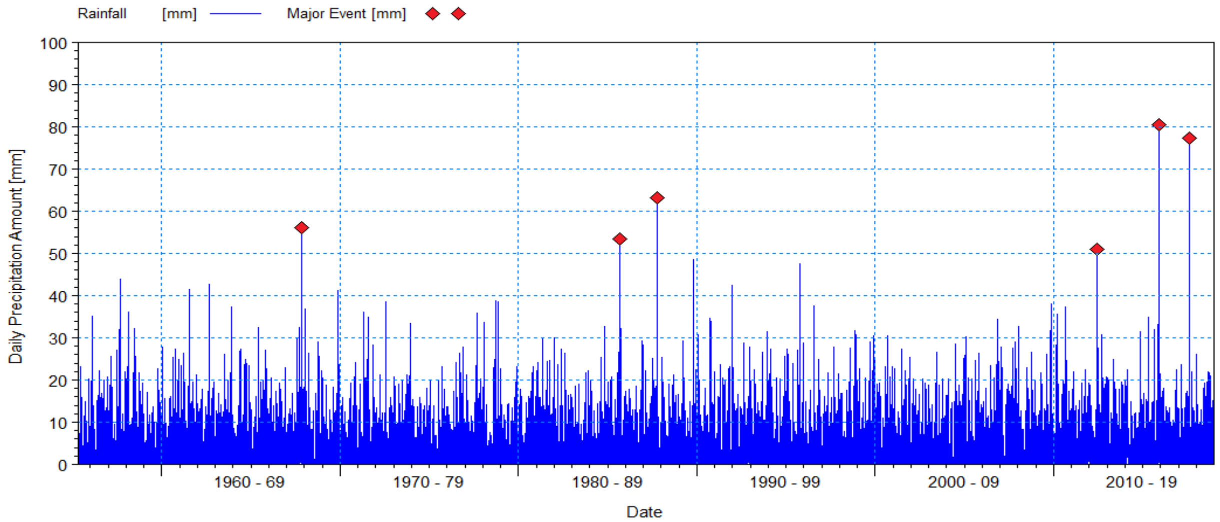

Figure 2.6: Daily precipitation amount recorded at Malin Head between 1955 and 2019

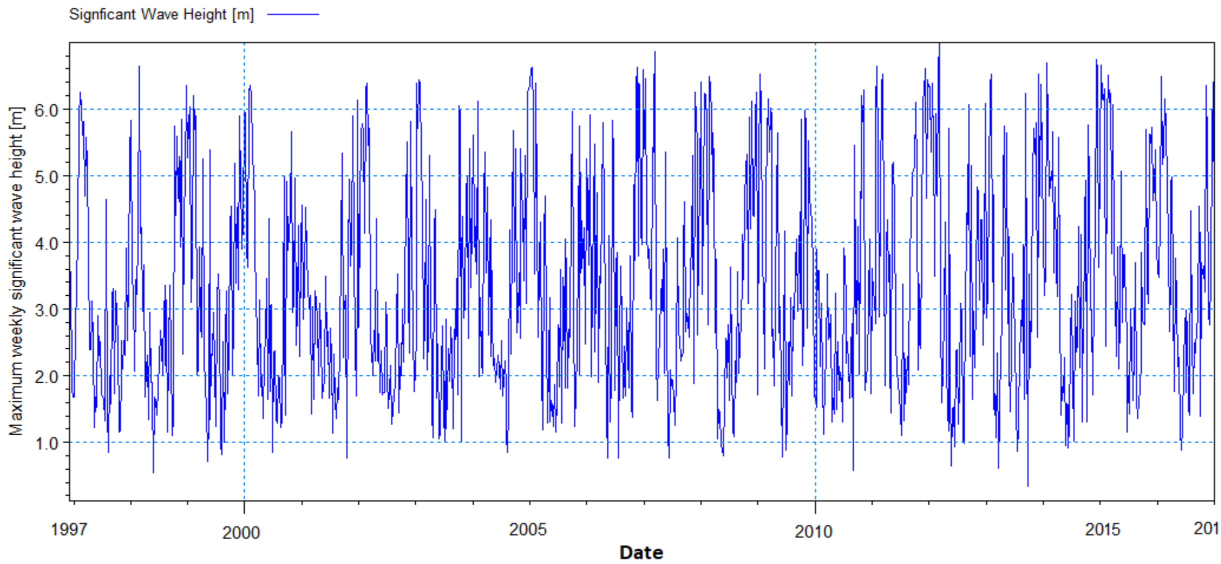

Figure 2.7: Weekly maximum inshore significant wave heights at Lagg beach between 1997 and 2017

3 DATA AVAILABILITY AND REQUIREMENTS

3.1 Wind and wave data

RPS hold an extensive database of offshore wind and wave data from the European Centre for Medium Range Weather Forecasts (ECMWF) European Waters Wave model. This data enabled RPS to generate 3-hourly wind wave and swell wave components defined in terms of significant wave height (H_{m0}), mean wave period (T_m) and mean wave direction. Wind velocities and directions were also available from the dataset.

The RPS dataset included data for offshore points along the western seaboard of the UK and Ireland for the period 1996 to 2018. Thus RPS had adequate information available to generate return period events as required for this study; no additional offshore wave data was therefore required.

3.2 Tidal levels

There are no long term tidal readings available from tidal gauges on the west coast of Ireland; however RPS' in house storm surge model of the whole of the western Atlantic analyses surges around the coast of Ireland on a daily basis. RPS used this model and the simulations already undertaken as part of the Irish Coastal Protection Strategy Study (ICPSS) to establish the extreme water levels along the Donegal Bay coastline, thus compensating for the lack of observations.

3.3 Bathymetry

Bathymetry data from the Irish Coastal Protection Strategy Study (ICPSS), the national CFRAM programme and the European Funded INFOMAR project was available from the outset of this study. Despite this, a data gap analysis indicated that there was a significant lack of inshore bathymetry and topography data across many of the five study areas and that key features such as the nearshore sand bar at the Five Finger Strand were not covered by existing surveys.

In order to address these critical data gaps and enable the development of robust numerical models, Murphy Surveys Ltd were commissioned to undertake a range of hydrographic and topographic surveys in 2017. Despite being appointed to undertake this survey work in December 2017, Murphy Surveys Ltd were unable to mobilise until February 2018 and due to continuing occurrences of unsuitable weather conditions were unable to complete the bathymetric survey until Jun 2018. Issues with the coverage of the initial survey data and deployment and technical capabilities of the current meter recording devices used meant that parts of the hydrographic survey had to be repeated again in August 2018. Survey data from this campaign was subsequently made available to RPS in late August 2018.

An initial review of the survey information found that Murphy Surveys Ltd had not sufficiently covered the survey areas as specified in the original tender specification and issues with the current meter readings still persisted. Upon request of RPS, Murphy Surveys Ltd re-surveyed the area in mid-September 2018 to eventually produce and deliver a useable dataset by late September 2018. Despite best efforts, Murphy Surveys Ltd were unable to obtain full coverage of the nearshore sand bar at the Five Finger Strand due to prolonged hazardous wave conditions. Upon instruction from Donegal County Council RPS proceeded with the study using the data available in October 2018.

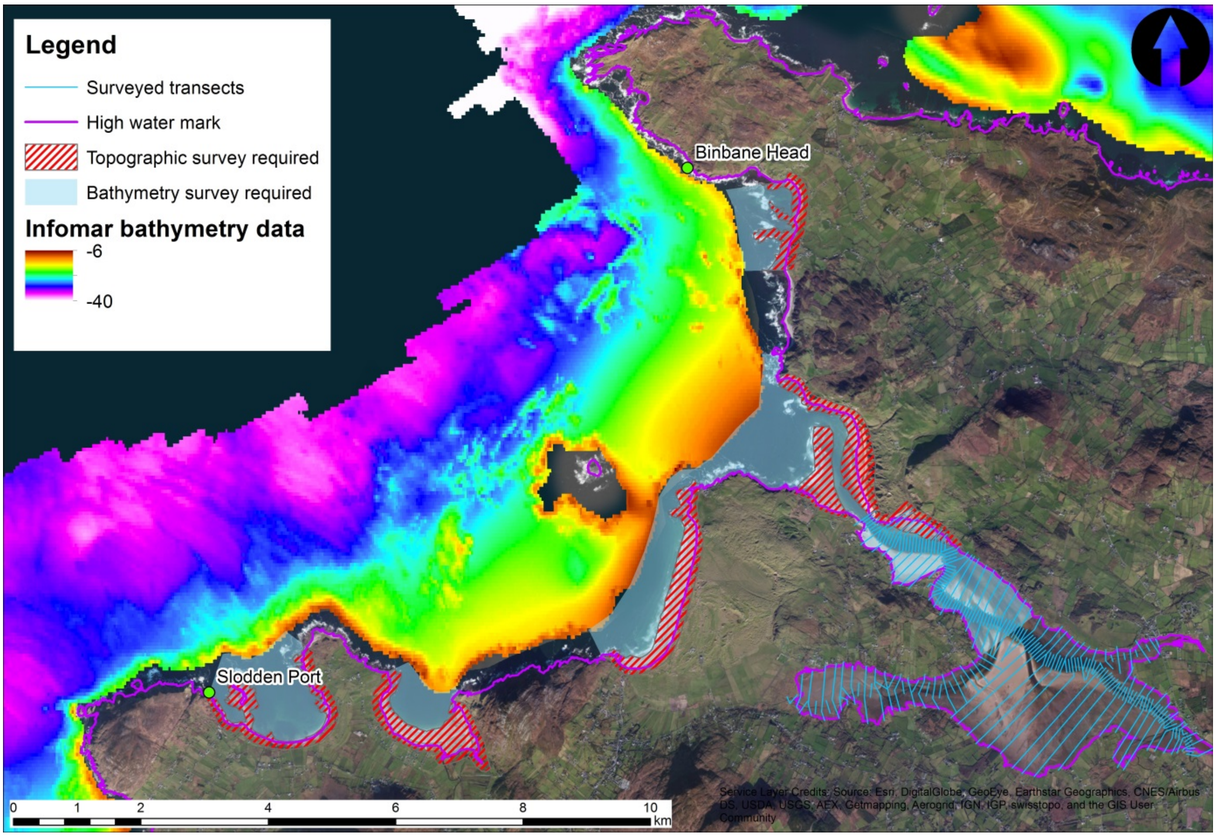

Figure 3.1 - Extent of topographic and bathymetric survey gaps prior to infill survey being completed

4 DATA AND ANALYSIS

4.1 Tidal Information

4.1.1 Standard tidal level Information

The normal astronomical tidal levels for the study area were derived using the data presented for Trawbreaga Bay in the Admiralty Tidal Tables for 2019. The resulting standard water levels for Trawbreaga Bay are presented in Table 4.1.

The hydrodynamic model used to simulate the tidal conditions at the study area was found to accurately represent these standard tidal conditions at the site. Further details of the results from the hydrodynamic model are presented in Section 6.

Table 4.1: Tidal elevations at Trawbreaga Bay to Chart Datum (CD) and Mean Sea Level (MSL)

Tidal Phase	Chart Datum [m]	OD Malin (OSGM02) [m]	Mean Sea Level [m]
Mean High Water Spring	4.0	1.72	1.74
Mean High Water Neap	3.1	0.82	0.84
Mean Low Water Neap	1.6	-0.68	-0.66
Mean Low Water Spring	0.6	-1.68	-1.66

4.1.2 Extreme tidal levels

As the wave heights that can approach the shoreline are strongly influenced by water depth, reference was made to an extreme tidal analysis undertaken as part of the Irish Coastal Protection Strategy Study (ICPSS) to establish extreme high water levels within the study area for a range of Annual Exceedance Probability (AEP) events. The location selected was in close proximity to Five Finger Strand and the extreme water levels are presented in Table 4.2.

Table 4.2: Extreme water level information at ICPSS Point NW46 at Trawbreaga bay

AEP [%]d	Extreme Water Level		
	Chart Datum [m]	OD Malin (OSGM02) [m]	Mean Sea Level [m]
50	4.98	2.70	2.72
20	5.13	2.85	2.87
10	5.24	2.95	2.98
2	5.48	3.06	3.22
1	5.58	3.29	3.32
0.5	5.68	3.39	3.42
0.1	5.97	3.63	3.65

4.2 Offshore wave and wind information

Wave and wind data from the European Centre for Medium-Range Weather Forecasts (ECMWF) European Waters Wave model for the years 1996 - 2018 were used as a source to generate 3 hourly annual wave records for an offshore point (56°N 8°W) as shown in Figure 4.1. The 3 hourly data included wind wave and swell wave components defined in terms of the significant wave height (H_{m0}), mean wave period, (T_m), and mean wave direction. Wind velocities and directions were also included in the dataset. ✓

Figure 4.1: Location of the offshore wave and wind data extraction from the ECMWF model

The wave and wind roses for the offshore point (56°N 8°W) are presented in Figure 4.2 and Figure 4.3 respectively. It will be seen from these plots that the dominant wave and wind directions are from the westerly sectors.

The annual average offshore significant wave height for this offshore point between 1996 and 2018 was found to be 2.94m. As would be expected, the monthly average significant wave heights were much larger during the winter months, November through to March (see Figure 4.4).

The probability exceedance curve for offshore significant wave heights between 1996 and 2018 is presented in Figure 4.5. Based on this information it can be seen that on average, the offshore significant wave heights will reach *c*. 10.91m for 12 hours of any given year.

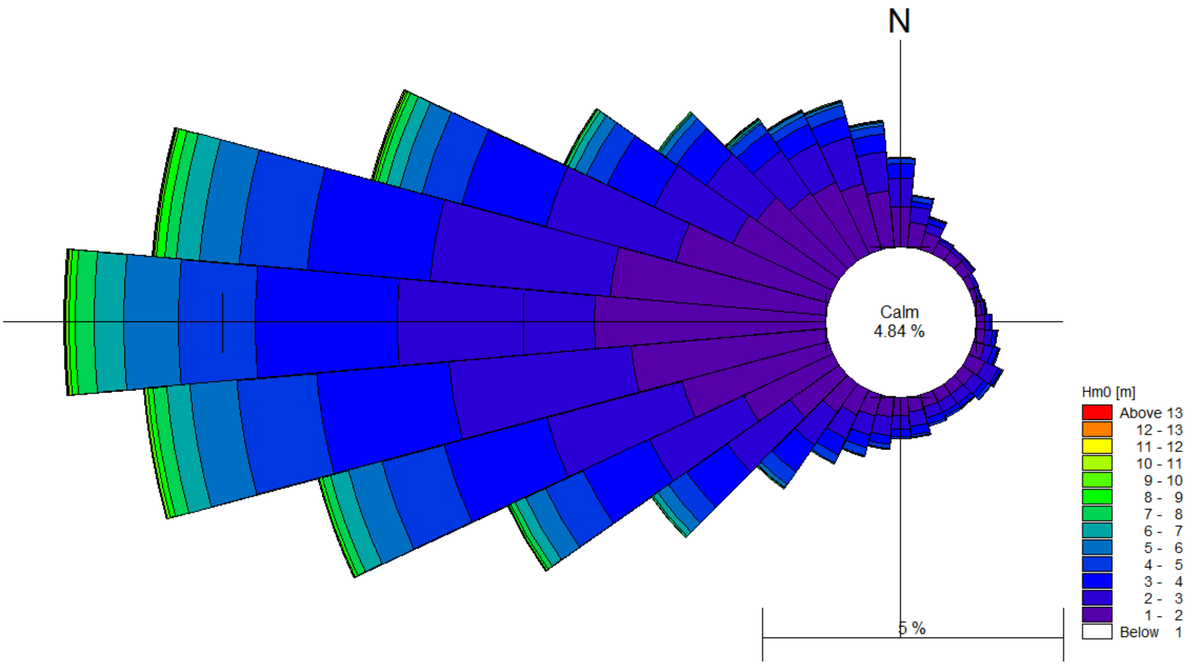

Figure 4.2: Wave rose at the offshore point (56°N, 8°W) for the 20 year period between 1996 and 2018

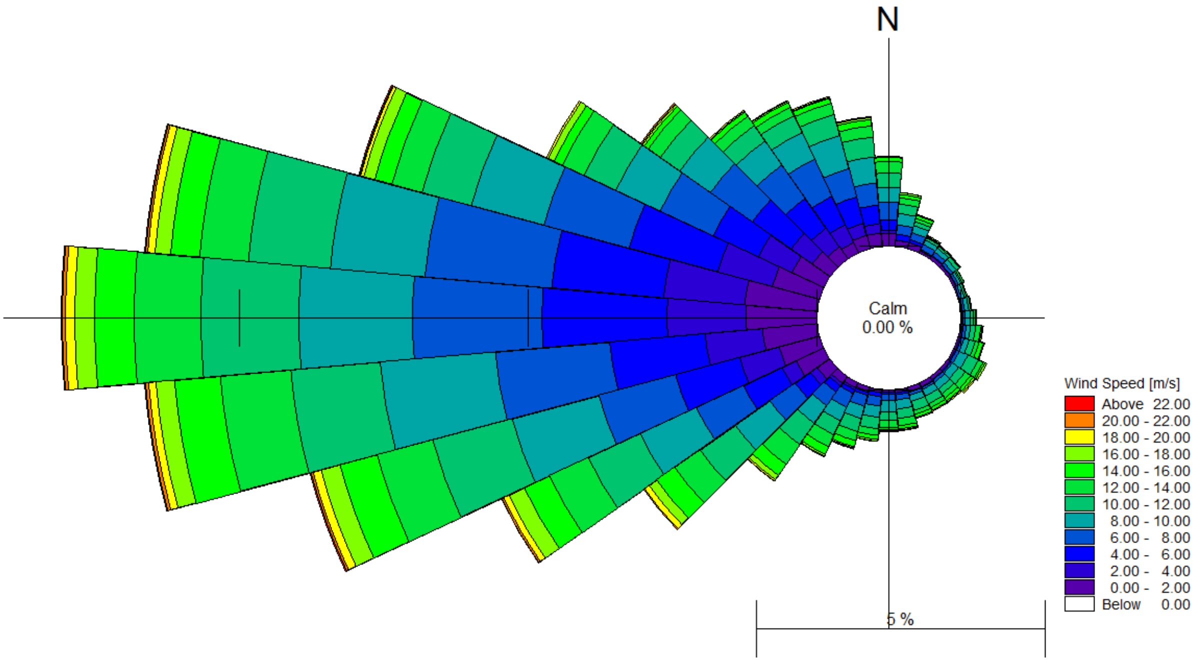

Figure 4.3: Wind rose at the offshore point (56°N, 8°W) for the 20 year period between 1996 and 2018

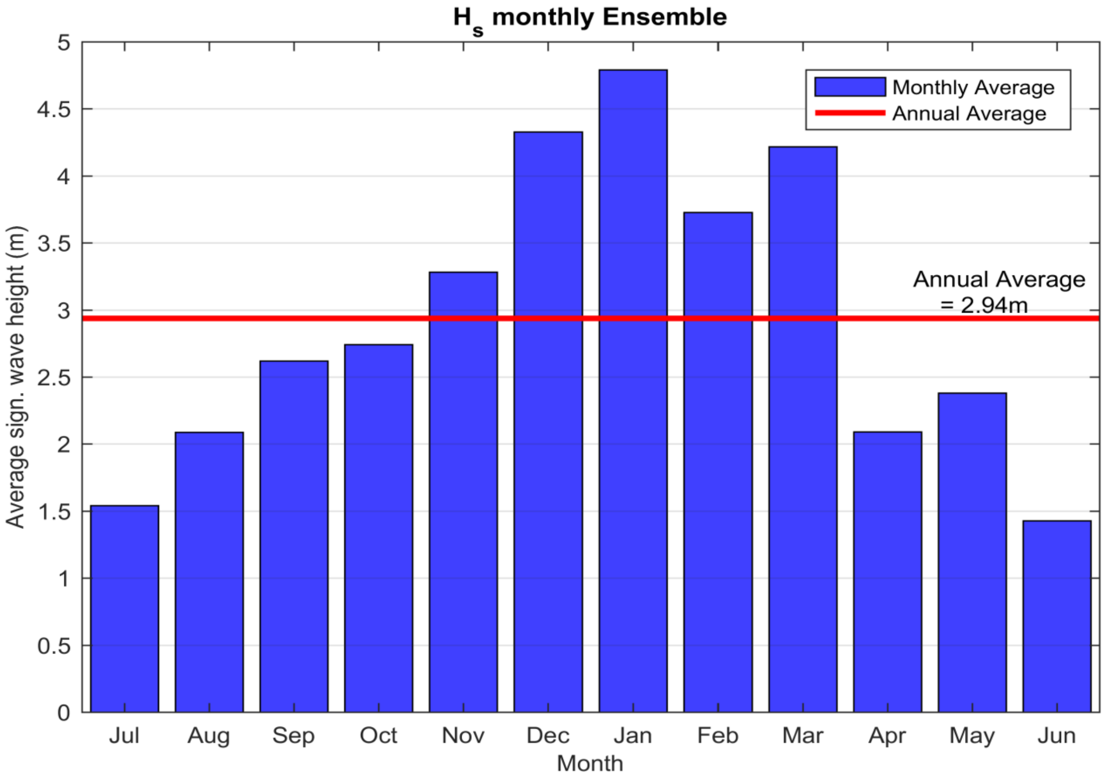

Figure 4.4: Annual and monthly average offshore significant wave heights for the offshore point at (56°N, 8°W) between 1996 and 2018

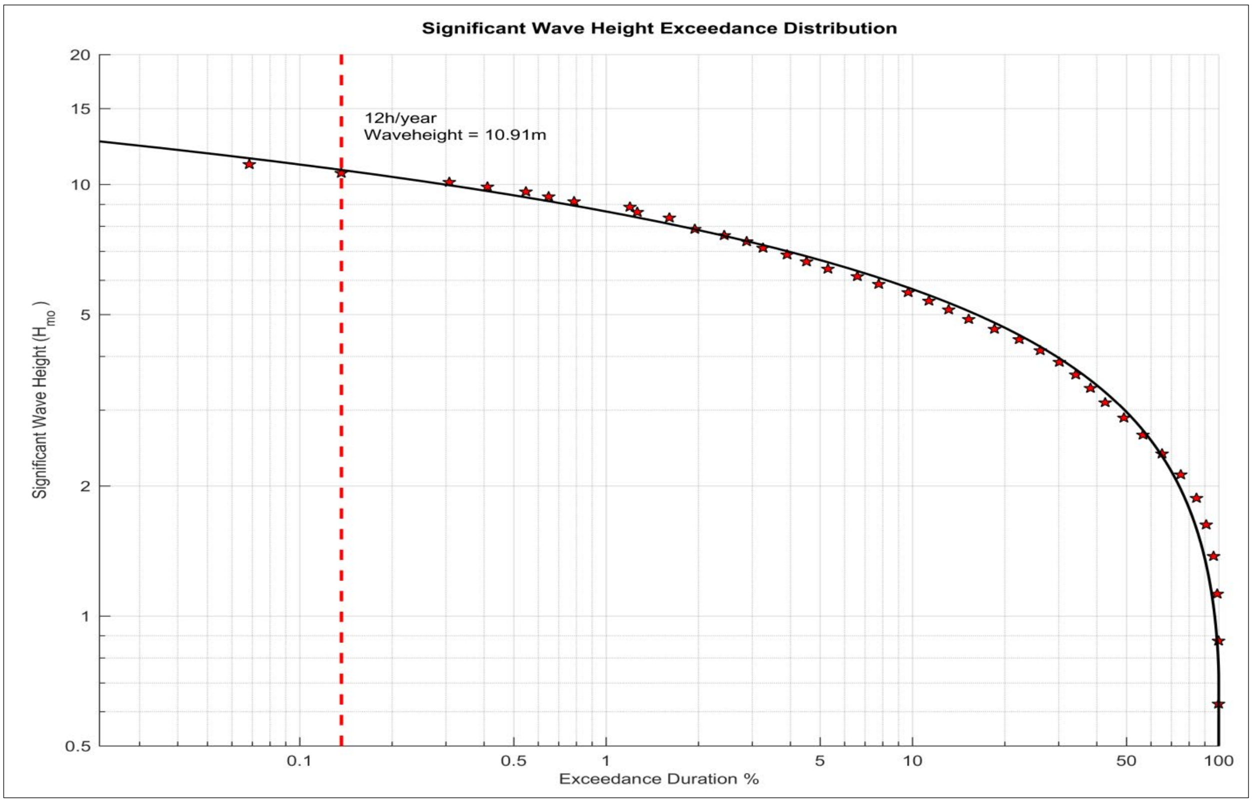

Figure 4.5: Significant wave height exceedance curve for the offshore point at (56°N, 8°W) between 1996 and 2018

4.2.1 Extreme Value Analysis (EVA)

An Extreme Event Analysis (EVA) of the ECMWF data was undertaken using the MIKE Zero EVA Editor toolbox. Due to the exposure of the study area to westerly and northerly waves, the dataset was divided into 30° sectors for analysis ensuring sufficient data points were in each sector to provide a robust statistical analysis.

The EVA was conducted by fitting a range of theoretical probability distributions to the 3-hourly ECMWF dataset. A partial duration series, also known as a peak over threshold model was used to select the largest events that occurred within each sector of the dataset.

In most cases a Weibull probability distribution provided a satisfactory fit to the dataset. Nonetheless a sensitivity study was conducted which applied a Truncated Gumbel and Generalised Pareto probability distribution however these did not significantly improve the fit provided by the Weibull distribution. In all cases a Maximum Likelihood estimation method was applied with all data fitted using a Monte Carlo simulation technique. This assessment was used to determine a series of significant wave heights at a range of return periods for each sector.

An example of an EVA analysis for offshore significant waves originating from 255°-285° is shown in Figure 4.6 below. It can be seen from this figure that a 1% AEP storm event (1 in 100 year return period) would produce an offshore significant wave height of *c.* 16.4m.

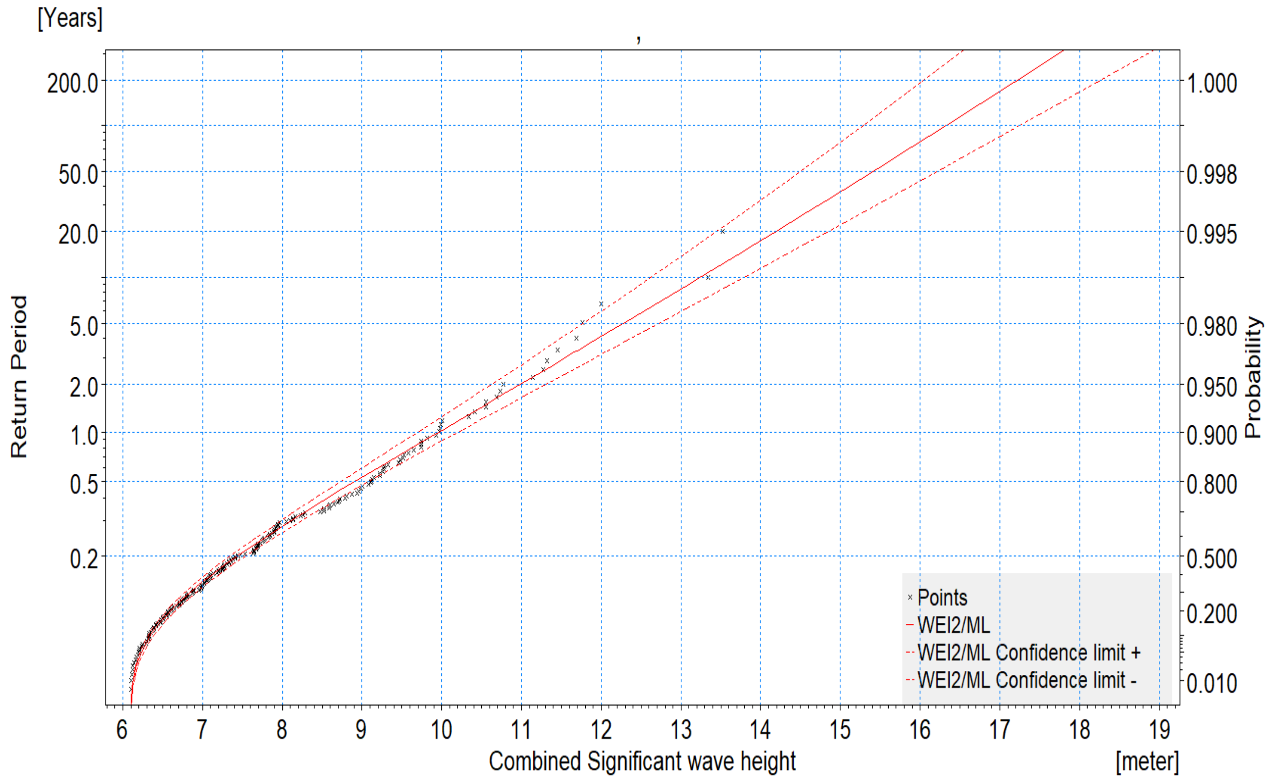

Figure 4.6 - Extreme Value Analysis of offshore significant wave heights at 255° - 285° (west)

An EVA was conducted on both significant wave heights and wind velocities and the results for various return periods across the relevant sectors are presented in Table 4.3 and Table 4.4 respectively.

Table 4.3: Extreme significant wave heights at various AEPs and directions

AEP [%]	Significant Wave Height [m]				
	255 – 285° West	285 – 315° NWW	315 – 345° WNW	345 – 015° North	015 – 045° NNE
50	10.91	9.8	7.3	6.01	3.79
20	12.19	11.37	8.6	7.15	4.59
10	13.16	12.55	9.57	8.02	5.19
5	14.12	13.74	10.55	8.89	5.79
2	15.39	15.29	11.85	10.04	6.58
1	16.35	16.48	12.82	10.9	7.18
0.5	17.31	17.66	13.8	11.76	7.78

Table 4.4: Extreme wind velocities at various return periods and directions

AEP [%]	Wind Velocity [m/s]				
	255 – 285° West	285 – 315° NWW	315 – 345° WNW	345 – 015° North	015 – 045° NNE
50	26.61	24.92	21.34	19.91	19.73
20	28.98	27.58	23.49	21.92	22.18
10	30.77	29.6	25.1	23.44	24.01
5	32.56	31.61	26.72	24.94	25.83
2	34.91	34.26	28.84	26.93	28.23
1	36.7	36.27	30.45	28.44	30.05
0.5	38.48	38.27	32.05	29.94	31.86

4.2.2 Joint Probability Analysis

As the wave heights that approach any shoreline are strongly influenced by the prevailing water level, a Joint Probability Analysis (JPA) between water levels and waves/wind was conducted. This analysis considered offshore wave height and sea level as well as wind velocities and sea level for different sectors. The JPA was conducted using the methodologies set out in the guidance produced by the Department for Environment, Food and Rural Affairs (DEFRA, 2005) and EA as documented in report FD2308 'Joint Probability: Dependence Mapping and Best Practice'.

The Joint Exceedance Curves for extreme waves & water levels and extreme wind velocities and & water levels for the westerly sector are shown in Figure 4.7and Figure 4.8 overleaf. The output data for these joint exceedance curves have been presented in in Table 4.5 and Table 4.6.

Table 4.5: Results of the joint probability analysis of extreme sea level and significant wave height for wave directions 255° to 285° (West)

Water Level [m]	Significant Wave Height [m] & Joint AEP [%.]						
	50	2	10	5	2	1	0.5
1.94	9.80	11.37	12.55	13.74	15.29	16.48	17.66
2.05	9.26	11.37	12.55	13.74	15.29	16.48	17.66
2.16	7.70	9.85	11.49	13.13	15.28	16.48	17.66
2.26	6.52	8.68	10.31	11.94	14.11	15.74	17.37
2.36	5.34	7.50	9.13	10.76	12.92	14.56	16.19
2.49	3.79	5.93	7.57	9.20	11.36	13.00	14.63
2.58	2.62	4.76	6.39	8.02	10.17	11.81	13.45
2.68	1.45	3.59	5.21	6.84	9.00	10.63	12.26
2.82	-	2.04	3.66	5.28	7.44	9.07	10.70
2.93	-	-	2.49	4.11	6.25	7.89	9.52
3.03	-	-	-	2.94	5.08	6.71	8.34
3.17	-	-	-	-	3.53	5.15	6.78
3.27	-	-	-	-	-	3.98	5.60
3.37	-	-	-	-	-	-	4.43

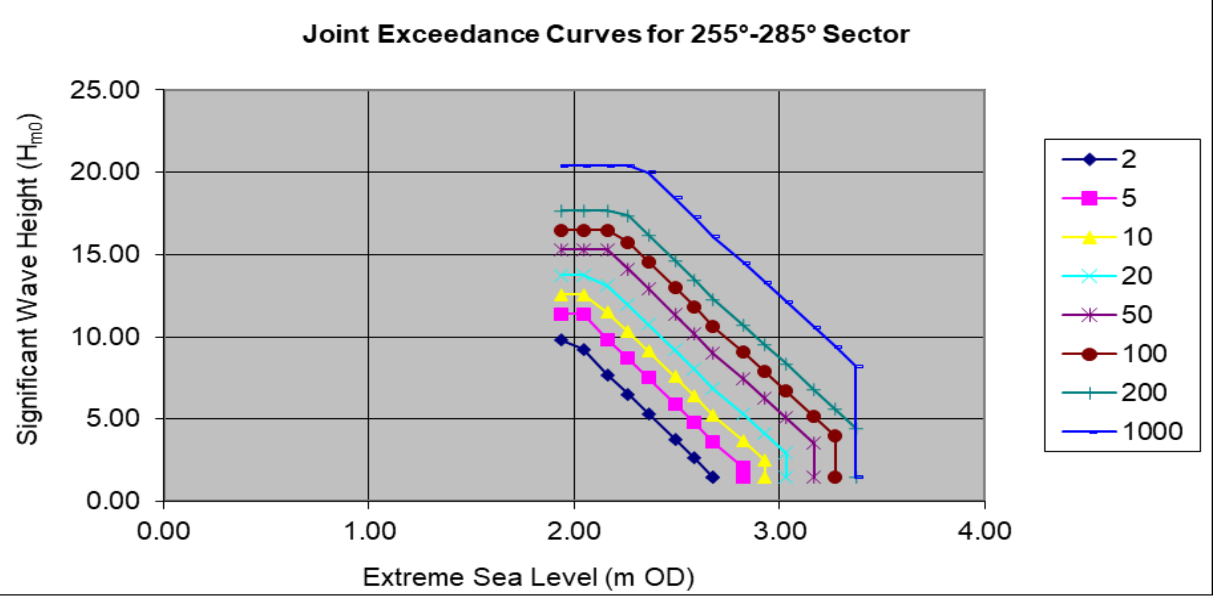

Figure 4.7: Joint exceedance curves for the extreme sea levels and significant wave height for wave directions 255° to 285° (West)

Table 4.6: Results of the joint probability analysis of extreme sea level and wind velocities for wind directions 255° to 285° (West)

Water Level [m]	Wind Velocity [m/s] & Joint AEP [%]						
	50	20	10	5	2	1	0.5
1.94	18.92	22.04	24.01	25.83	28.23	30.05	31.86
2.05	17.13	20.19	22.58	24.95	28.06	30.05	31.86
2.16	14.69	17.84	20.14	22.54	25.66	28.01	30.37
2.26	12.89	16.01	18.37	20.69	23.84	26.20	28.55
2.36	11.14	14.16	16.55	18.88	22.01	24.38	26.73
2.49	8.82	11.82	14.11	16.51	19.57	21.96	24.33
2.58	7.07	10.07	12.34	14.66	17.81	20.11	22.50
2.68	5.32	8.32	10.59	12.85	15.98	18.34	20.65
2.82	-	6.01	8.27	10.54	13.54	15.93	18.29
2.93	-	-	6.52	8.79	11.79	14.08	16.47
3.03	-	-	-	7.04	10.04	12.31	14.62
3.17	-	-	-	-	7.72	9.99	12.26
3.27	-	-	-	-	-	8.24	10.51
3.37	-	-	-	-	-	-	8.76

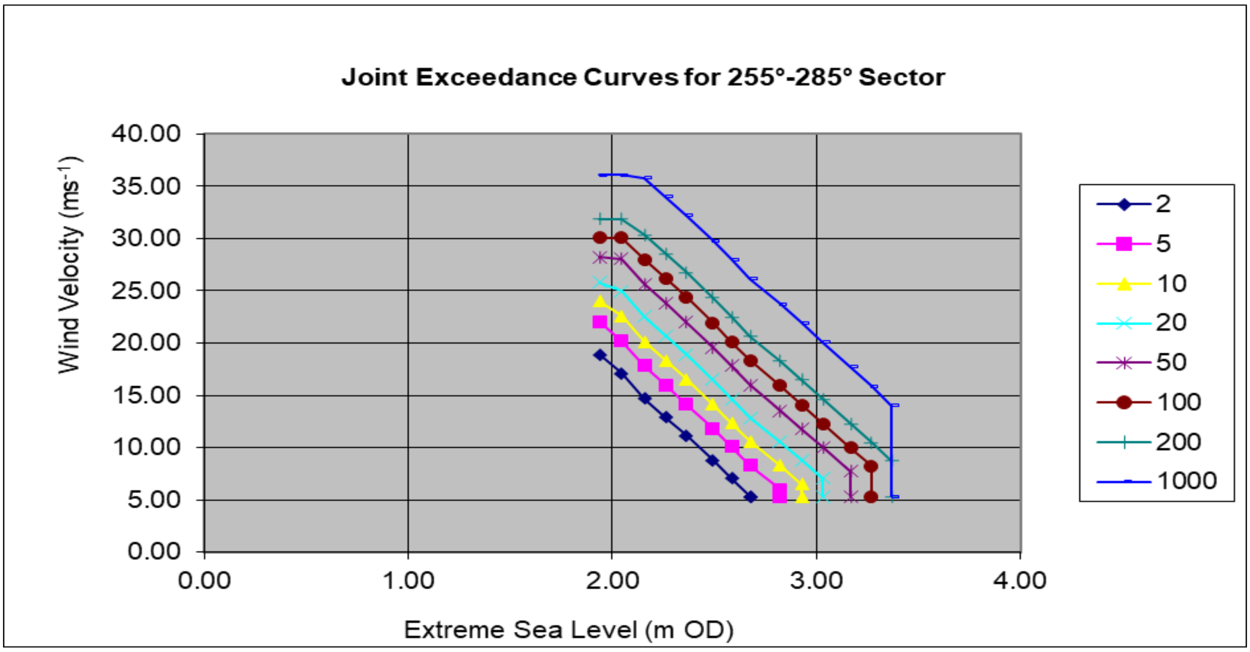

Figure 4.8: Joint exceedance curves for the extreme sea levels and significant wave height for wave directions 255° to 285° (West)

5 HYDRAULIC MODELS

5.1 General

The assessment of the coastal processes across the study area was undertaken using RPS' in-house suite of MIKE coastal process modelling software. The MIKE software developed by DHI, Denmark is recognised worldwide as state of the art software for the simulation of coastal processes. The coupled flow, wave and sediment transport models were utilised to describe the coastal processes at the study site. The MIKE 21 Coupled Flexible Mesh (FM) model is a dynamic modelling system for application within coastal and estuarine environments.

The Hydrodynamic Module and the Spectral Wave Module are the basic computational components of the modelling system. Using the MIKE 21 Coupled FM model it is possible to simulate the interaction between waves and currents using dynamic coupling between the Hydrodynamic Module and the Spectral Wave Module.

5.1.1 Hydrodynamic module

The Hydrodynamic Module is the basic computational component of the entire MIKE 21 FM modelling system providing the hydrodynamic basis for the Transport Module, ECO Lab Module, Mud Transport Module, Sand Transport Module and Particle Tracking Module.

The modelling system is based on the numerical solution of the two-dimensional shallow water equations - the depth-integrated incompressible Reynolds averaged Navier-Stokes equations. Thus, the model consists of continuity, momentum, temperature, salinity and density equations. In the horizontal domain both Cartesian and spherical coordinates can be used.

The spatial discretisation of the primitive equations is performed using a cell-centred finite volume method. The spatial domain is discretised by subdivision of the continuum into non-overlapping element/cells. In the horizontal plane an unstructured grid comprising of triangles or quadrilateral elements is used. An approximate Riemann solver is used for computation of the convective fluxes, which makes it possible to handle discontinuous solutions. For the time integration, an explicit scheme is used

5.1.2 Spectral wave module

The Spectral Wave Module, MIKE 21 SW, simulates the growth, decay and transformation of wind-generated waves and swell in offshore and coastal areas. The discretisation of the governing equation in geographical and spectral space is performed using a cell-centred finite volume method. In the geographical domain, an unstructured mesh technique is used. The time integration is performed using a fractional step approach where a multi-sequence explicit method is applied for the propagation of wave action.

5.2 Model bathymetry and structure

The analysis required the topography and bathymetry of the study area to be included in the model. RPS therefore utilised their existing bathymetric dataset as used for the Irish Coastal Waters Storm Surge Model which was developed using flexible mesh technology with mesh size (model resolution) varying from c. 24km along the offshore Atlantic boundary to c. 200m around the Irish coastline and supplemented this with the inshore survey data explicitly collected for this study. The extent and bathymetry of this model is presented in Figure 5.1. This model incorporates bathymetric data from the Irish National Seabed survey (INSS), INFORMAR and other local bathymetric surveys collated by RPS for the Irish Coastal Protection Strategy Study (ICPSS).

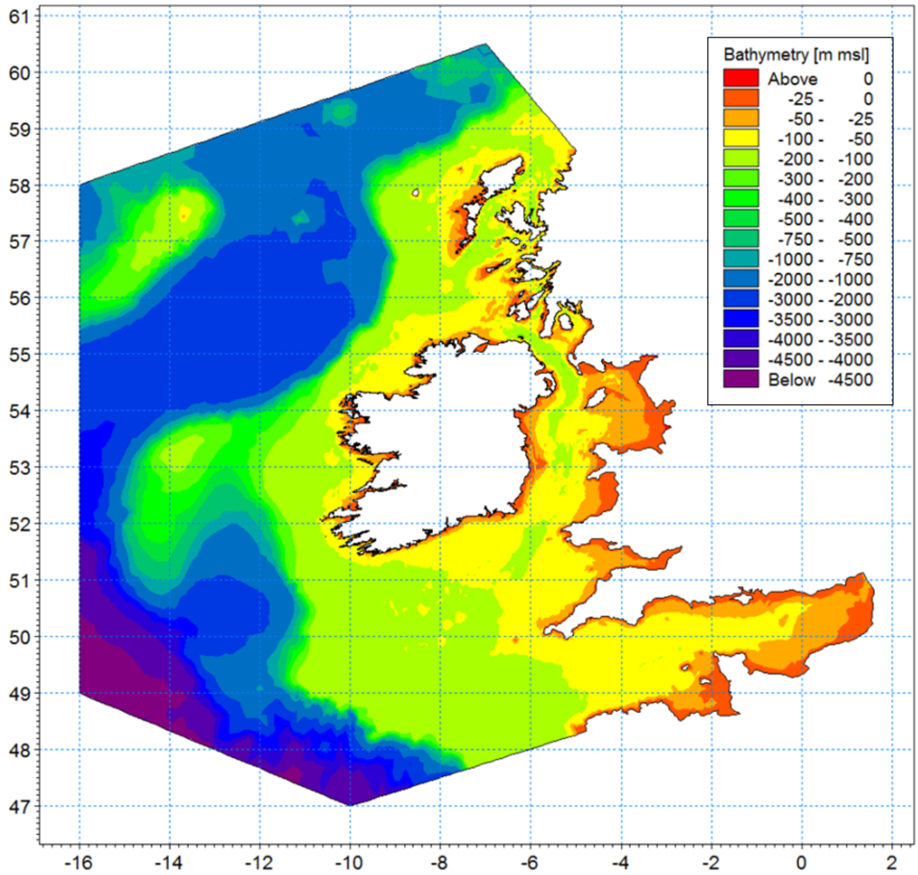

Figure 5.1: Extent and bathymetry of Irish Coastal Waters Storm Surge model.

Data from the ICPSS model was used to provide the boundary conditions for a finer tidal model of the study area. This model was also constructed using flexible mesh technology with the mesh size varying from c. 2-3km at the boundaries to 10m around the coastline.

Bathymetry data from RPS' Irish Coastal Protection Strategy Study (ICPSS), the national CFRAM programme and the European Funded INFOMAR project was available from the outset of this study. Data gaps were filled using additional survey data which was collected and supplied by Murphy Surveys Ltd. Flexible mesh technology was implemented with the mesh size (model resolution) varying from c. 2-3km along the offshore Atlantic boundary to c. 10m around the coastline, particularly south of Five Finger Strand where there is a narrow channel. The overall extent and bathymetry of the model is shown in Figure 5.2. The bathymetry in the study area can be seen in Figure 5.3.

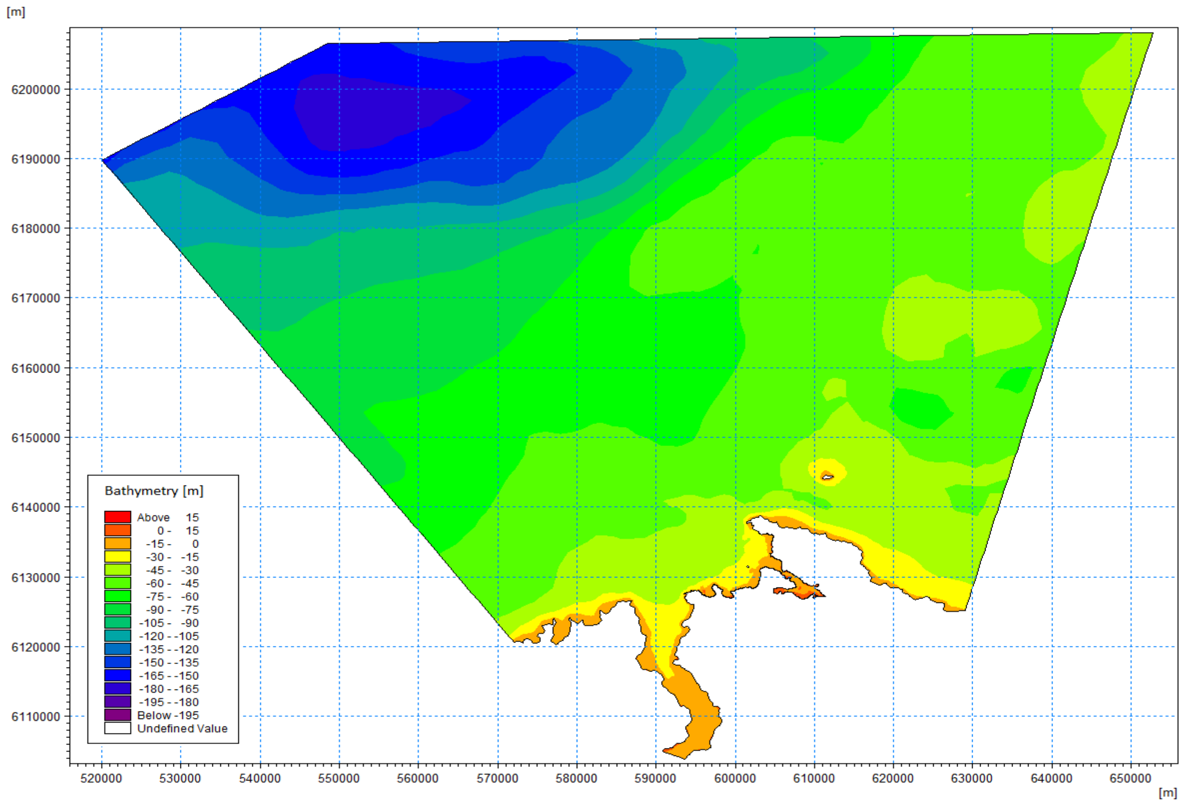

Figure 5.2: Extent and bathymetry of the north Donegal model

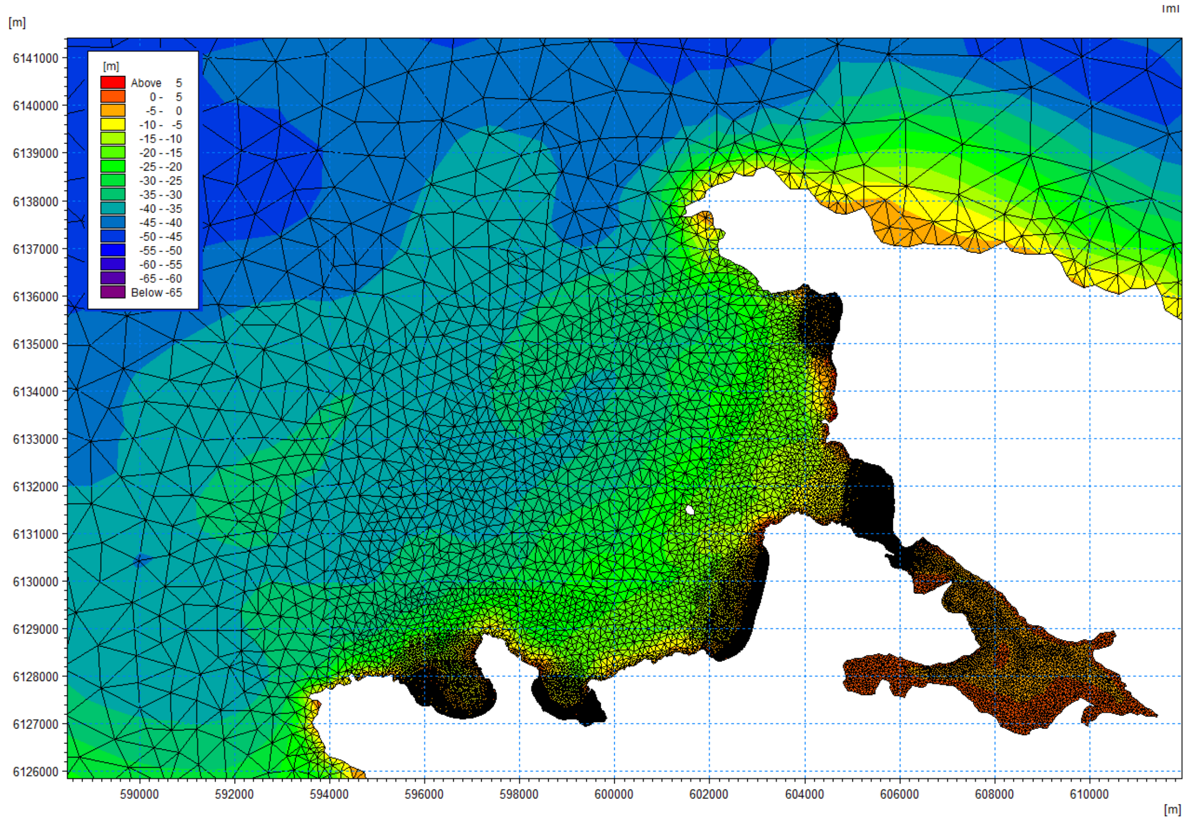

Figure 5.3: Mesh structure and bathymetry of the Donegal model in the region of the five study areas

6 COASTAL PROCESS MODELLING

6.1 Tidal regime

The Hydrodynamic Module, described in Section 5 simulates water level variations and flows in response to a variety of forcing functions in lakes, estuaries and coastal regions.

The tidal regime simulated by the MIKE 21 model is presented in the form of typical spring flow patterns at mid-flood, high water, mid-ebb and low water in Figure 6.2 to Figure 6.5 respectively. The length and direction of the vectors displayed on each of the figures are proportional to the magnitude of the current velocity at each nodal point in the grid.

As can be seen from the figures, the tidal current speeds across most of the study sites excluding Lagg beach tend to be less than 0.1m/s at all phases of a typical spring tidal cycle. Current speeds of this magnitude would not be sufficient to transport significant volumes of sediment at Rockstown Harbour, Tullagh Bay, Pollan Strand or Binbane. Sediment transport in these areas would therefore rely primarily on wave induced sediment transport (i.e. littoral currents).

The tidal regime in the area of Lagg beach and the tidal inlet to Trawbreaga Bay is much more complex. It can be seen from Figure 6.2 to Figure 6.5 that current speeds can regularly exceed 1.0m/s at the tidal inlet and along Lagg beach. Current speeds of this magnitude could potentially mobilise sediment on the seabed and facilitate high rates of sediment transport.

The narrow tidal inlet at Lagg Point causes faster currents and larger tidal energy flux at the entrance to the Trawbreaga Bay channel while reducing the tidal amplitude within the estuary. This phenomenon known as tidal choking also results in a notable phase difference between tides outside and inside of the Bay as shown in Figure 6.1. These factors could result in a gradual increase in bed levels within Trawbreaga Bay due to the asymmetric transport of suspended bed material. Tidal choking is not as prominent during neap tides. Furthermore, it will be seen from that Figure 6.1 that the tidal range observed inside of Trawbreaga Bay is similar to the tidal range reported in Table 4.2 but larger outside of the Bay. This is due to the tidal choking which limits exchange of water and thus surface elevation within the Bay.

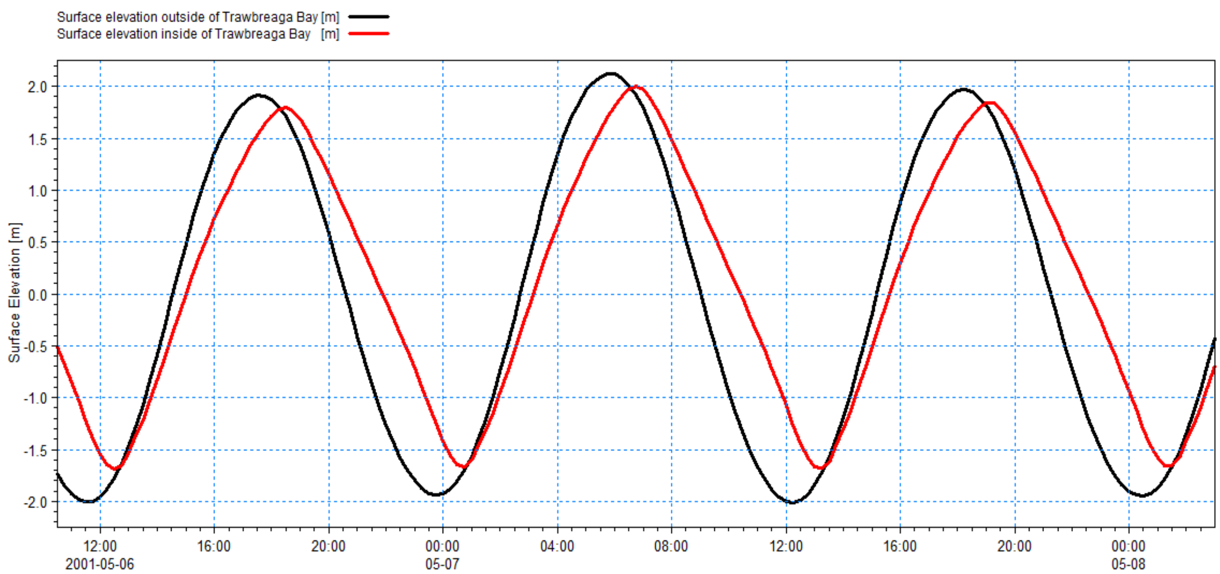

Figure 6.1: Phase difference in tides inside and outside of Trawbreaga Bay as a result of tidal choking at Lagg point

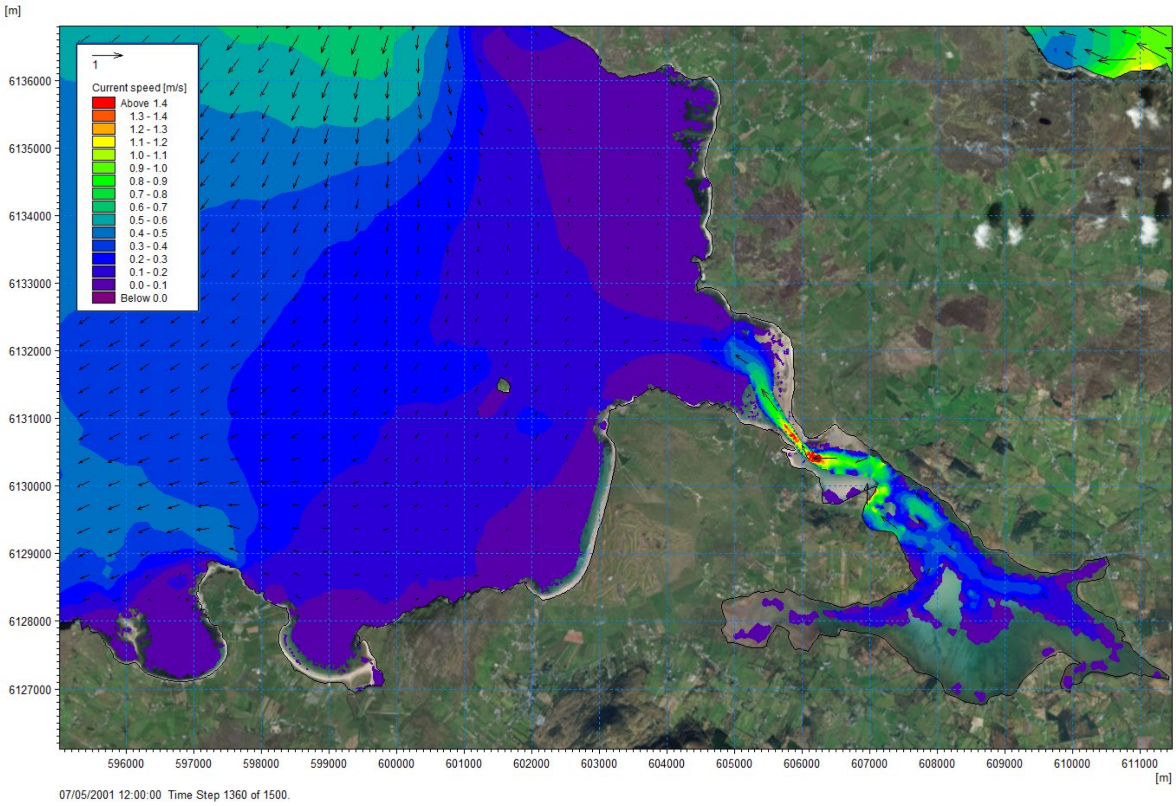

Figure 6.2 – Tidal regime in the study area during a typical spring, mid flood tidal cycle

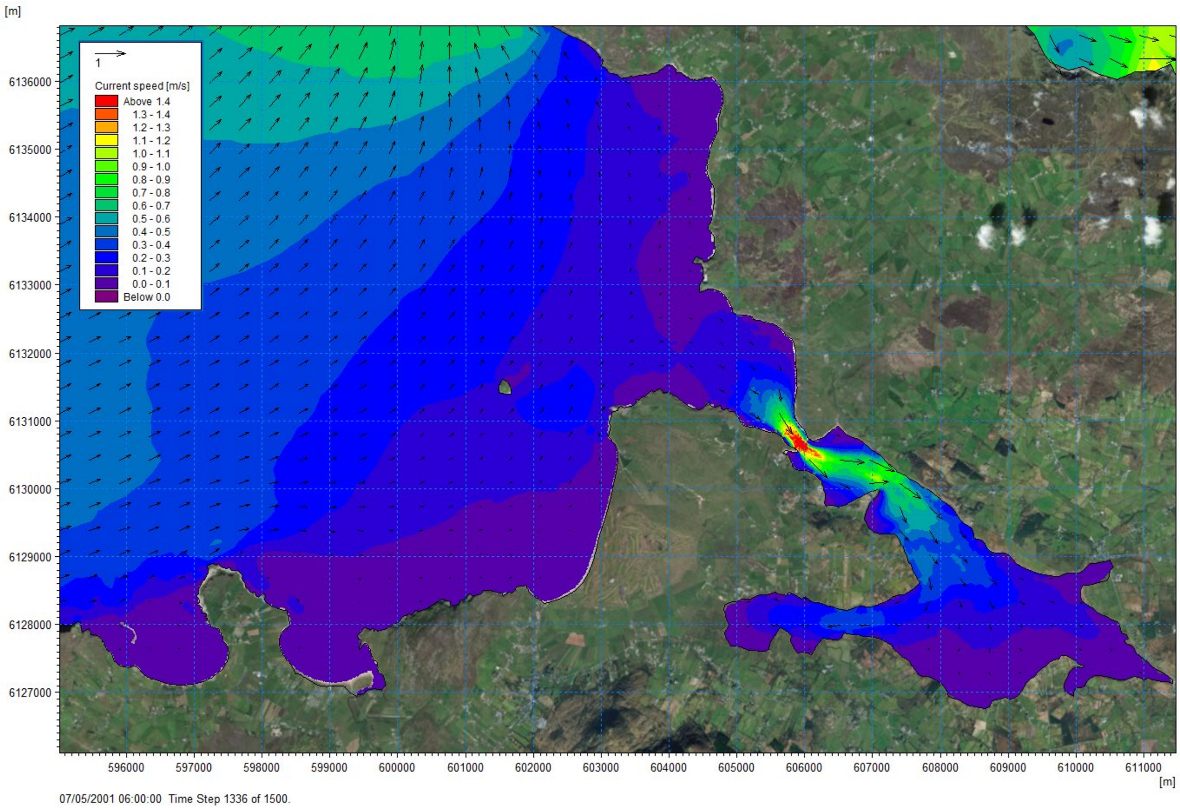

Figure 6.3 - Tidal regime in the study area during a typical spring, high water tidal cycle

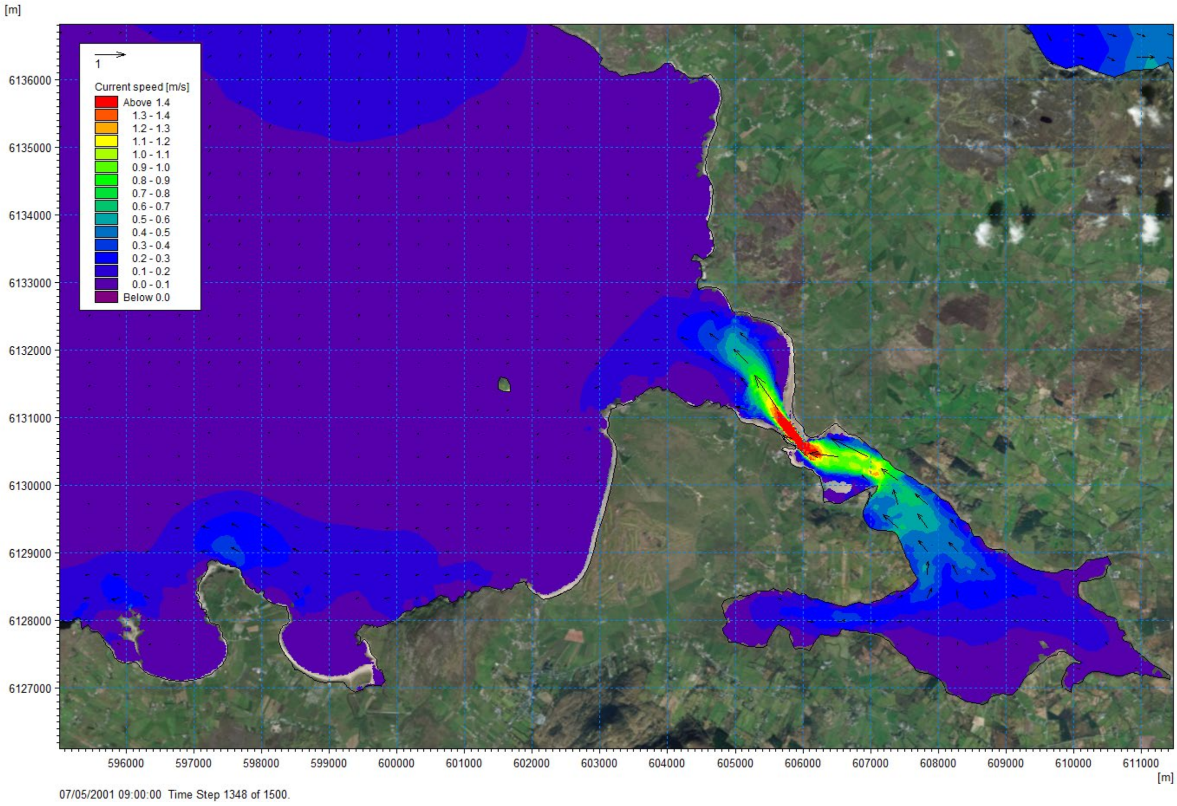

Figure 6.4 - Tidal regime in the study area during a typical spring, mid ebb tidal cycle

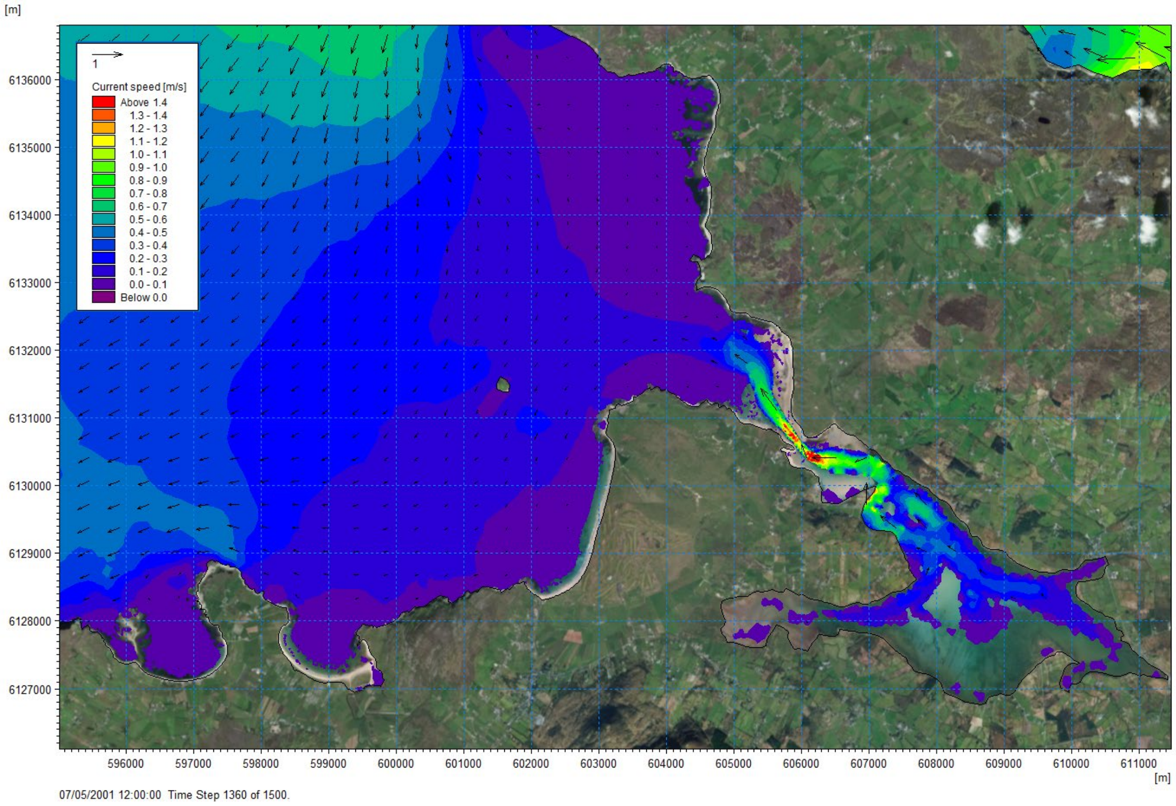

Figure 6.5 - Tidal regime in the study area during a typical spring, low water tidal cycle

6.2 Inshore wave climate

The inshore wave climate across the five study areas was established by transforming the offshore data for 1996-2018 inshore using the MIKE 21 Spectral Wave (SW) model. Figure 6.6 below illustrates the nearshore wave roses at the five locations of interest. It should be noted that for the purposes of this assessment significant wave heights measuring less than 1m were deemed as calm and were omitted from the wave roses.

It is evident from Figure 6.6 that although the offshore waves are predominately westerly, the inshore wave directions range from westerly to northerly with the majority of locations within the study area experiencing north-westerly wave conditions. It was found that the significant wave height of over 70% of the waves at Tullagh Bay between 1996 and 2018 were less than 1m owing to the orientation of the bay to the offshore wave direction.

A more detailed assessment of the long-term inshore wave climates at each of the study areas is presented in the following Sections of this report. RPS also transformed a series of extreme offshore wave events into the study areas to assess inshore wave conditions during various return period events. An initial assessment of the wave climate found that the largest, most energetic waves approached Rockstown Harbour and Tullagh Bay from the North West whilst the most arduous wave conditions were observed at the remaining three sites during events from the west. Based on this information RPS simulated up to 14 different combinations of offshore waves and wind from the north westerly and westerly sectors with corresponding water levels to derive the inshore wave climate at each of the study sites under 1 in 1 up to 1 in 200 year return period storm conditions

For the purposes of brevity, RPS have only presented the inshore wave climates for 1 in 1, 1 in 50 and 1 in 200 year return period storm conditions from the west in the following Sections of this report.

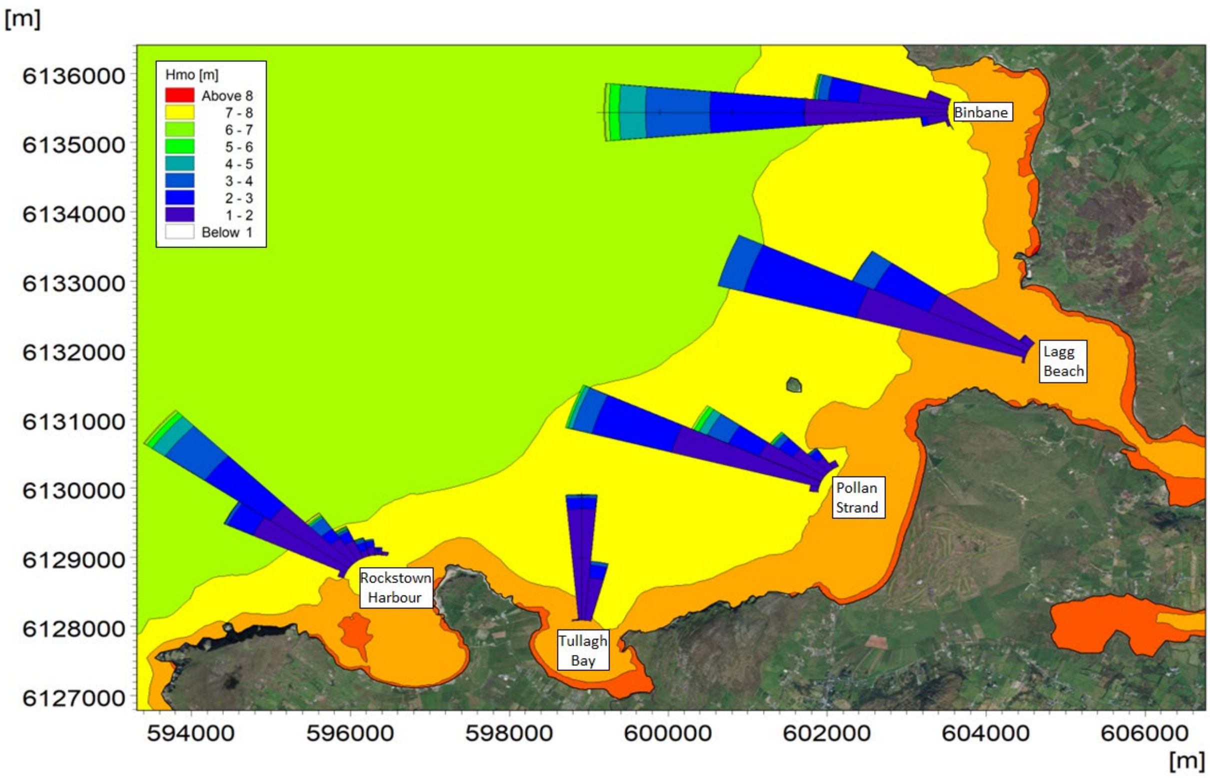

Figure 6.6: The nearshore wave climate at each location between 1996 and 2018

6.2.1 Rockstown Harbour and Tullagh Bay

The annual average nearshore significant wave heights at Rockstown Harbour and Tullagh Bay between 1996 and 2018 were found to be 1.74m and 0.76m respectively. The annual average significant wave height at Tullagh Bay was notably smaller owing to the sheltered orientation of the bay. At both sites the monthly average significant wave heights were largest during the winter months between November and March. The annual and monthly average significant wave heights at Rockstown Harbour and Tullagh Bay are illustrated in Figure 6.8 and Figure 6.10 respectively.

The probability exceedance curve for nearshore significant wave heights at Rockstown Harbour and Tullagh Bay between 1996 and 2018 are presented in Figure 6.9 and Figure 6.11. Based on this information it can be seen that on average, the offshore significant wave heights could reach *c.* 7.59m and 3.94m for 12 hours of any given year at Rockstown Harbour and Tullagh Bay respectively.

The inshore wave climates during 0.5%, 2% and 50% AEP storm conditions are presented in Figure 6.12 to Figure 6.14 for Rockstown Harbour and Tullagh Bay. It will be seen from these figures that the inshore wave climates are highly modified by the horseshoe shape of the embayments and the numerous rocky outcrops that characterise both sites.

RPS extracted inshore wave climate information for both sites for three AEP events presented in this report; the location of these extraction points are illustrated in Figure 6.7. The inshore wave climate information is presented in Table 6.1 and Table 6.2 for Rockstown Harbour and Tullagh Bay respectively. It will be seen from these Tables that both sites experience very similar inshore wave conditions during all of the simulated extreme return period storm events. The inshore significant wave heights at both sites were generally less than 2.60m and 1.85m during 0.5% and 50% AEP storm conditions respectively

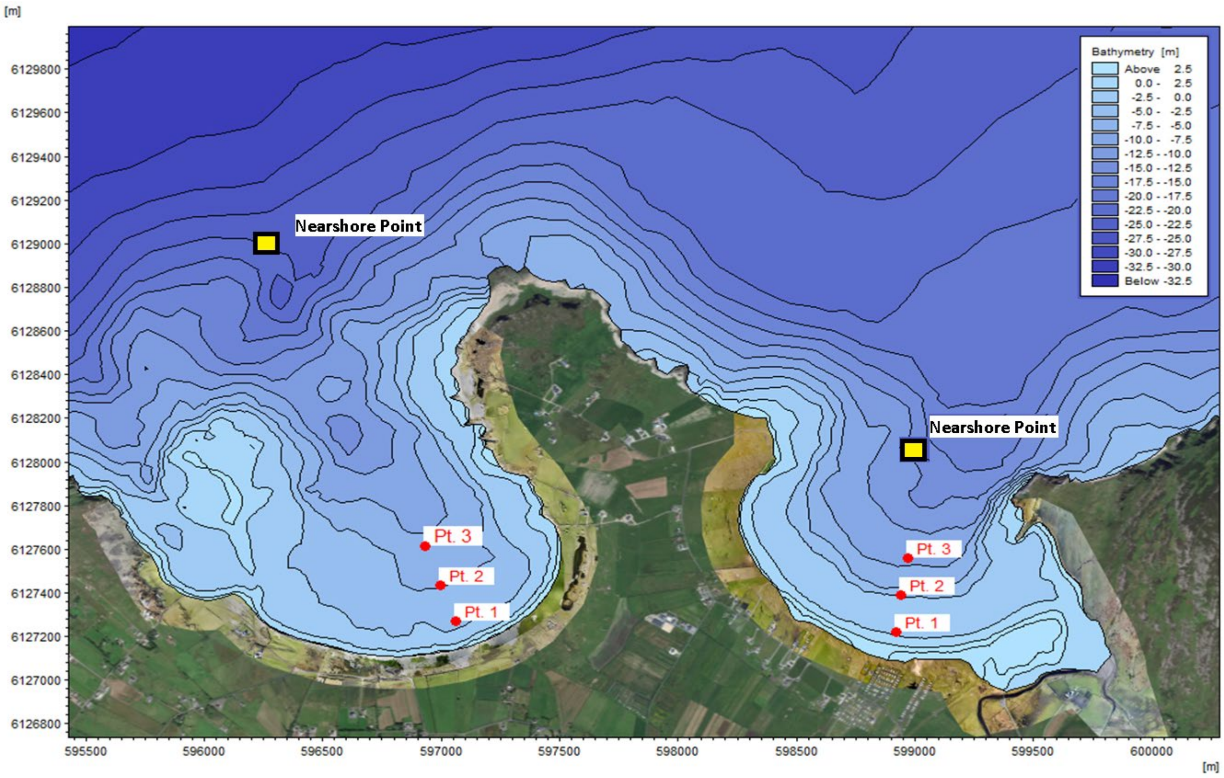

Figure 6.7: Location of inshore wave extraction points at Rockstown Harbour & Tullagh Bay

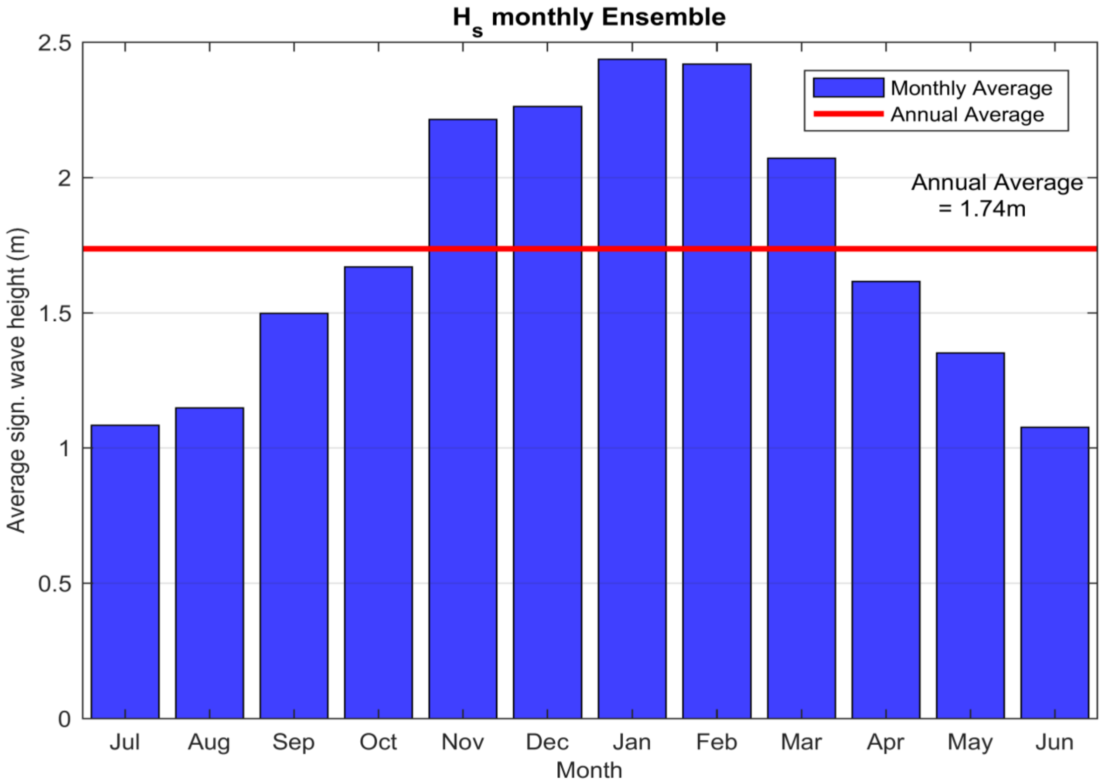

Figure 6.8: Annual and monthly average nearshore significant wave at Rockstown Harbour between 1996 and 2018

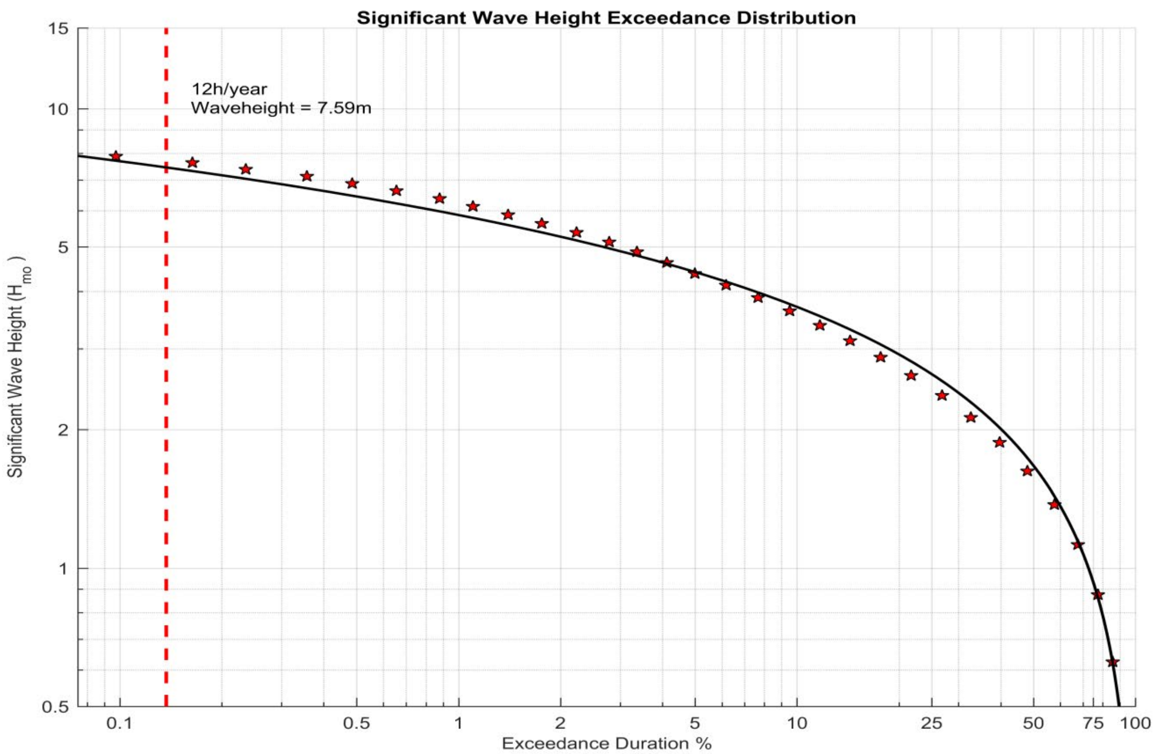

Figure 6.9: Nearshore significant wave height exceedance curve at Rockstown Harbour between 1996 and 2018

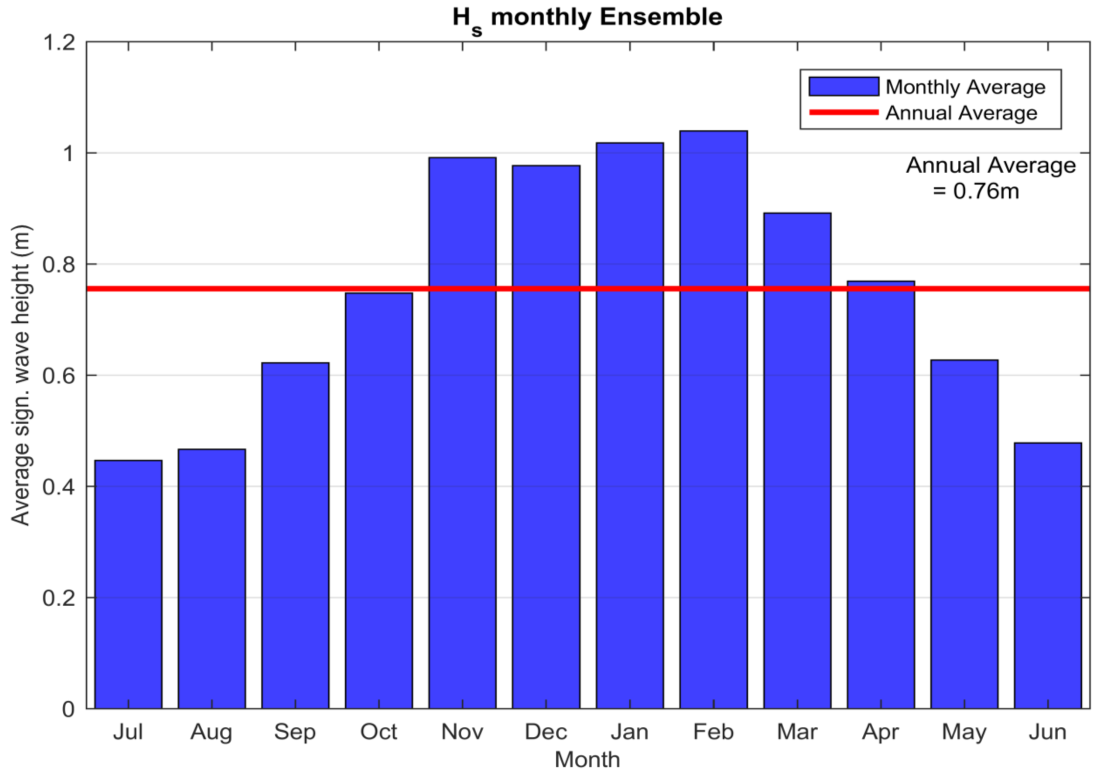

Figure 6.10: Annual and monthly average nearshore significant wave at Tullagh Bay between 1996 and 2018

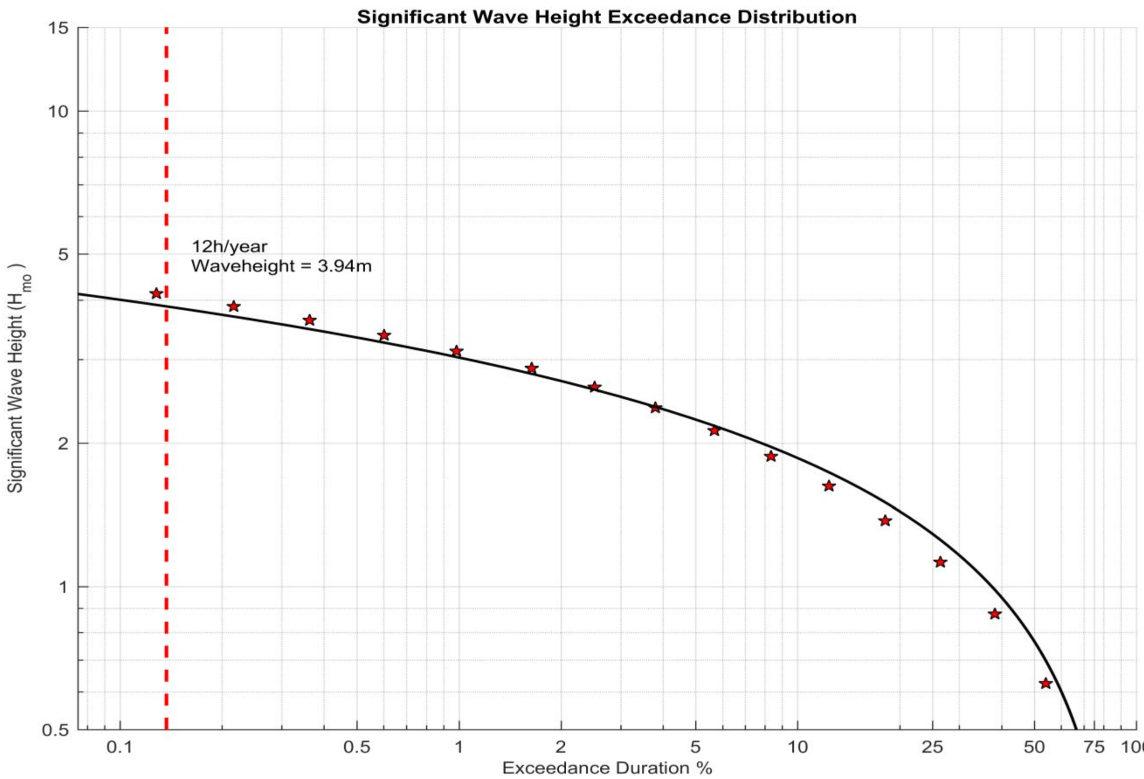

Figure 6.11: Nearshore significant wave height exceedance curve at Tullagh Bay between 1996 and 2018

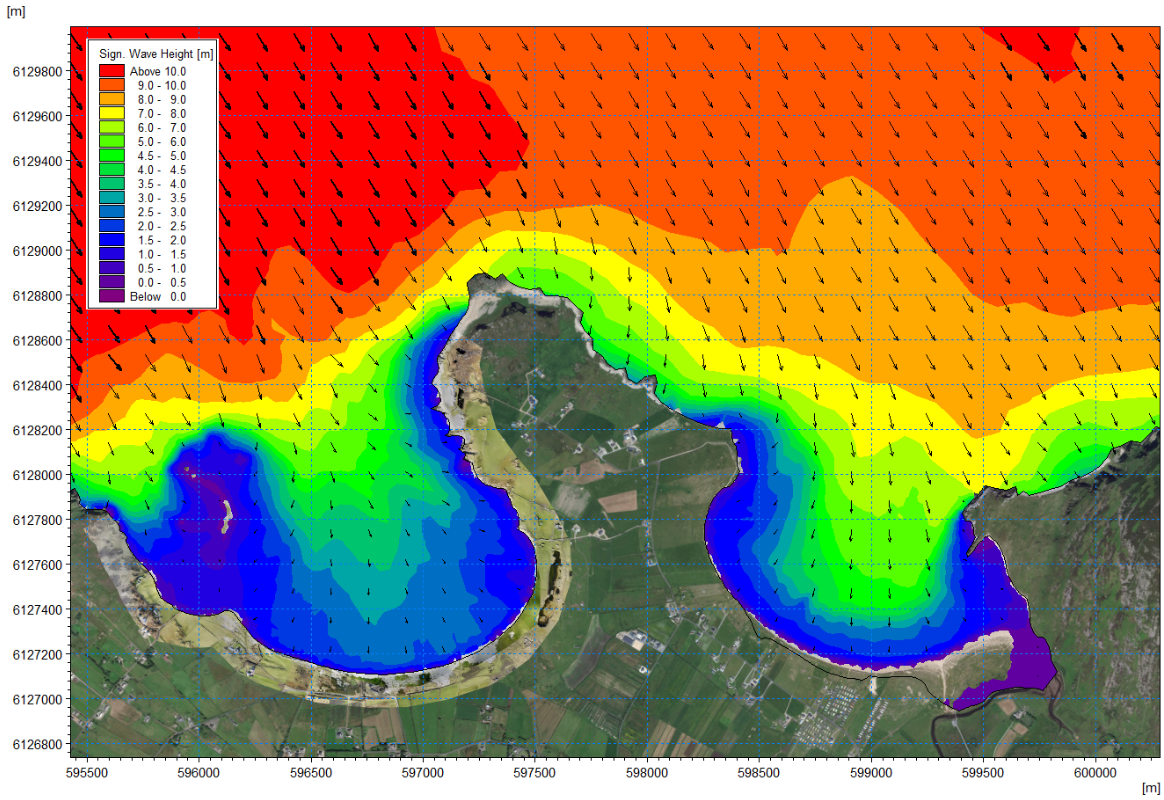

Figure 6.12: 0.5% AEP storm event from 330º – Rockstown Harbour & Tullagh Bay

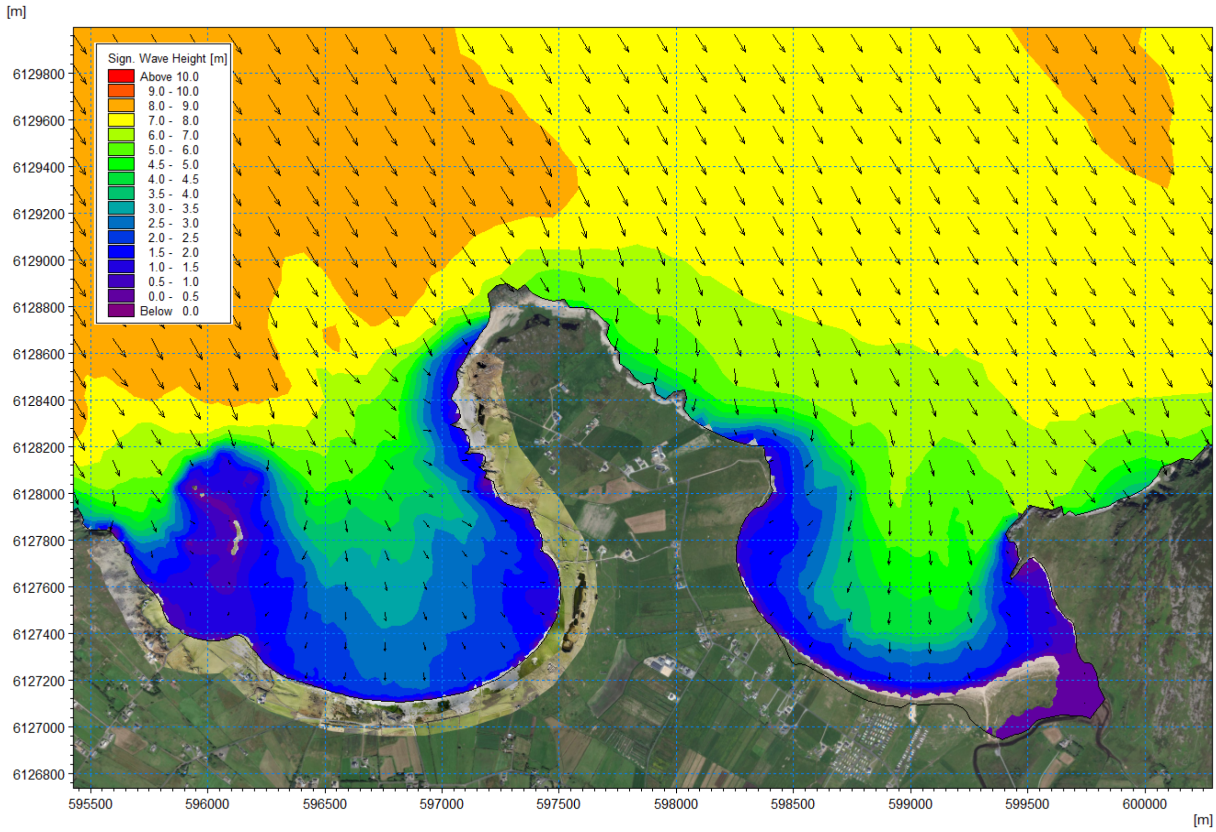

Figure 6.13: 2% AEP storm event from 330º – Rockstown Harbour & Tullagh Bay

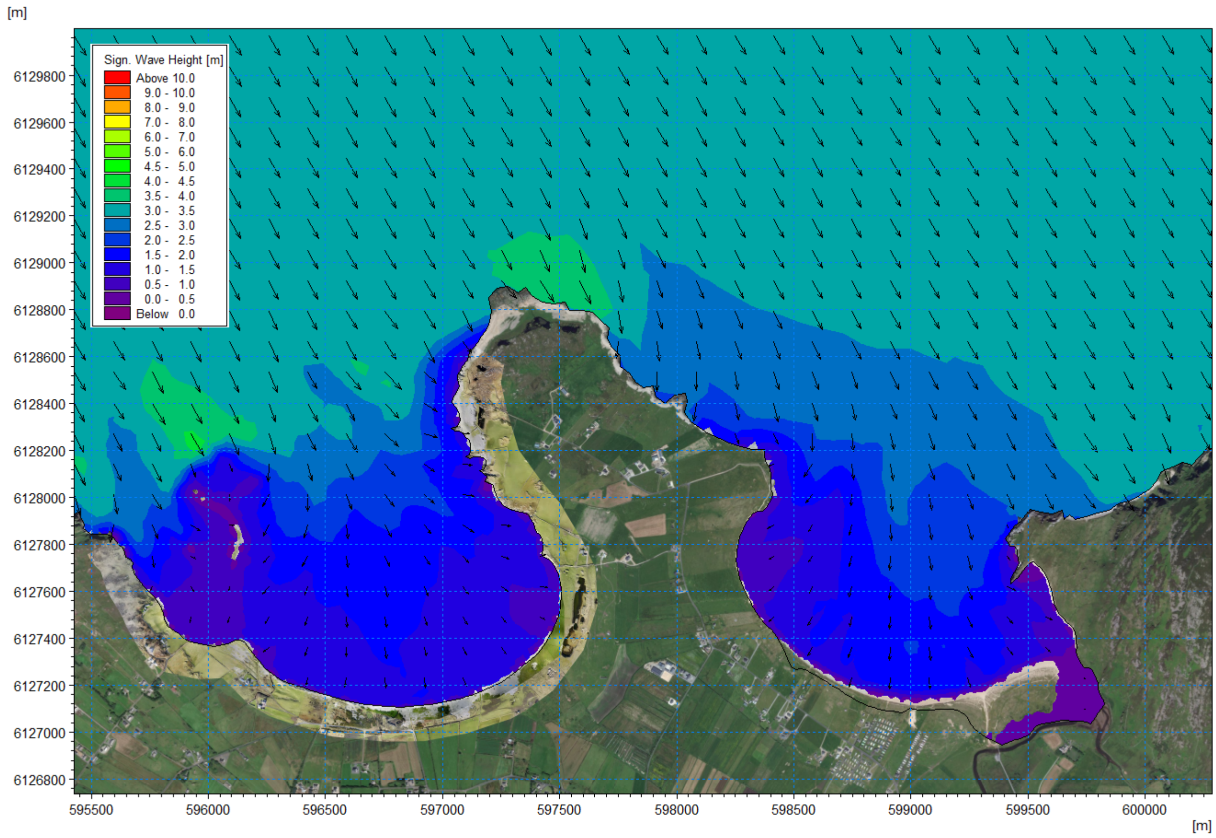

Figure 6.14: 50% AEP storm event from 330º – Rockstown Harbour & Tullagh Bay

Table 6.1: Summary of inshore wave conditions at Rockstown during various return period events

AEP [%]	Point	Significant Wave Height (Hs m)	Mean Wave Period (Tm_{01} s)	Wave Direction (°N)
50	1	1.79	8.64	338
	2	1.86	8.85	338
	3	2.14	9.04	337
2	1	2.48	10.19	338
	2	2.58	10.44	338
	3	3.00	10.69	337
0.5	1	2.60	10.57	338
	2	2.67	10.59	338
	3	3.15	11.09	337

Table 6.2: Summary of inshore wave conditions at Tullagh Bay during various return period events

AEP [%]	Point	Significant Wave Height (Hs m)	Mean Wave Period (Tm_{01} s)	Wave Direction (°N)
50	1	1.84	8.28	5
	2	2.73	8.87	3
	3	2.86	9.08	2
2	1	2.09	9.75	5
	2	3.69	10.40	3
	3	4.50	10.69	2
0.5	1	2.19	10.12	5
	2	3.89	10.77	3
	3	4.85	11.06	3

6.2.2 Pollan Strand

The annual average nearshore significant wave height at Pollan Strand between 1996 and 2018 was found to be 1.55m. As can be seen in Figure 6.16 the monthly average significant wave heights were much larger during the winter months between November and March.

The probability exceedance curve for nearshore significant wave heights at Pollan Strand between 1996 and 2018 is presented in Figure 6.17. Based on this information it can be seen that on average, the offshore significant wave heights could reach *c*. 6.38m for 12 hours of any given year at Pollan Strand.

The inshore wave climates at Pollan Strand during 0.5%, 2% and 50% AEP storm conditions are presented in Figure 6.18 to Figure 6.20. It will be seen from these figures that the waves propagating towards Pollan Strand gradually reduce in height as they begin to encounter shallow bathymetry and that the height of indecent waves remain relatively uniform along the entire length of Pollan Strand.

RPS extracted inshore wave climate information for the three return period events presented in this report; the location of these extraction points are illustrated in Figure 6.15. The corresponding inshore wave climate information for Pollan Strand is presented in Table 6.3. It will be seen from this Table that the inshore significant wave heights during 0.5% AEP and 50% AEP events are approximately 2.43m and 1.88m respectively. These results indicate that the inshore wave heights at Pollan Strand are governed primarily by prevailing water depth. As such, this site could experience a significant increase in wave energy under future climate change conditions whereby sea levels could rise by up to +1.0m under the High End Future Scenario (HEFS).

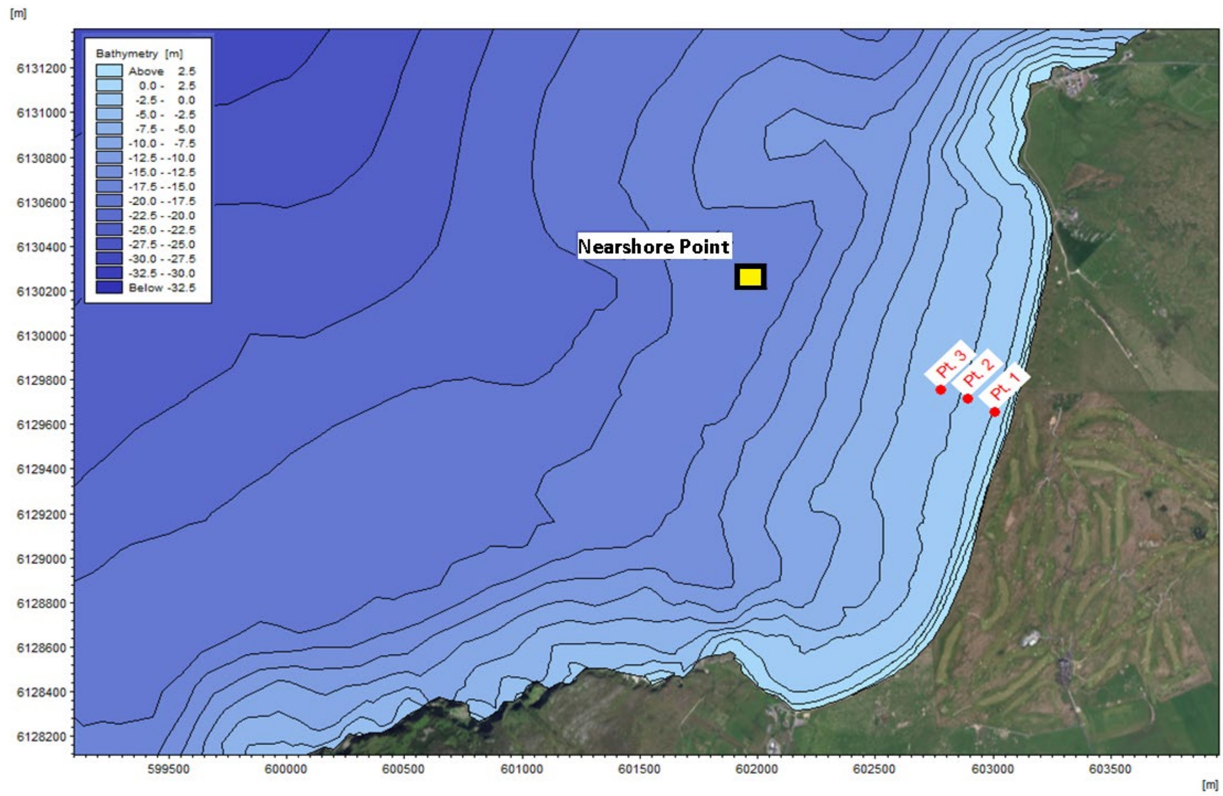

Figure 6.15: Location of inshore wave extraction points at Pollan Strand

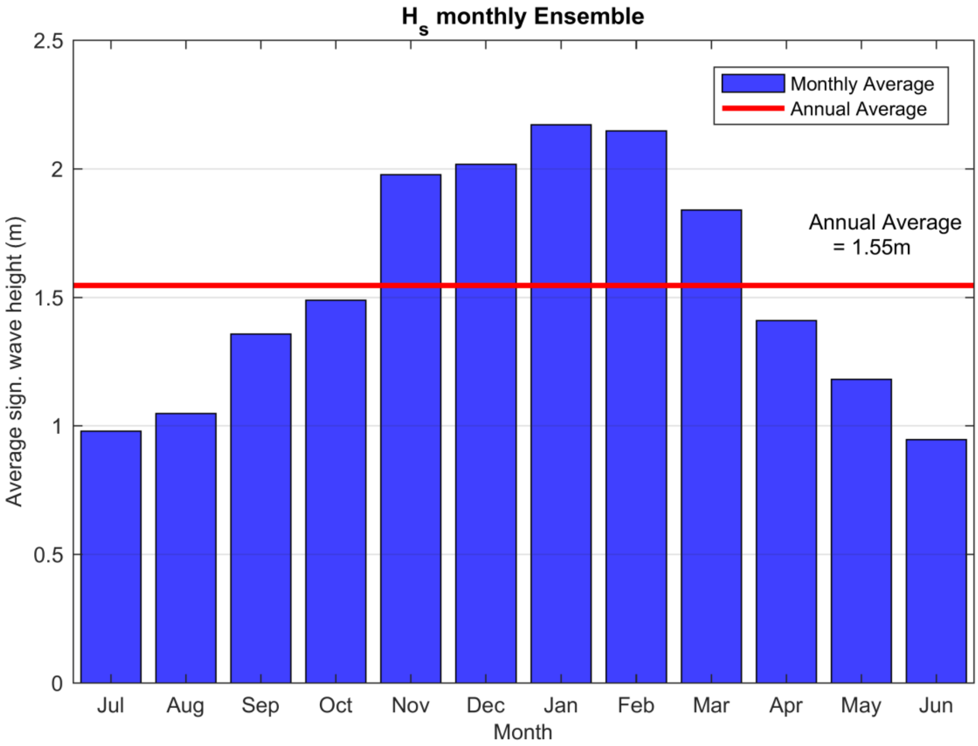

Figure 6.16: Annual and monthly average nearshore significant wave at Pollan strand between 1996 and 2018

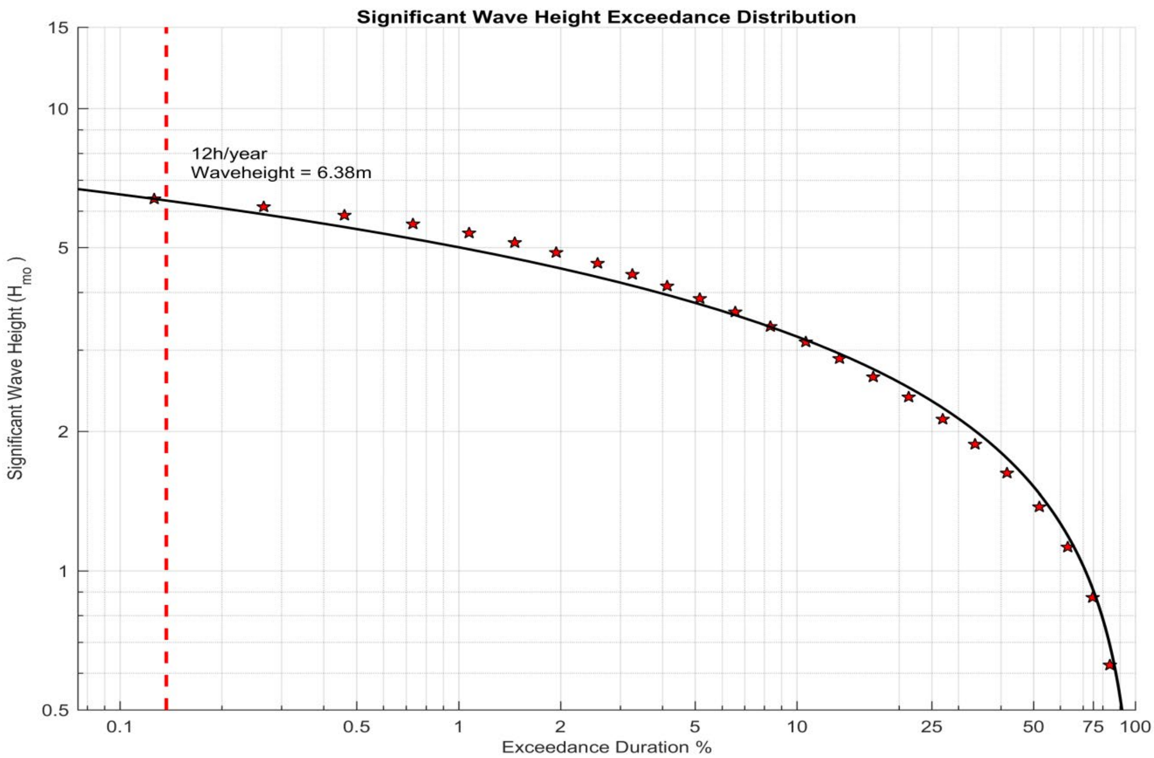

Figure 6.17: Nearshore significant wave height exceedance curve at Pollan strand between 1996 and 2018

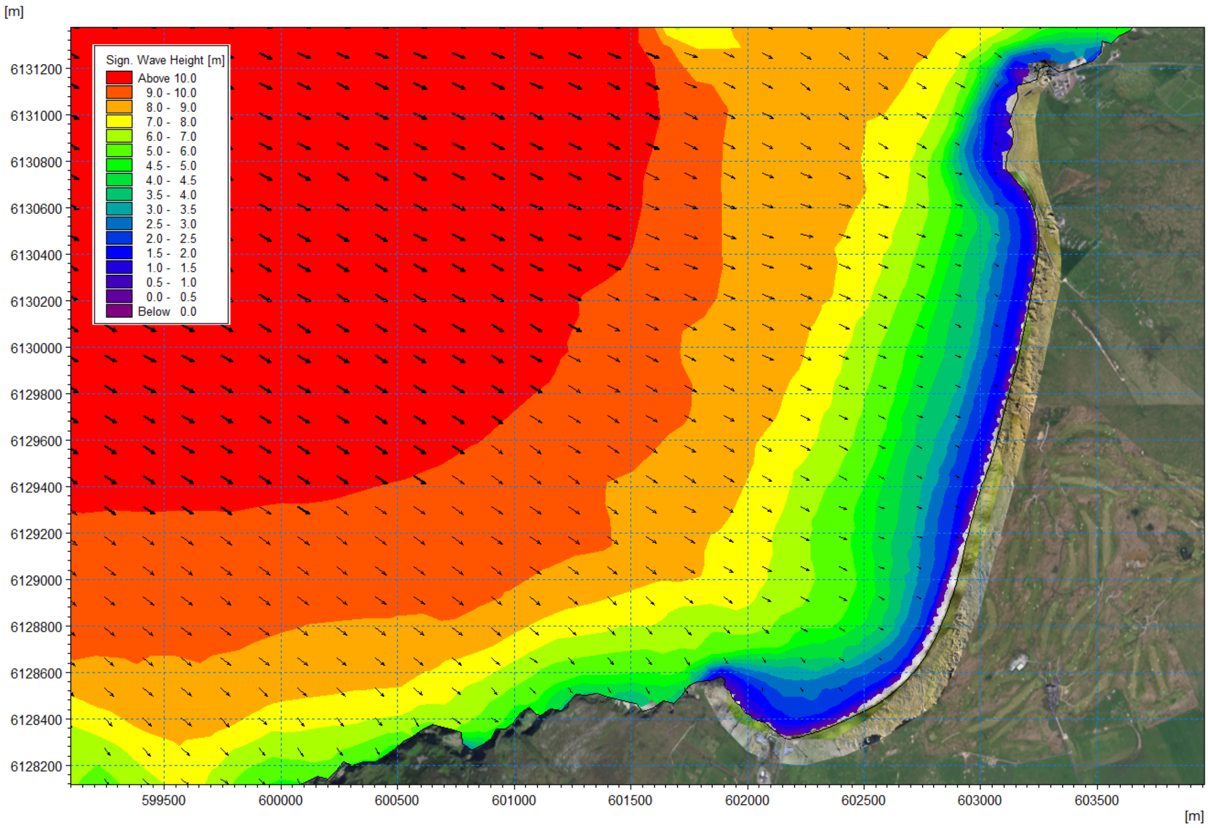

Figure 6.18: 0.5% AEP storm event from 270º –Pollan Strand

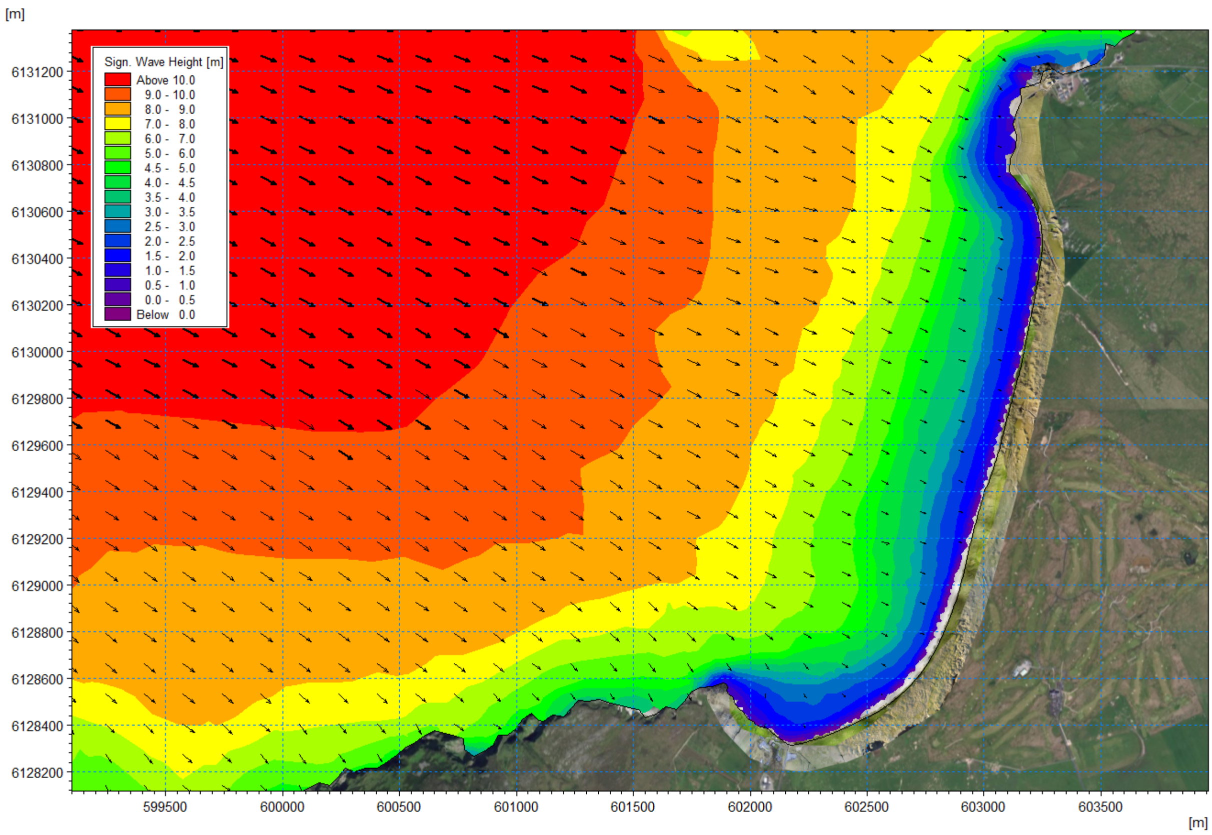

Figure 6.19: 2% AEP storm event from 270º – Pollan Strand

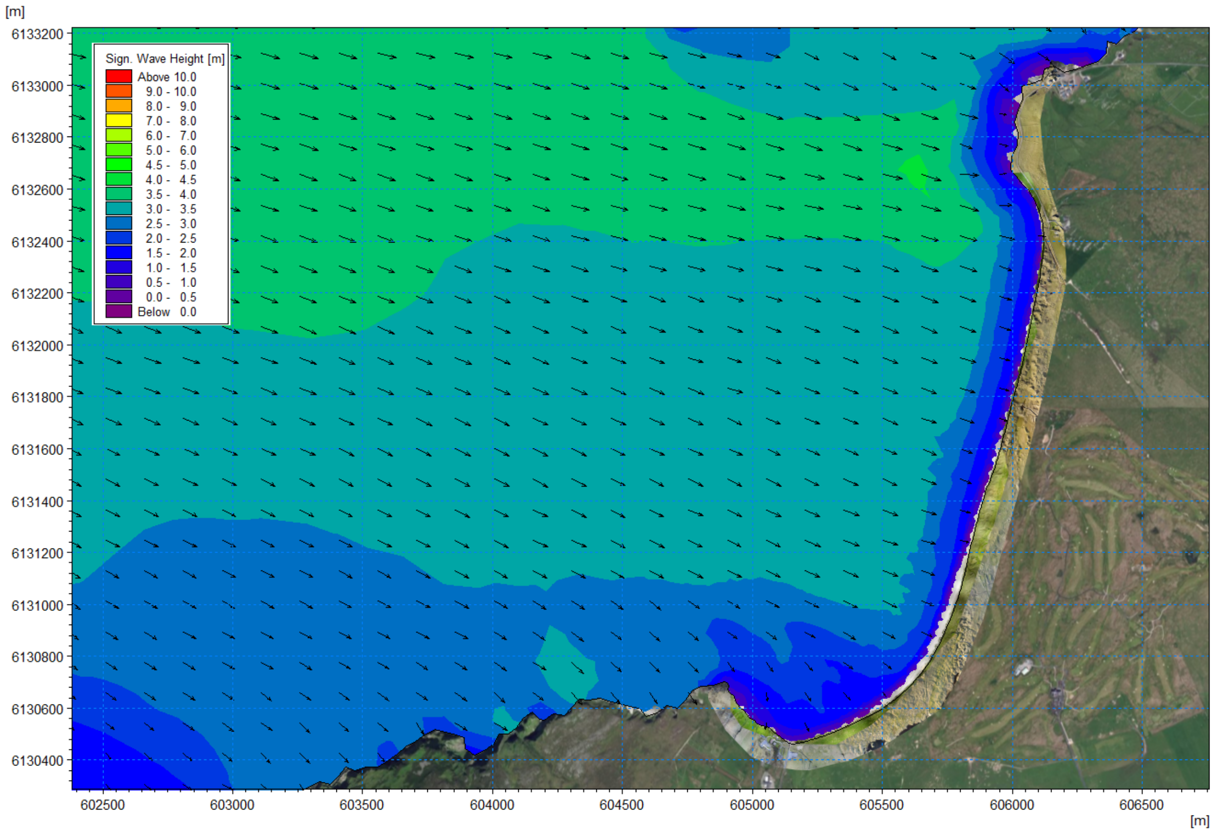

Figure 6.20: 50% AEP storm event from 270º – Pollan Strand

Table 6.3: Summary of inshore wave conditions at Pollan Strand during various return period events

AEP [%]	Point	Significant Wave Height (Hs m)	Wave Period (T01 s)	Wave Direction (ºN)
50	1	1.88	8.45	290
	2	2.86	8.60	265
	3	3.65	9.25	264
2	1	2.29	8.30	290
	2	3.24	8.70	266
	3	3.94	8.98	265
0.5	1	2.43	8.30	290
	2	3.40	8.70	265
	3	4.16	8.98	265

6.2.3 Lagg Beach

The annual average nearshore significant wave height at Lagg beach between 1996 and 2018 was found to be 1.76m. As with the other sites described in the previous Sections of this report the monthly average significant wave heights were much larger during the winter months between November and March (see Figure 6.22).

The probability exceedance curve for nearshore significant wave heights at Lagg beach between 1996 and 2018 is presented in Figure 6.23. This plot indicates that on average, the offshore significant wave heights could reach *c.* 6.84m for 12 hours of any given year at Lagg beach.

The inshore wave climates at Lagg beach during 0.5%, 2% and 50% storm conditions are presented in Figure 6.24 to Figure 6.26. It will be seen from these figures that the waves propagating towards Lagg beach are highly modified and diffracted by the complex bathymetry across the tidal inlet at Lagg point. Despite this, waves still impact almost normal to the shoreline.

RPS extracted inshore wave climate information for the three return period events presented in this report; the location of these extraction points are illustrated in Figure 6.21. The corresponding inshore wave climate information for Lagg beach is presented in Table 6.4. It will be seen from this Table that there is a notable difference between the inshore significant wave heights during 0.5% AEP and 505 AEP events. This indicates that other factors such as the morphology of the nearshore bathymetry including the ebb-delta and tidal inlet are more important in governing the inshore wave climate than prevailing sea levels. Despite that, wave energy along this coastline would still be expected to increase under future climate change conditions.

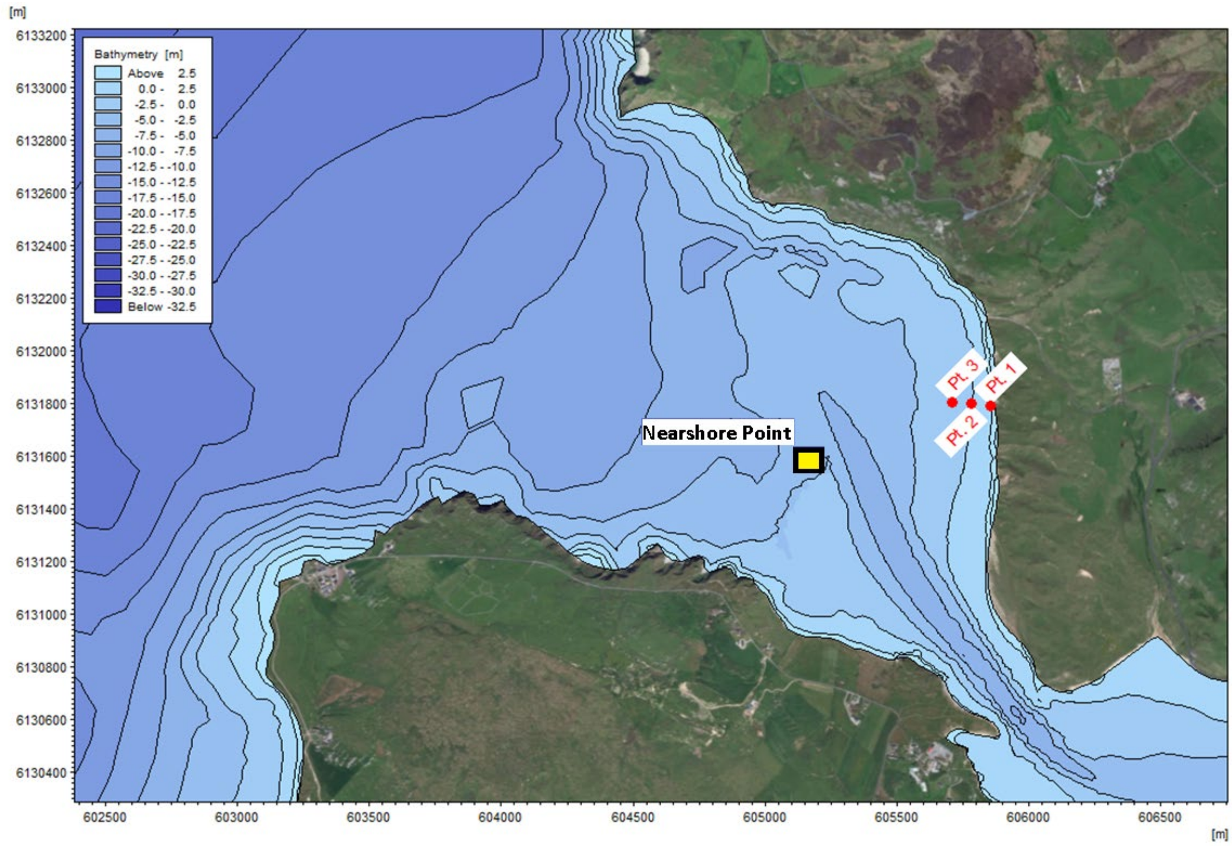

Figure 6.21: Location of inshore wave extraction points at Lagg Beach

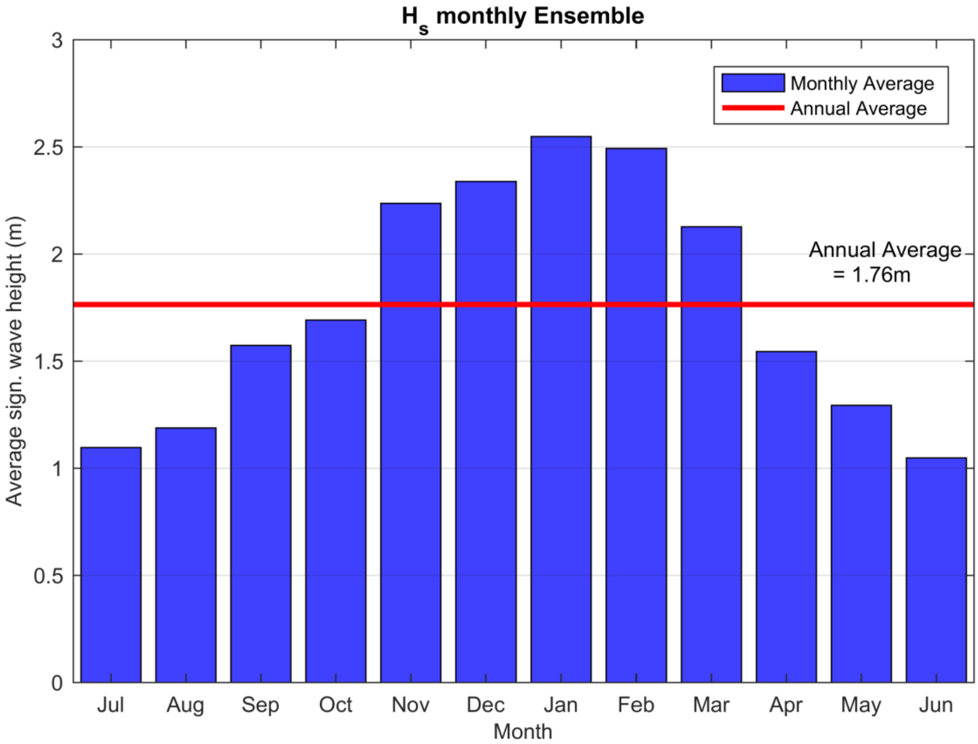

Figure 6.22: Annual and monthly average nearshore significant wave at Lagg beach between 1996 and 2018

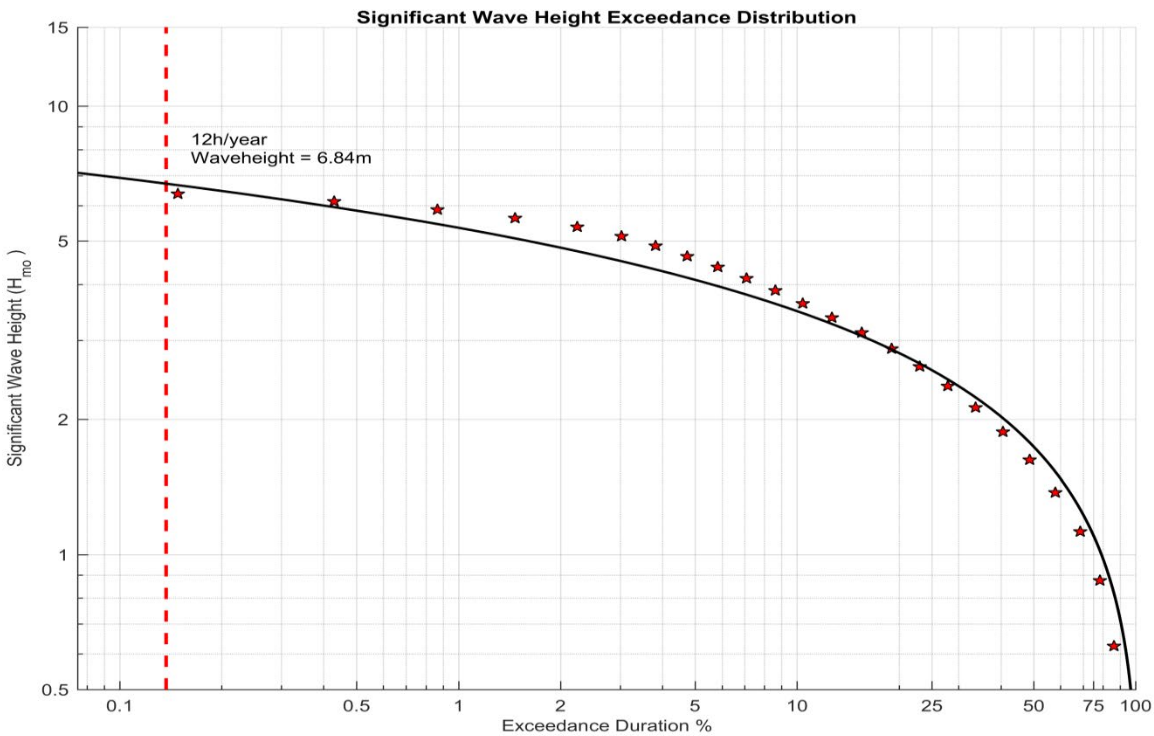

Figure 6.23: Nearshore significant wave height exceedance curve at Lagg beach between 1996 and 2018

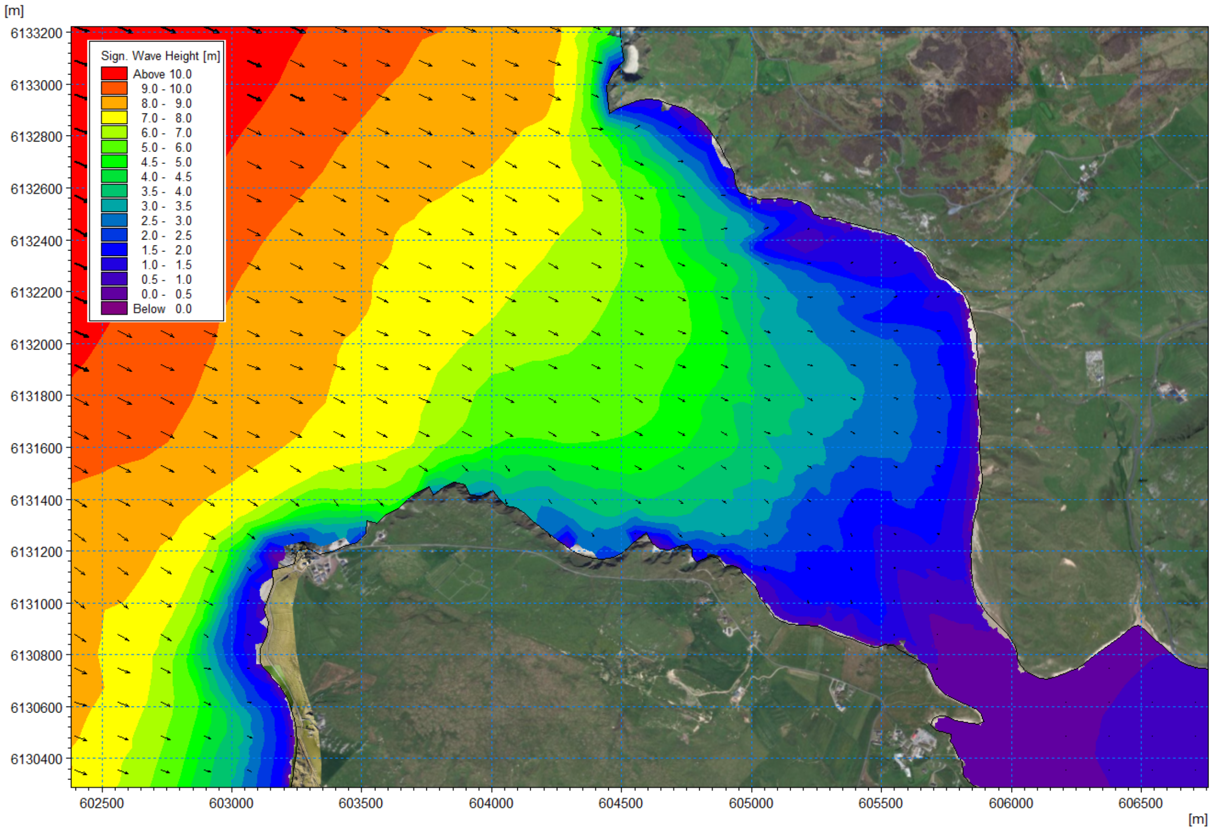

Figure 6.24: 0.5% AEP storm event from 270° – Lagg Beach

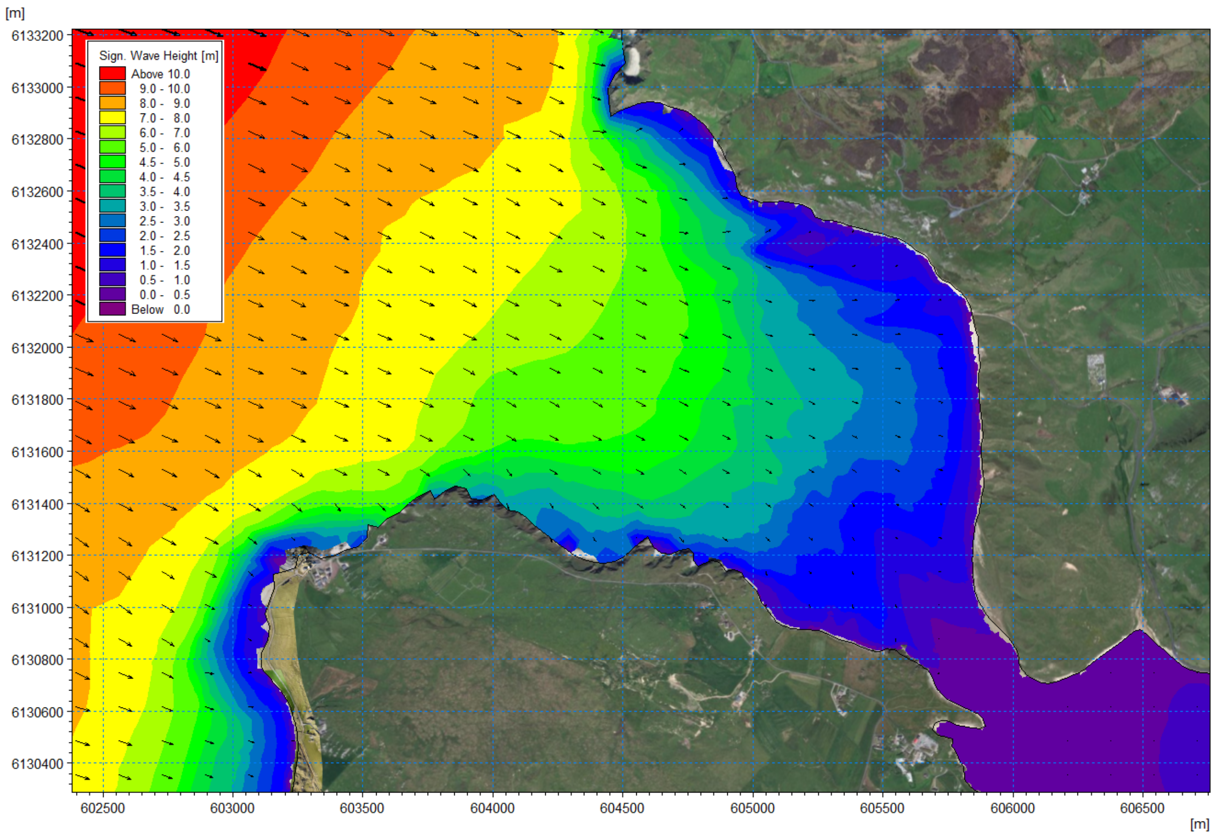

Figure 6.25: 2% AEP storm event from 270° – Lagg Beach

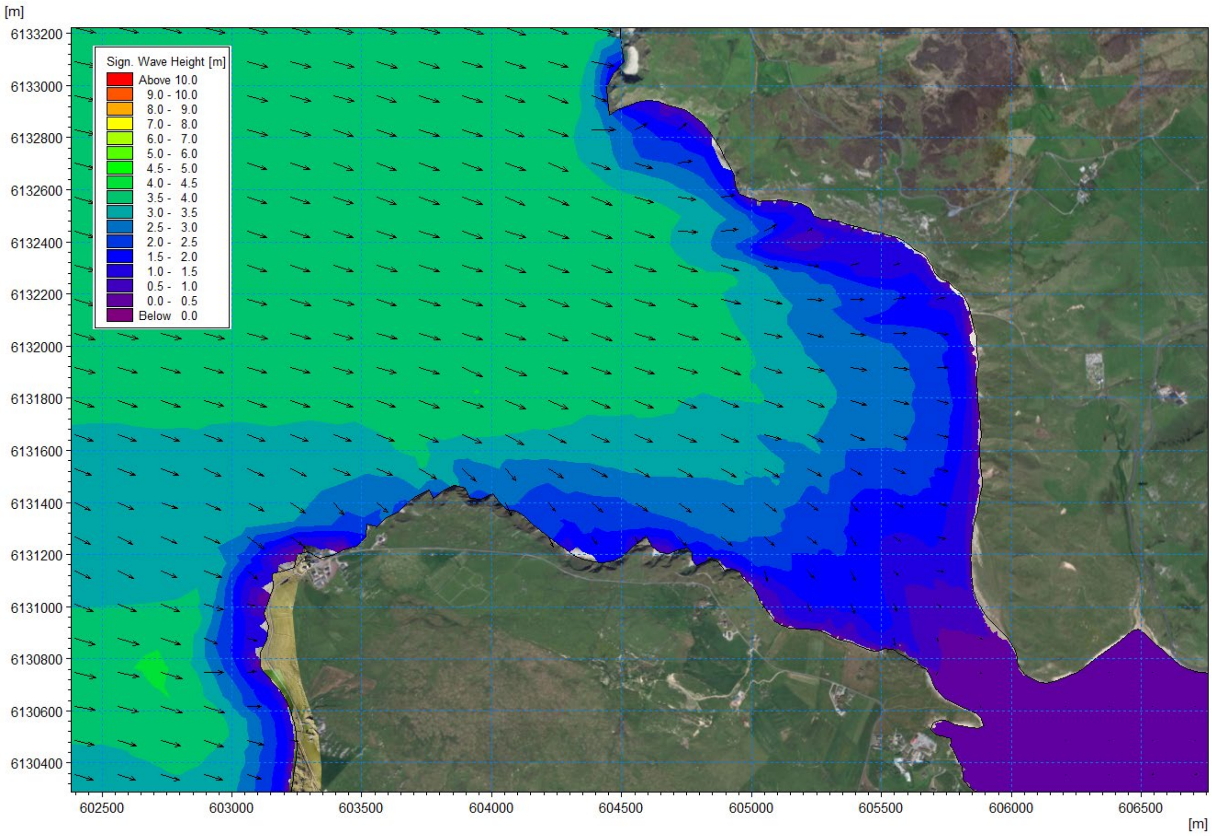

Figure 6.26: 50% AEP storm event from 270º – Lagg Beach

Table 6.4: Summary of inshore wave conditions at Lagg Beach during various return period events

AEP [%]	Point	Significant Wave Height (Hs m)	Wave Period (T01 s)	Wave Direction (ºN)
50	1	0.76	6.56	277
	2	1.91	7.60	281
	3	2.16	7.60	284
2	1	1.20	6.68	277
	2	2.23	7.54	281
	3	2.49	7.54	284
0.5	1	1.38	6.68	277
	2	2.35	7.54	281
	3	2.60	7.54	284

6.2.4 Binbane Coast

The annual average nearshore significant wave height at Binbane between 1996 and 2018 was found to be 1.68m. As with the other sites described in the previous Sections of this report the monthly average significant wave heights were much larger during the winter months between November and March (see Figure 6.28).

The probability exceedance curve for nearshore significant wave heights at Binbane between 1996 and 2018 is presented in Figure 6.29. This plot indicates that on average, the offshore significant wave heights could reach *c.* 6.61m for 12 hours of any given year at Binbane.

The inshore wave climates at Binbane during 0.5%, 2% and 50% AEP storm conditions are presented in Figure 6.30 to Figure 6.32. It will be seen from these figures that the waves propagating towards Binbane are highly modified and diffracted by the nearshore rocky outcrops. Despite this, waves still impact almost normal to the shoreline.

RPS extracted inshore wave climate information for the three return period events presented in this report; the location of these extraction points are illustrated in Figure 6.27. The corresponding inshore wave climate information for Binbane is presented in Table 6.5. It will be seen from this Table that the inshore significant wave heights during 0.5% AEP and 50% AEP events are approximately 2.00m and 1.60m respectively. These results indicate that the inshore wave heights at Binbane are significantly influenced by prevailing water depth. As such, this site could experience a significant increase in wave energy under future climate change conditions whereby sea levels could rise by up to +1.0m under the High End Future Scenario (HEFS).

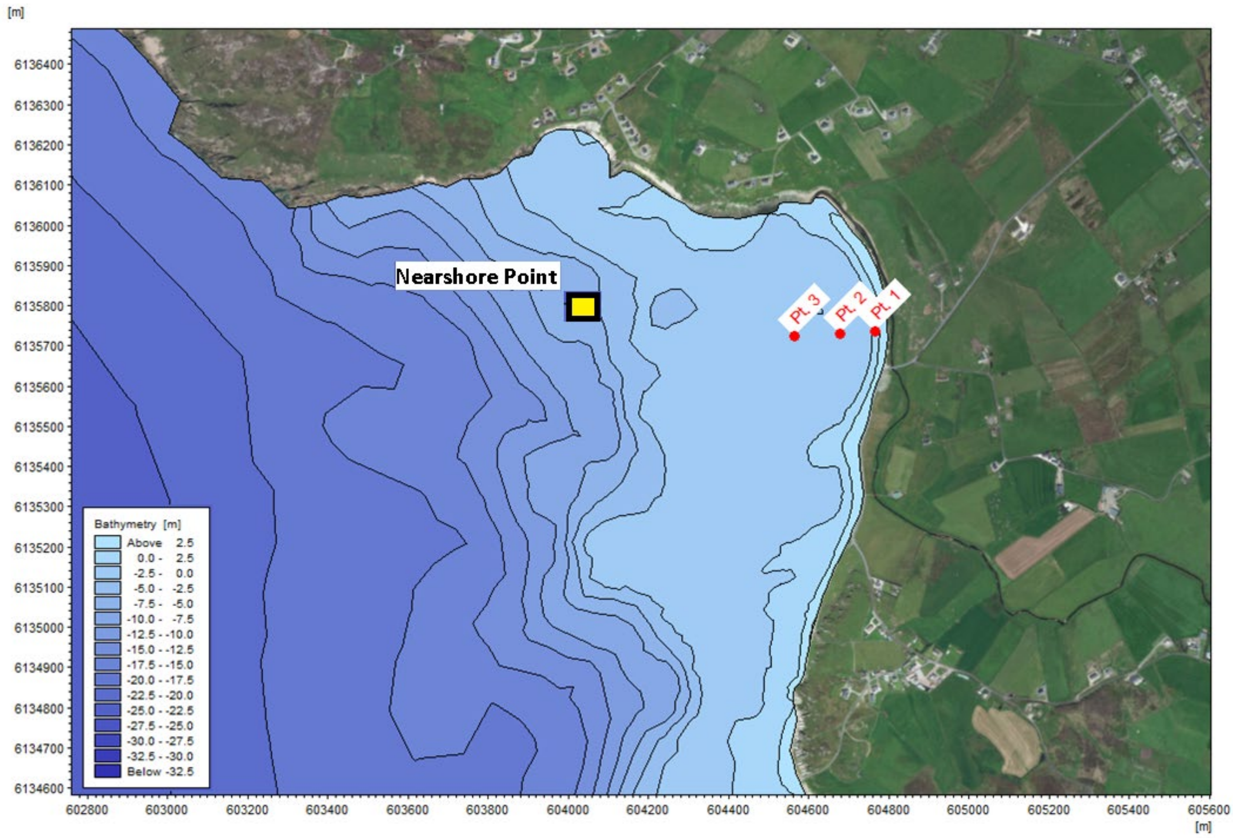

Figure 6.27: Location of inshore wave extraction points at Binbane Coast

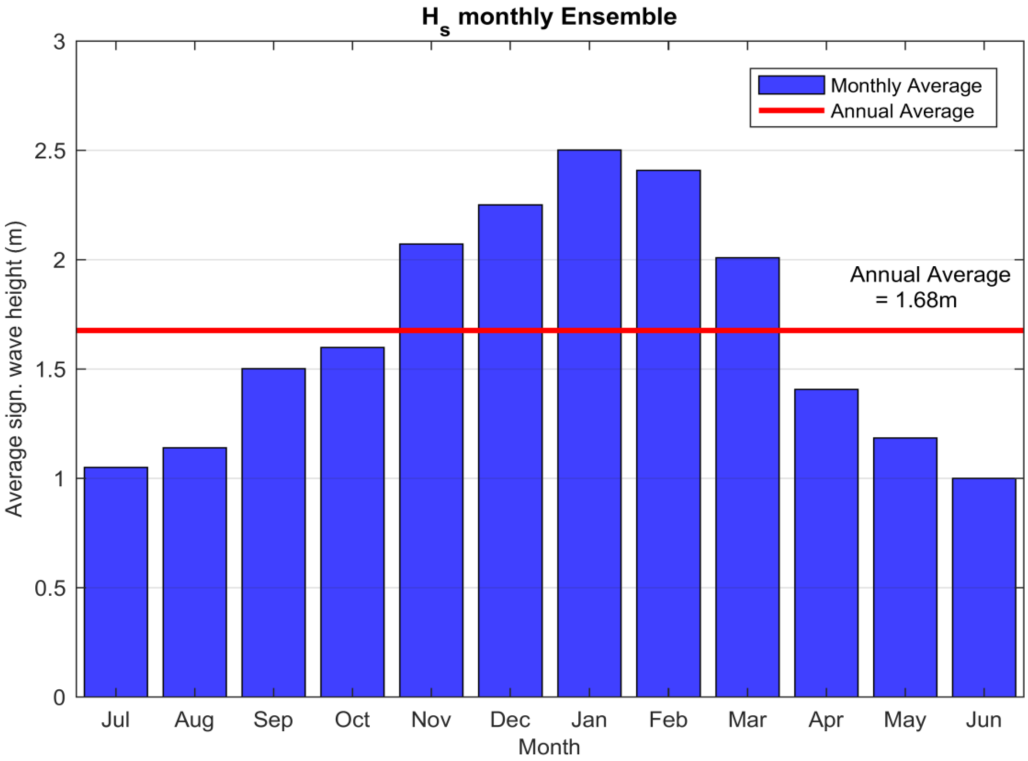

Figure 6.28: Annual and monthly average nearshore significant wave at Binbane coast between 1996 and 2018

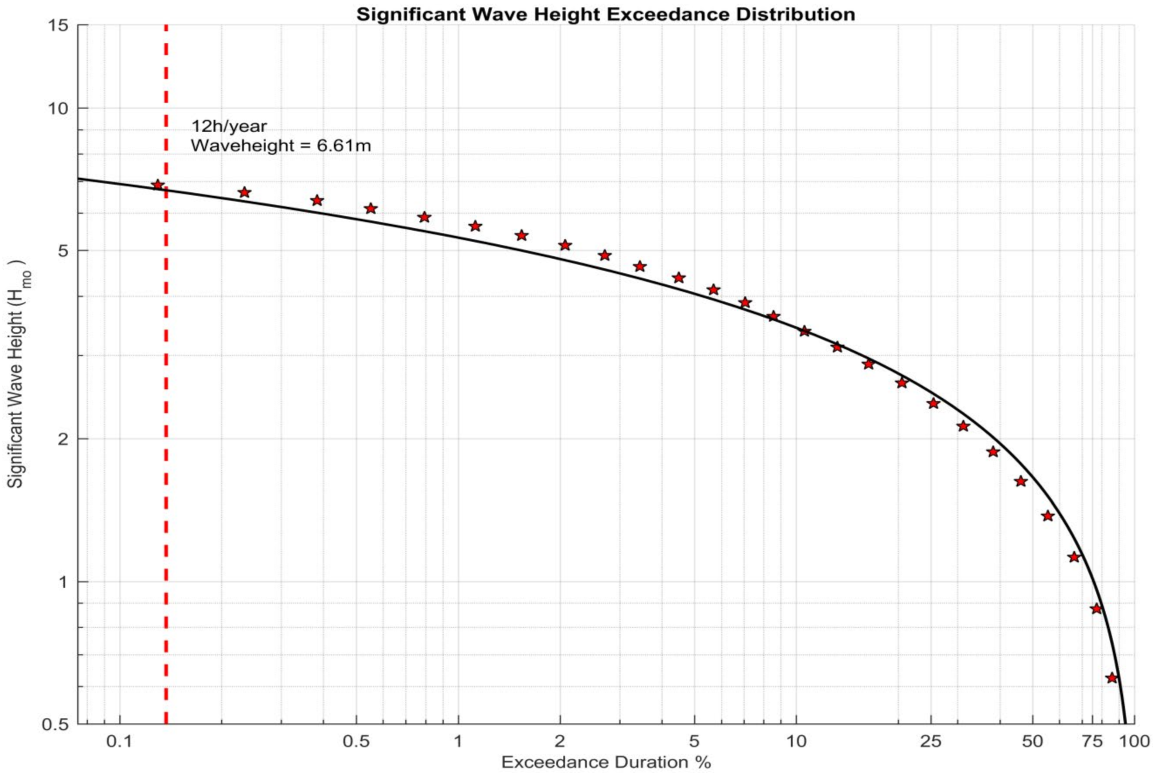

Figure 6.29: Nearshore significant wave height exceedance curve at Binbane coast between 1996 and 2018

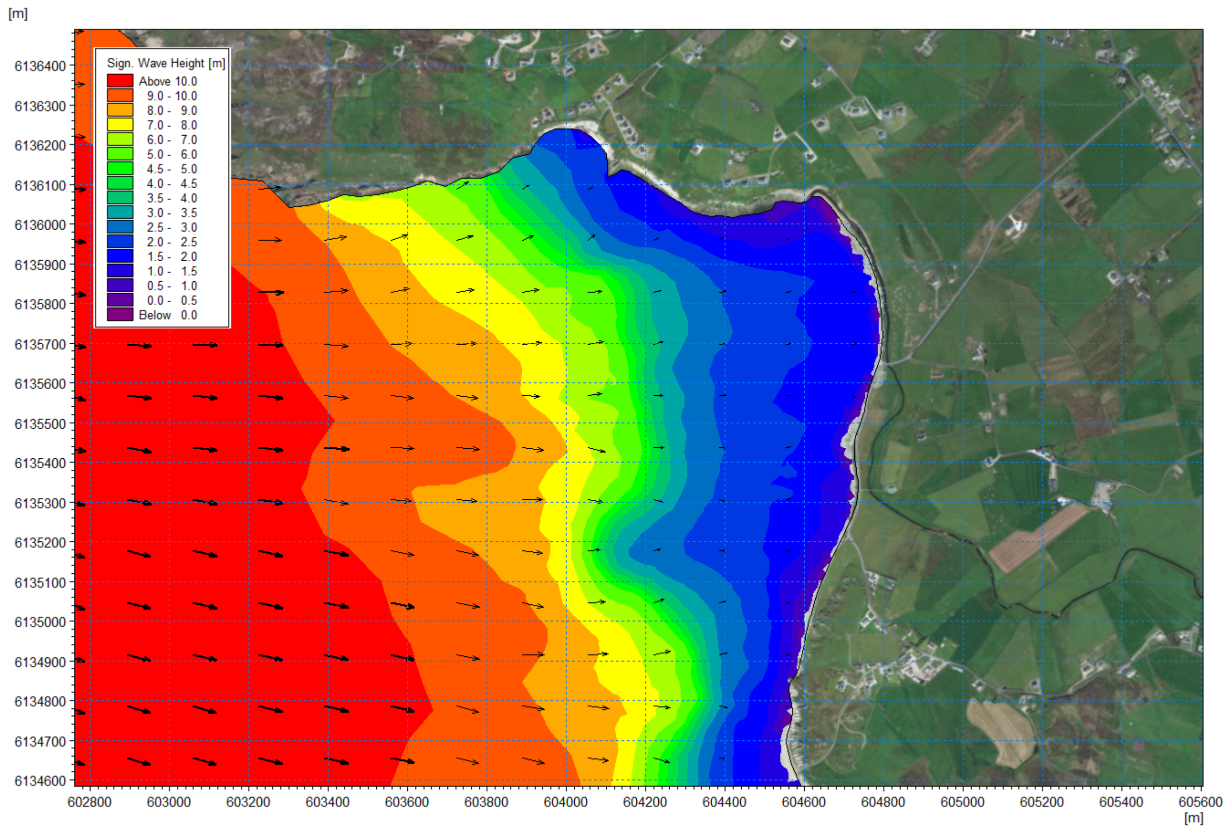

Figure 6.30: 0.5% AEP storm event from 270º – Binbane Coast

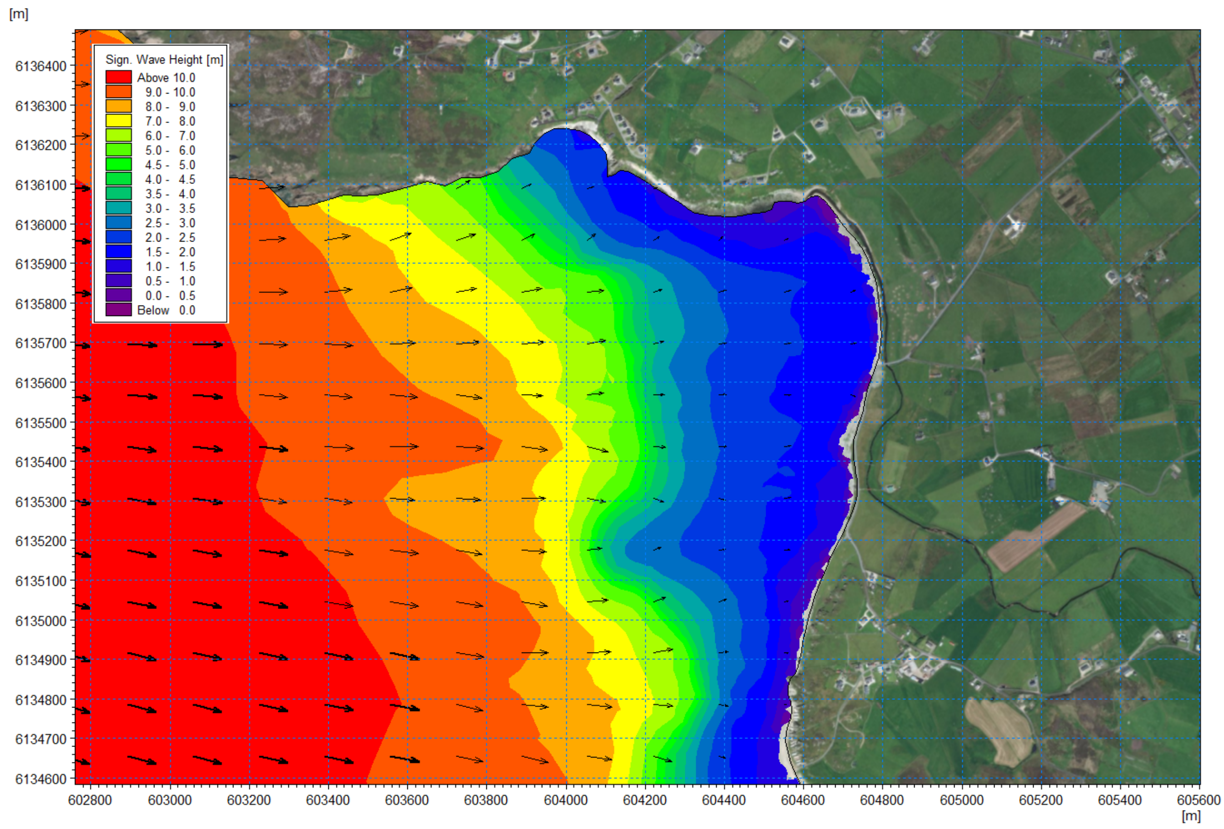

Figure 6.31: 2% AEP storm event from 270º – Binbane Coast

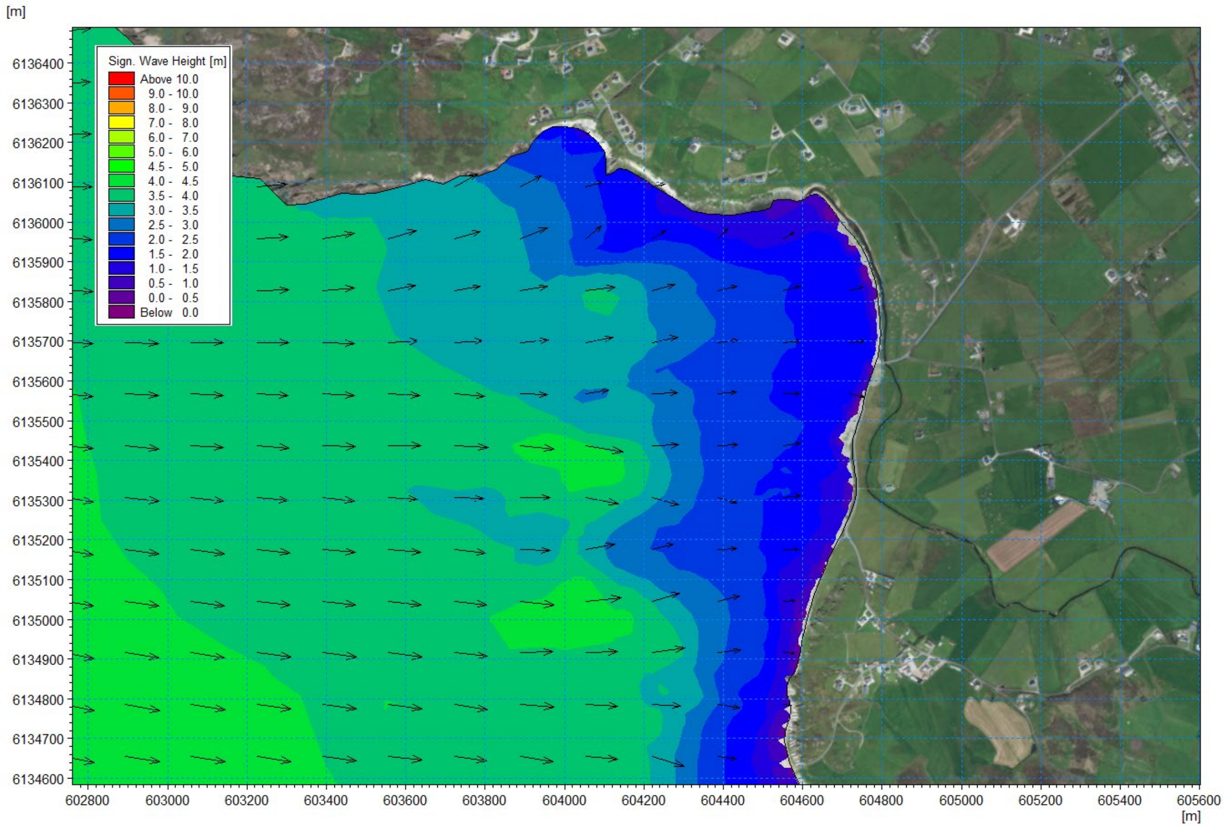

Figure 6.32: 50% AEP storm event from 270º – Binbane Coast

Table 6.5: Summary of inshore wave conditions at Binbane Coast during various return period events

AEP [%]	Point	Significant Wave Height (Hs m)	Wave Period (T01 s)	Wave Direction (ºN)
50	1	1.60	8.03	267
	2	1.91	8.37	266
	3	2.02	8.62	265
2	1	2.03	7.95	267
	2	2.23	8.20	266
	3	2.35	8.76	265
0.5	1	2.00	7.95	267
	2	2.35	8.20	266
	3	2.47	8.76	265

6.3 Sediment Transport

Before developing an erosion management strategy it is important to first understand the nature of the sediment transport regime across the Inishowen peninsula and to determine if sediment transport has changed in any way over the last number of decades.

To this end RPS utilised the results from the inshore wave modelling for the period between 1997 – 2016 in conjunction with the LitDrift model to quantify and assess the littoral transport across Pollan Strand. It should be noted that the Pollan Strand was chosen for this analysis as this beach was found to generally be representative of the other beaches in the study area in respect to wave exposure, nearshore bathymetry and coastline evolution. Importantly, the sediment transport processes along Pollan Strand are not subject to the same degree of complex 2D coastal processes that affect sites like Lagg beach. Furthermore, given that Ballyliffin Golf Club is within the immediate hinterland of Pollan Strand, output from this analysis could be used to ensure the assessment of future coastline evolution in this important area was reasonable and proportionate. The location of the cross-shore profiles that were used to assess the long-term sediment transport regime at Pollan Strand are illustrated in Figure 6.33 below.

Littoral transport is the term used for the transport of non-cohesive sediments, i.e. mainly sand, in the littoral zone along a shoreline mainly due to the action of breaking waves and to a lesser extent the longshore currents. The LitDrift model is a powerful tool that can be used to assess shoreline erosion and accretion, quantify littoral budgets and also to determine the *equilibrium orientation* of a coastline whereby the transport of sediment is on average close to zero.

For reference, it should be noted that LitDrift is a 1D model and that a negative sediment drift indicates sediment moving northwards, whilst a positive sediment drift indicates sediment is moving southwards.

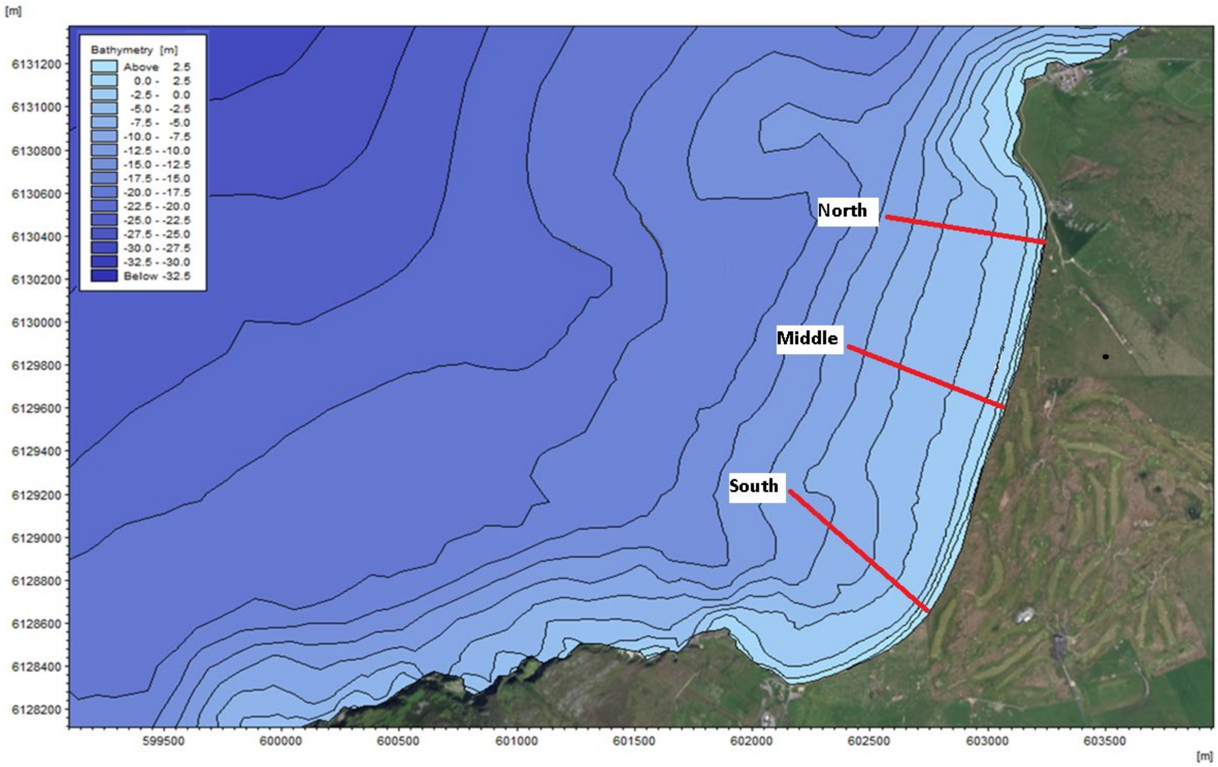

Figure 6.33: Location of the cross-shore profiles at Pollan Strand used to assess the long-term sediment transport regime between 1997 and 2016

The average annual net drift across the 3 profiles for the period between 1997 and 2016 is illustrated in Figure 6.34. The average annual net sediment drift was found to be in the order of 90,000m^3 in a southerly direction, however as can be seen from the same figure the direction and magnitude of sediment transport along Pollan Strand is highly variable. As would be expected, the highest rates of sediment transport were found to occur during periods of arduous weather, i.e. high water levels and increased wave energy.

Figure 6.35 shows the direction of sediment transport along Pollan Strand to be highly variable. In fact, RPS' analysis found that the shoreline at Pollan Strand, like Lagg beach and Binbane coast is orientated very close to the natural *equilibrium orientation* whereby the transport of sediment is on average close to zero. That is to say that although sediment transport rates can under certain circumstances be relatively high, the sand tends to work back and forth along the same beach. As a result, the *net* transport of sediment is much lower than what it would be if the orientation of the shorelines were notably different.

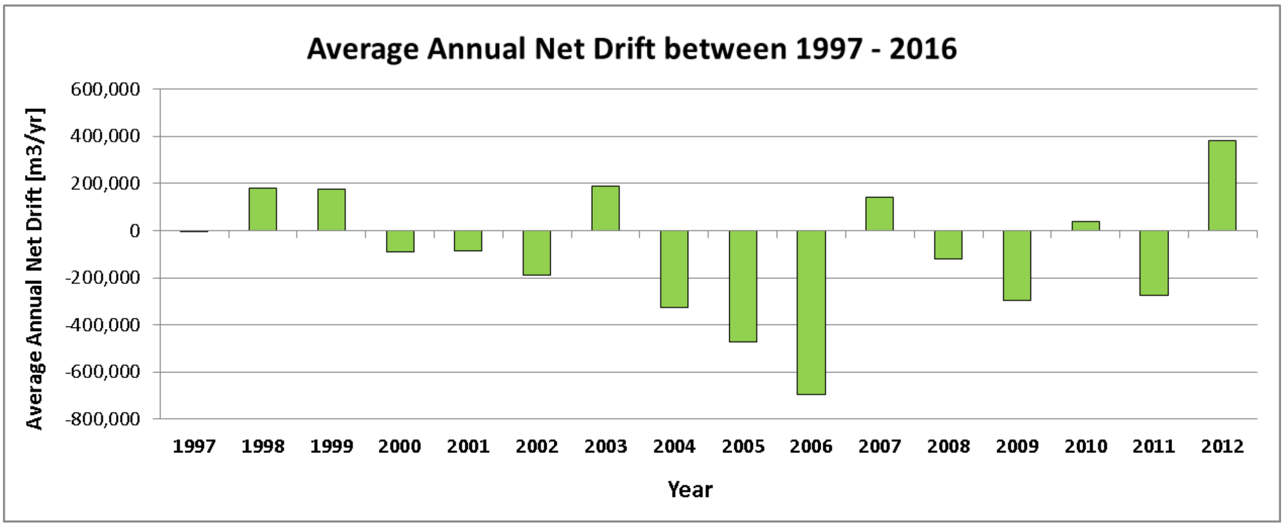

Figure 6.34: Average annual net sediment drift based on all 3 profiles at Pollan Strand (minus and positive transport indicates southerly and northerly transport respectively)

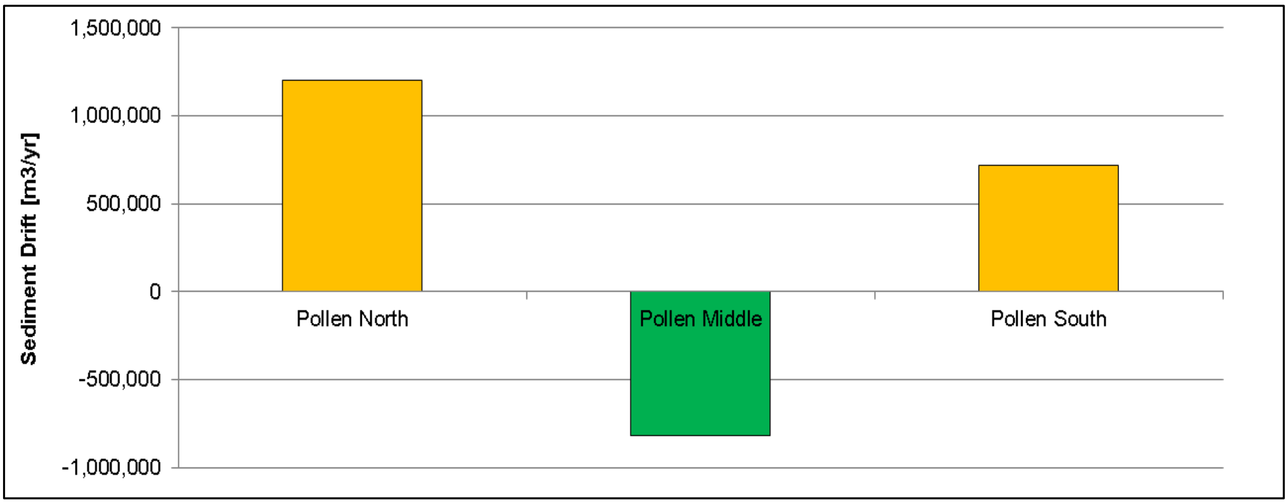

Figure 6.35: Average direction and magnitude of sediment transport across all 3 profiles at Pollan Strand between 1997 and 2016 (minus and positive transport indicates southerly and northerly transport respectively)

The positive (southwards) and negative (northwards) components of the net annual sediment drift at across all three profiles at Pollan Strand are illustrated in Figure 6.36 below. It will be seen from these Figures that there are two peaks of sediment transport across most profiles. This can be attributed to the swell wave component and wind wave component of the incident waves breaking at different locations along the beach profile.

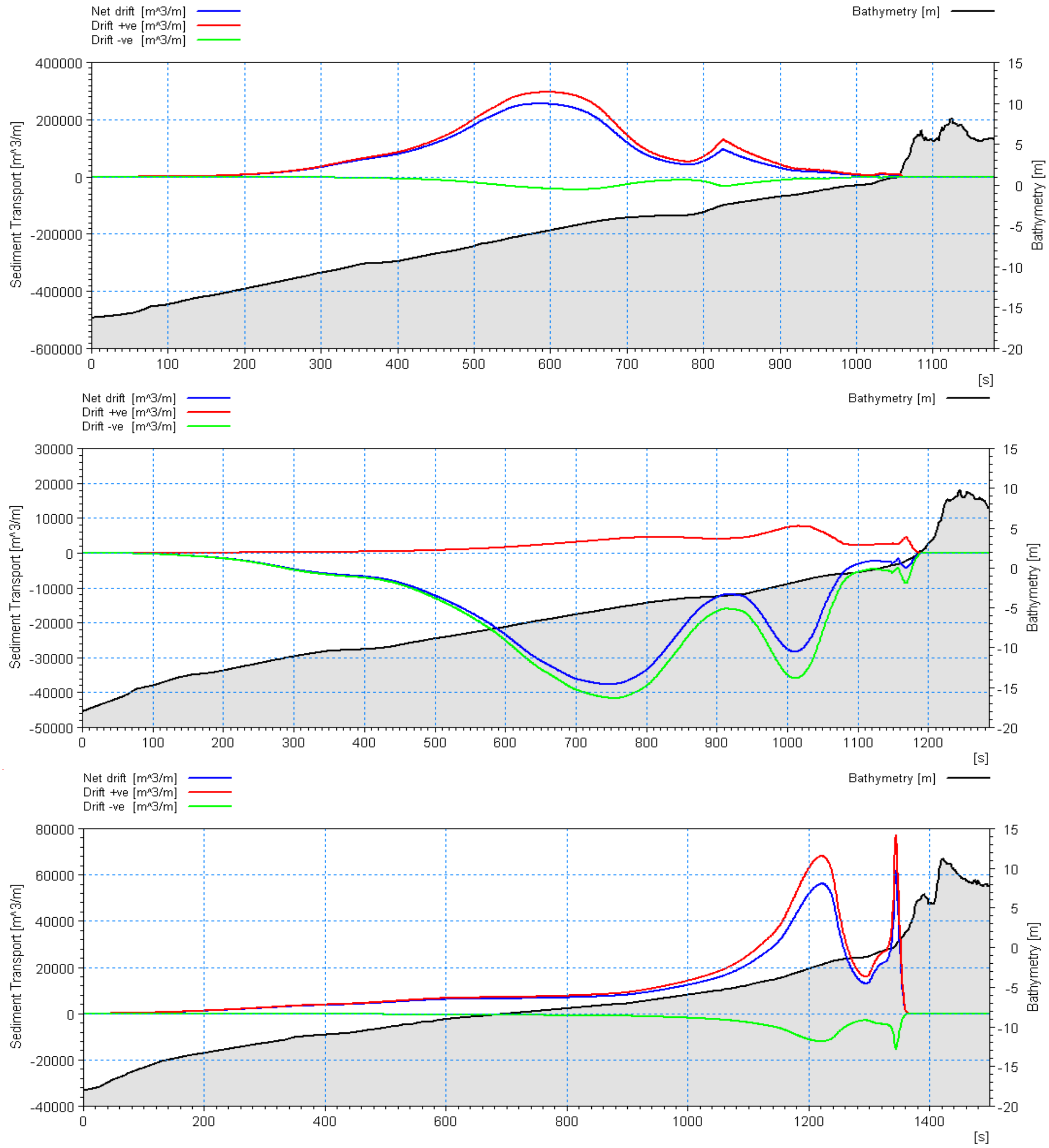

Figure 6.36: The southward and northward components of the net annual littoral drift at the north (top), middle (middle) and south (bottom) profiles along Pollan Strand

7 VULNERABILITY OF THE COASTLINES

7.1 General

Coastal erosion is an important natural phenomenon that has been occurring uninterruptedly for millions of years (until recent human intervention). Erosion plays a fundamental role in redistributing sediment throughout a coastal system and contributes to the formation of a variety of coastal landscapes many of which have now been designated owing to their unique environmental characteristics (see Section 8). However, erosion can also result in significant negative impacts in areas where there isn't enough area to accommodate the ongoing exchange of sediment and the potential retreat of the shoreline. This is particularly problematic in urbanised areas where important infrastructure, sites of cultural heritage and important amenities can be threatened by erosion.

An assessment of the potential consequences of coastal erosion is therefore a key element in the development of any coastal erosion management strategy. The following section of this report assesses and quantifies the risk associated with coastal erosion at the five sites within the study area

7.2 Threat of Erosion

RPS used two methods to calculate the predicted extent of future coastal change by 2050 and 2100 under the Medium Range Future Scenario (MRFS) and High End Future Scenario (HEFS) climate change scenarios whereby relative sea levels are expected to rise by +0.5m and +1.0m respectively.

The first method used to projected future rates of coastal change was based on the Historical Trend Analysis Rule (HTAR). This method relates the historical sea level rise and coastal retreat rates with future sea level rise and future coastal retreat rates based on the equation below:

$$\mathbf{R_2 = (R_1/S_1). * S_2}$$

Whereby:

S_1=historical sea-level rise rate (m/yr)

S_2= future sea level rise rate (m/yr)

R_1= historical retreat rate (m/yr)

R_2= future retreat rate (m/yr)

The HTAR is a commonly used method in coastal management and is widely used in throughout England to assist with Shoreline Management Plans. For the purposes of this study RPS used a historical sea level rise rate of 2mm per year in conjunction with the historical rates of retreat for the various sites as described in Table 2.1 in Section 2. The sea level rise as expected under the MRFS and HEFS climate change projections were then converted to metres per year and used to calculate future rates of coastal change for 2050 and 2100 under both scenarios.

The second method used to calculate future coastal change was based on the equilibrium profile theory which asserts that a beach profile will maintain an equilibrium shape and that as sea level rises the equilibrium profiles will be forced landward and upward to preserve their shape relative to the new sea level. RPS applied the equilibrium profile theory to typical profiles taken from each of the study areas to estimate the extent of coastal retreat by 2050 and 2100 under future climate change projections.

In order to take a conservative approach, RPS compared the results from each of these methods and then prepared detailed future scenario coastal change maps based on whichever method indicated the greater extent of coastal retreat.

It should be noted that RPS also referred to information published by Geological Survey Ireland to determine which regions of the five sites were likely to erode based on the composition of the substratum and which areas would likely remain stable due to the presence of hard rock and rocky outcrops. The underlying geology across the study area is illustrated in Figure 7.1 below. The yellow regions in the figure represent areas where the lithology is characterised by marine gravel and sands (often raised) and thus susceptible to coastal erosion. The lithology of the other regions in the figure is characterised by other sediment which is not as liable to erosion (such as bedrock outcrops or till derived from metamorphic rocks).

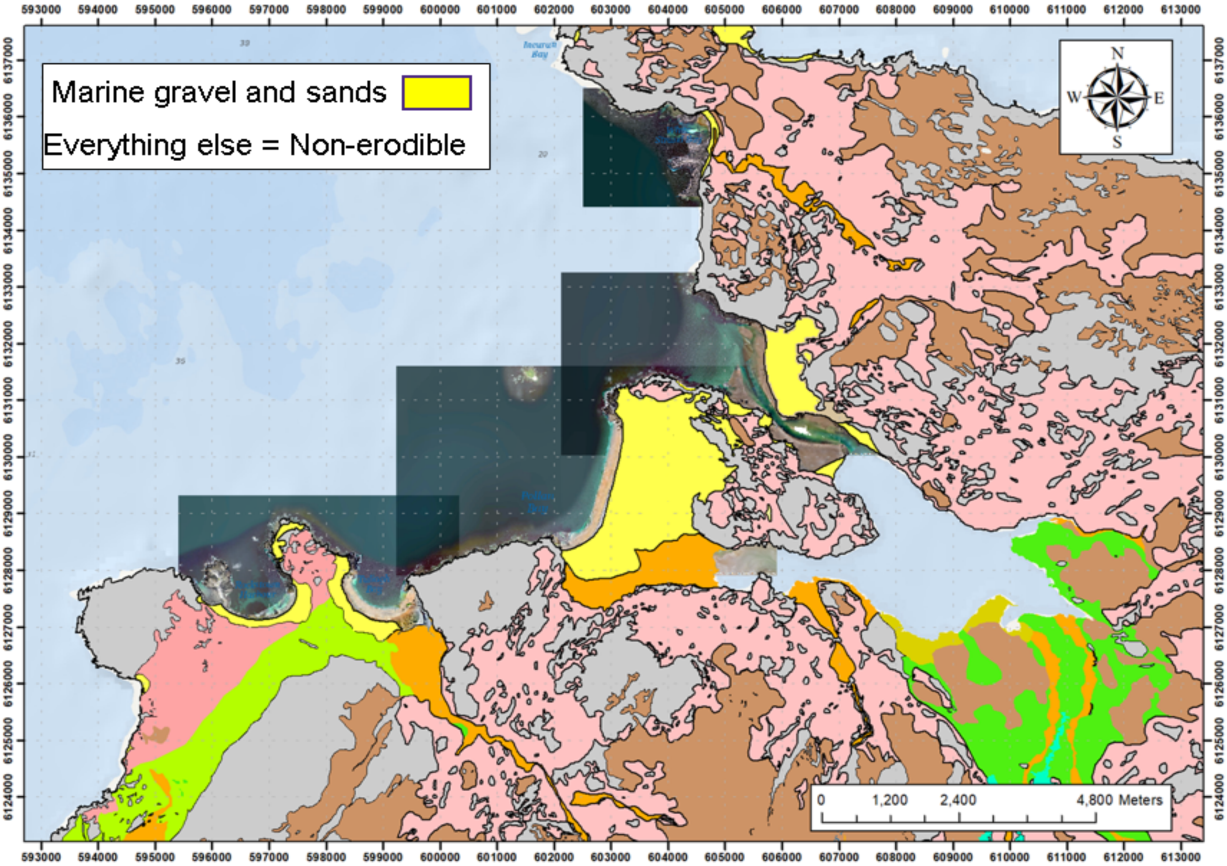

Figure 7.1: Quaternary sediments in the Inishowen Peninsula area with areas susceptible to erosion shown in yellow (Geological Survey Ireland, 2019)

7.2.1 Uncertainty in erosion assessments

Although great care and modern, widely-accepted best practice methods have been used to prepare the future coastline evolution maps, there is a range of inherent uncertainties associated with assessing the threat of future coastal erosion and preparing coastline evolution maps. These include:

- Uncertainty in the underlying geology and hence in the annual rate of coastal change
- Uncertainty in the geographical accuracy of historical imagery
- Uncertainty in long-term, multi-decadal morphological processes such as the flood ebb delta changes observed at Lagg beach

As such, the coastline evolution maps presented in the following Sections should be interpreted with caution. Furthermore, it is worth noting that it is RPS' opinion that theses maps represent close to a "worst-case scenario" and that the complex coastal processes of the Inishowen peninsula are such that the future rates of coastal erosion are likely to be lower than those presented in this report.

7.3 Future coastal change and risk assessment

7.3.1 Coastal change at Rockstown Harbour

The projected extent of coastal retreat at Rockstown Harbour by 2050 and 2100 as determined by each of the analysis methods described in Section 7.2 under both the Medium Range Future Scenario (MRFS) and High End Future Scenario (HEFS) for climate change are presented in Table 7.1. The corresponding coastline evolution maps for each climate change scenario are presented in Figure 7.2 and Figure 7.3.

It should be noted that the impact of coastal erosion on cultural heritage has been assessed in respect to the NIAR dataset. This dataset list all historical monuments and cultural heritage sites in Ireland and is described in more detail in Section 8.4 of this report.

Table 7.1: Predicted coastal retreat at Rockstown harbour by 2050 and 2100 using the Equilibrium Profile and Historical Trend Analysis methods

Timescale	Equilibrium Profile / Bruun Rule		Historical Trend Analysis	
	MRFS	HEFS	MRFS	HEFS
Retreat by 2050 [m]	11	22	18	30
Retreat by 2100 [m]	18	35	29	49

The assets determined to be as risk by 2050 and 2100 under both MRFS and HEFS climate change scenarios i.e. those assets currently situated seawards of the relevant projected coastline shown in Figure 7.2 and Figure 7.3 are summarised in Table 7.2. It will be seen from this table that despite the relatively high projected future erosion rates, the main asset at risk is a small parcel of land that runs parallel to the shoreline and localised sections of a minor road. This could potentially affect access to a number of buildings on the western extent of the beach. However, the underlying geology in this area is reported to be comprised of hard rock and therefore likely to mitigate erosion in this area.

Table 7.2: Assets at risks at Rockstown harbour by 2050 and 2100 under MRFS and HEFS coastal retreat scenarios

Asset	MRFS Coastal Change		HEFS Coastal Change	
	By 2050	By 2100	By 2050	By 2100
Loss of land	56,566m^2	135,091m^2	90,760m^2	260,955m^2
Buildings	0	0	0	6
Roads	40m	259m	111m	639m
Cultural Heritage	0	0	0	0
Other	Potential loss of small pier			

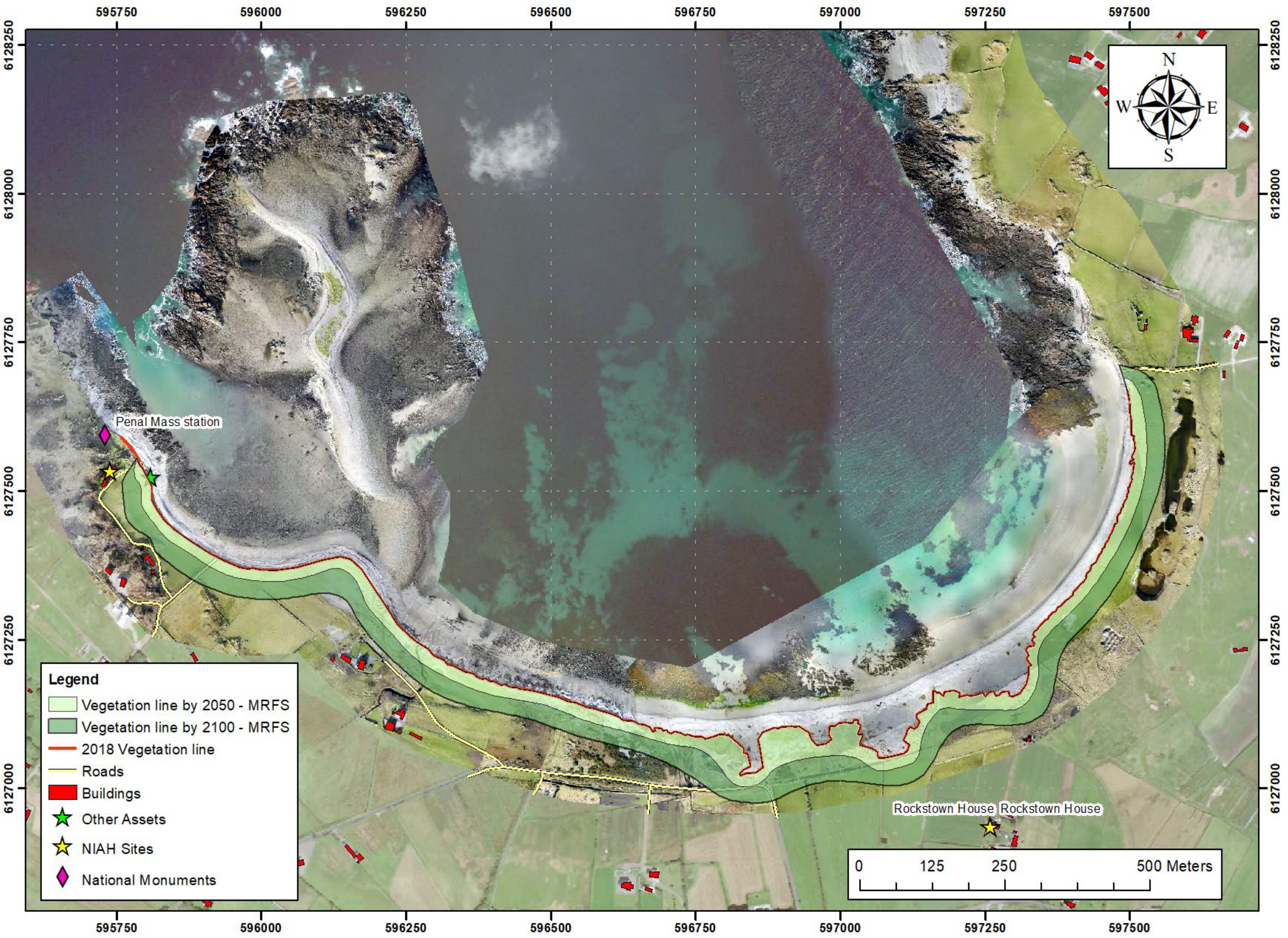

Figure 7.2: Predicted coastal change at Rockstown harbour by 2050 and 2100 under the Medium Range Future Scenario – i.e. SLR of +0.5m

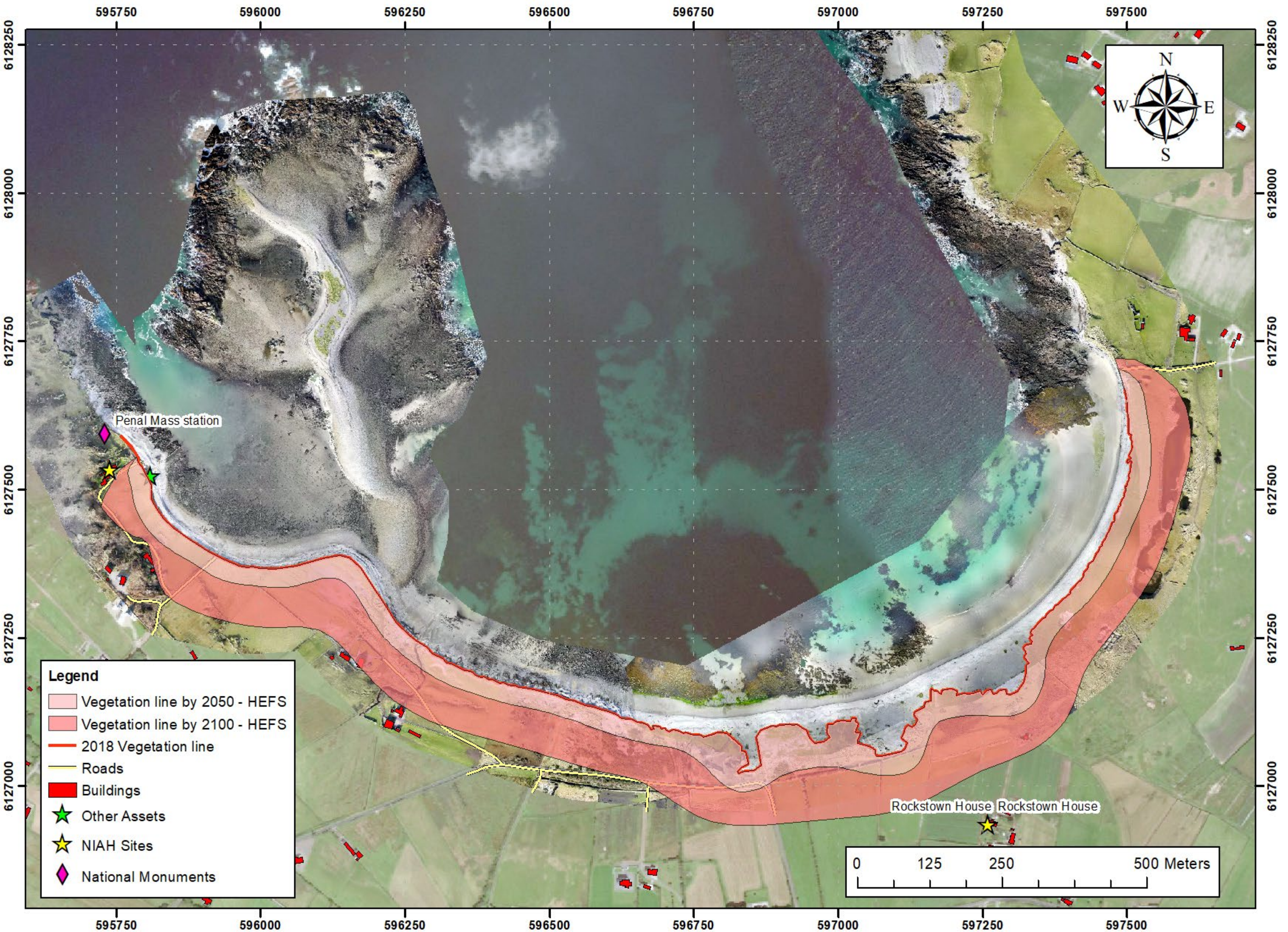

Figure 7.3: Predicted coastal change at Rockstown harbour by 2050 and 2100 under the High End Future Scenario – i.e. SLR of +1.0m

7.3.2 Coastal change at Tullagh Bay

The projected extent of coastal retreat at Tullagh Bay by 2050 and 2100 for the MRFS and HEFS climate change scenarios are presented in Table 7.3. The corresponding coastline evolution maps for each climate change scenario are presented in Figure 7.4 and Figure 7.5.

Table 7.3: Predicted coastal retreat at Tullagh Bay by 2050 and 2100 using the Equilibrium Profile and Historical Trend Analysis methods

Timescale	Equilibrium Profile / Bruun Rule		Historical Trend Analysis	
	MRFS	HEFS	MRFS	HEFS
Retreat by 2050 [m]	11	22	27	45
Retreat by 2100 [m]	18	36	43	72

It will be seen from Figure 7.4 and Figure 7.5 that despite the projected coastal retreat there is actually very little at risk from coastal erosion at Tullagh Bay. A parcel of land that runs parallel to the coast will likely be lost over the long-term as sea levels rise with future climate change, forcing the shoreline to retreat to maintain the existing profile. A caravan park situated in relatively close proximity to the shoreline may also be affected in the longer term, however it should be possible to re-configure the layout of this amenity to facilitate future coastal change if necessary. As summarised in Table 7.4 below, there are no built assets or sites of cultural heritage at risk by 2050 or 2100 under either future climate change scenario.

Table 7.4: Assets at risks at Tullagh Bay by 2050 and 2100 under MRFS and HEFS coastal retreat scenarios

Asset	MRFS Coastal Change		HEFS Coastal Change	
	By 2050	By 2100	By 2050	By 2100
Loss of land	41,197m^2	122,843m^2	74,780m^2	203,447m^2
Buildings	0	0	0	3
Roads	0	0	0	0
Cultural Heritage	0	0	0	0
Other	n/a	Potential impact to caravan park	n/a	Potential impact to caravan park

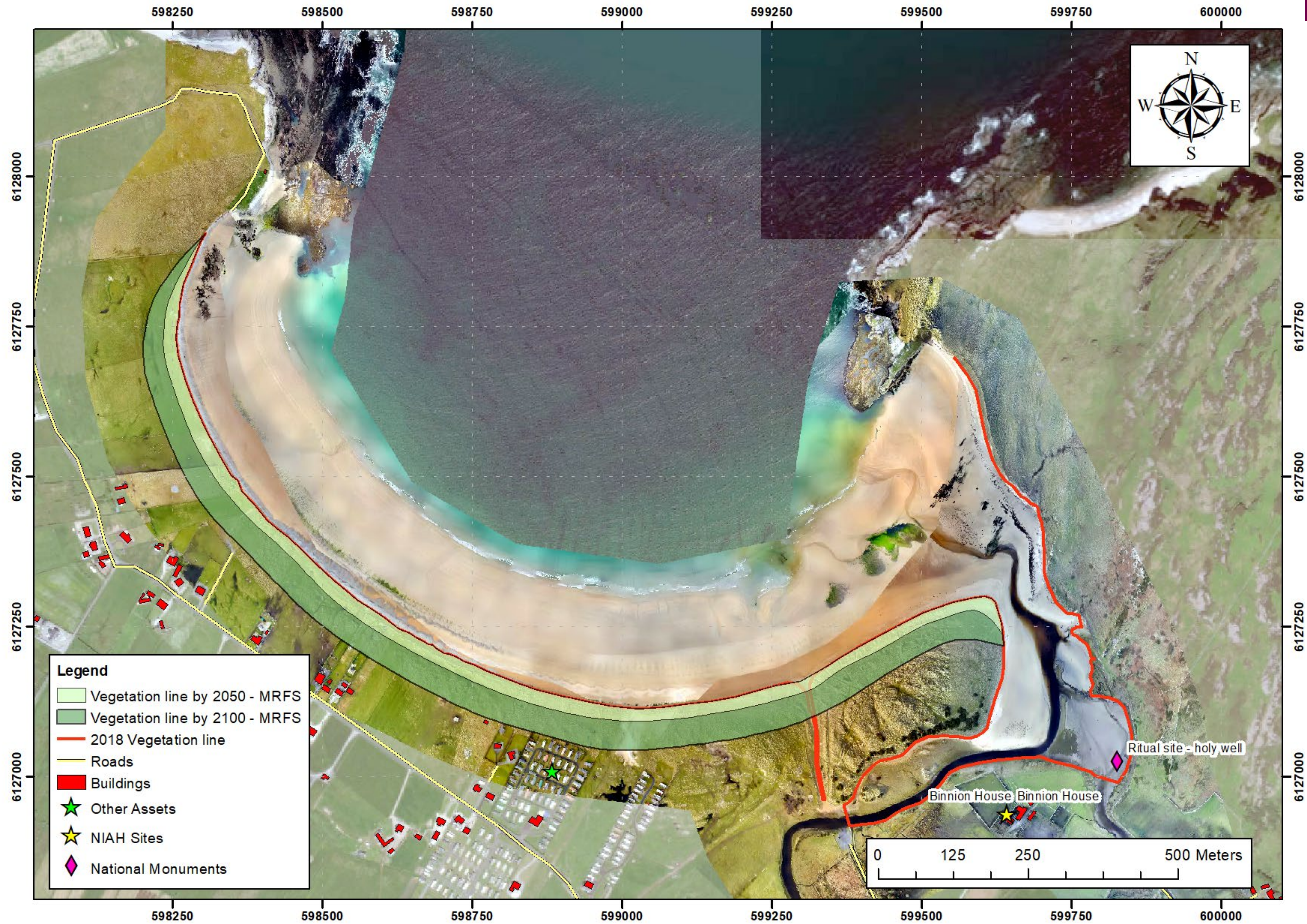

Figure 7.4: Predicted coastal change at Tullagh Bay by 2050 and 2100 under the Medium Range Future Scenario – i.e. SLR of +0.5m

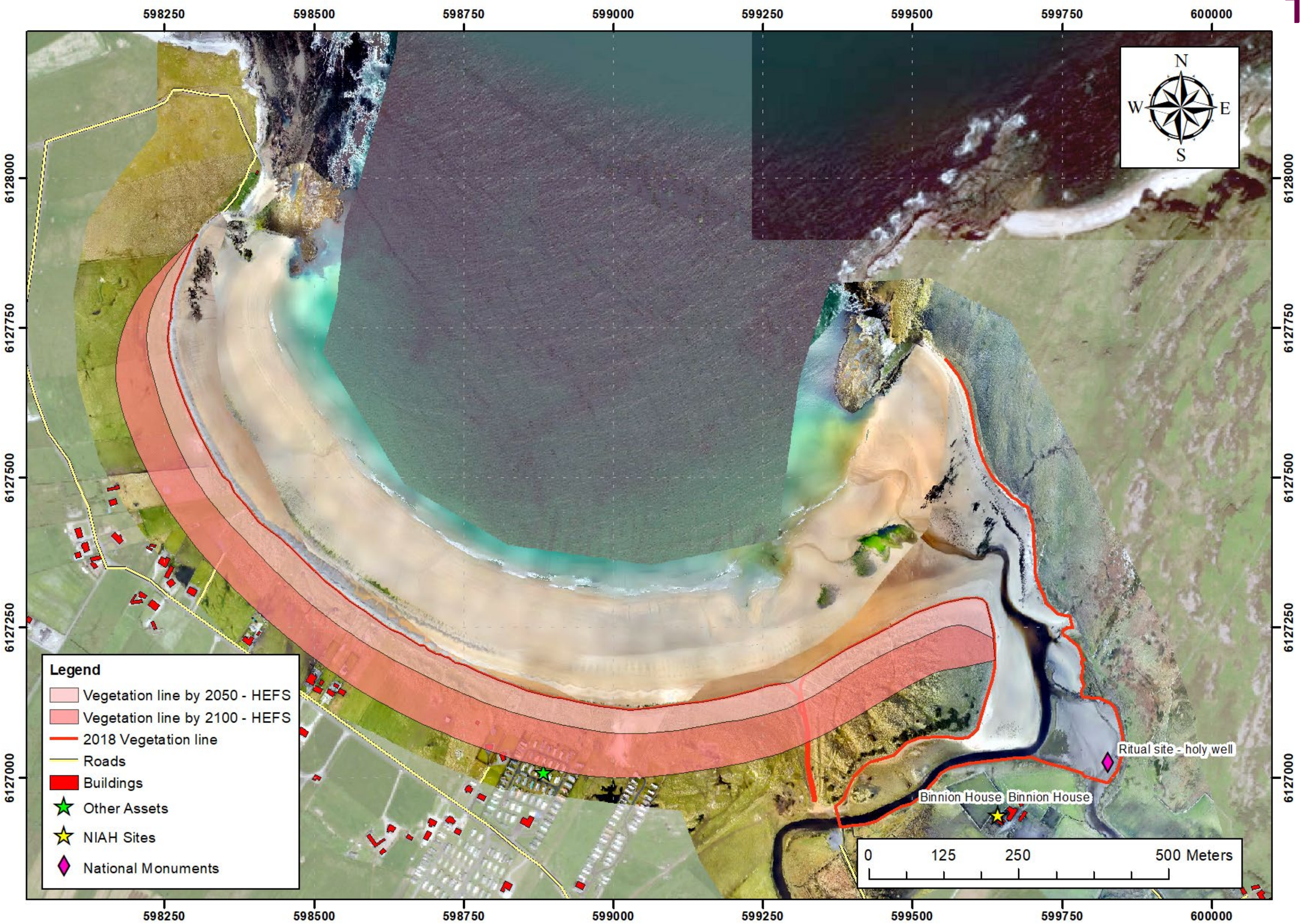

Figure 7.5: Predicted coastal change at Tullagh Bay by 2050 and 2100 under the High End Future Scenario – i.e. SLR of +1.0m

7.3.3 Coastal change at Pollan Strand

The projected extent of coastal retreat at Pollan Strand by 2050 and 2100 for the MRFS and HEFS climate change scenarios are presented in Table 7.5. The corresponding coastline evolution maps for each climate change scenario are presented in Figure 7.6 and Figure 7.7.

Table 7.5: Predicted coastal retreat at Pollan strand by 2050 and 2100 using the Equilibrium Profile and Historical Trend Analysis methods

Timescale	Equilibrium Profile / Bruun Rule		Historical Trend Analysis	
	MRFS	HEFS	MRFS	HEFS
Retreat by 2050 [m]	18	29	7	15
Retreat by 2100 [m]	28	47	12	23

As illustrated in Figure 7.6 and Figure 7.7 the effect of future coastal erosion is likely to be a relatively uniform retreat of the shoreline along the Pollan Strand. The maximum extent of coastal retreat is unlikely to affect the built assets and public carpark at the southern section of the Strand owing to the underlying hard geology. Future coastal retreat is likely to impact operations at Ballyliffin Golf Club by potentially compromising tees or greens situated on the fringe of the dune system.

The assets determined to be as risk by 2050 and 2100 under both MRFS and HEFS climate change scenarios are summarised in Table 7.6.

Table 7.6: Assets at risks at Pollan strand by 2050 and 2100 under MRFS and HEFS coastal retreat scenarios

Asset	MRFS Coastal Change		HEFS Coastal Change	
	By 2050	By 2100	By 2050	By 2100
Loss of land	50,231m^2	125,930m^2	80,233m^2	198,985m^2
Buildings	0	0	0	0
Roads	0	0	0	0
Cultural Heritage	0	0	0	0
Other	Potential impact to Ballyliffin G.C			Potential loss of access to several buildings

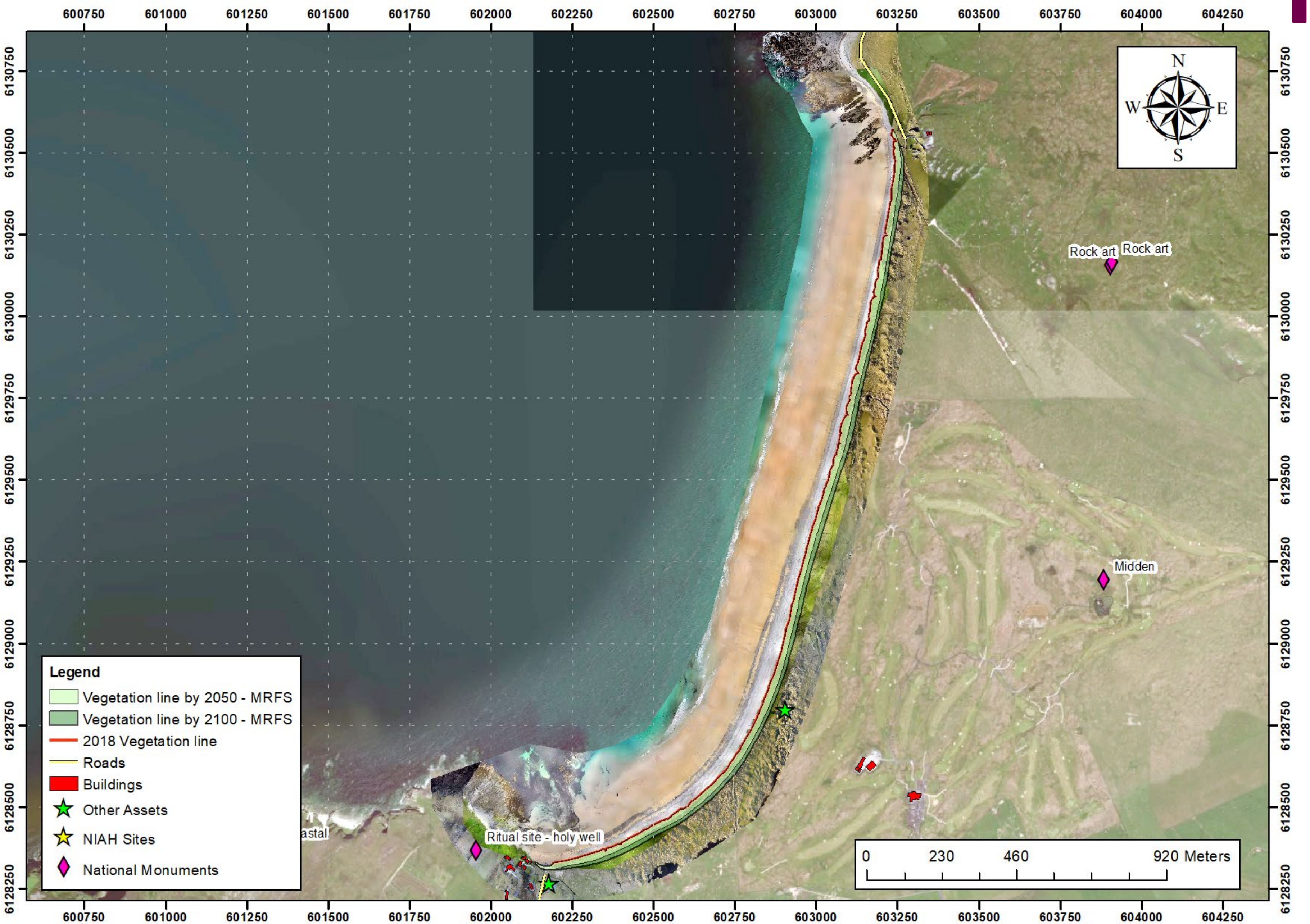

Figure 7.6: Predicted coastal change at Pollan Strand by 2050 and 2100 under the Medium Range Future Scenario – i.e. SLR of +0.5m

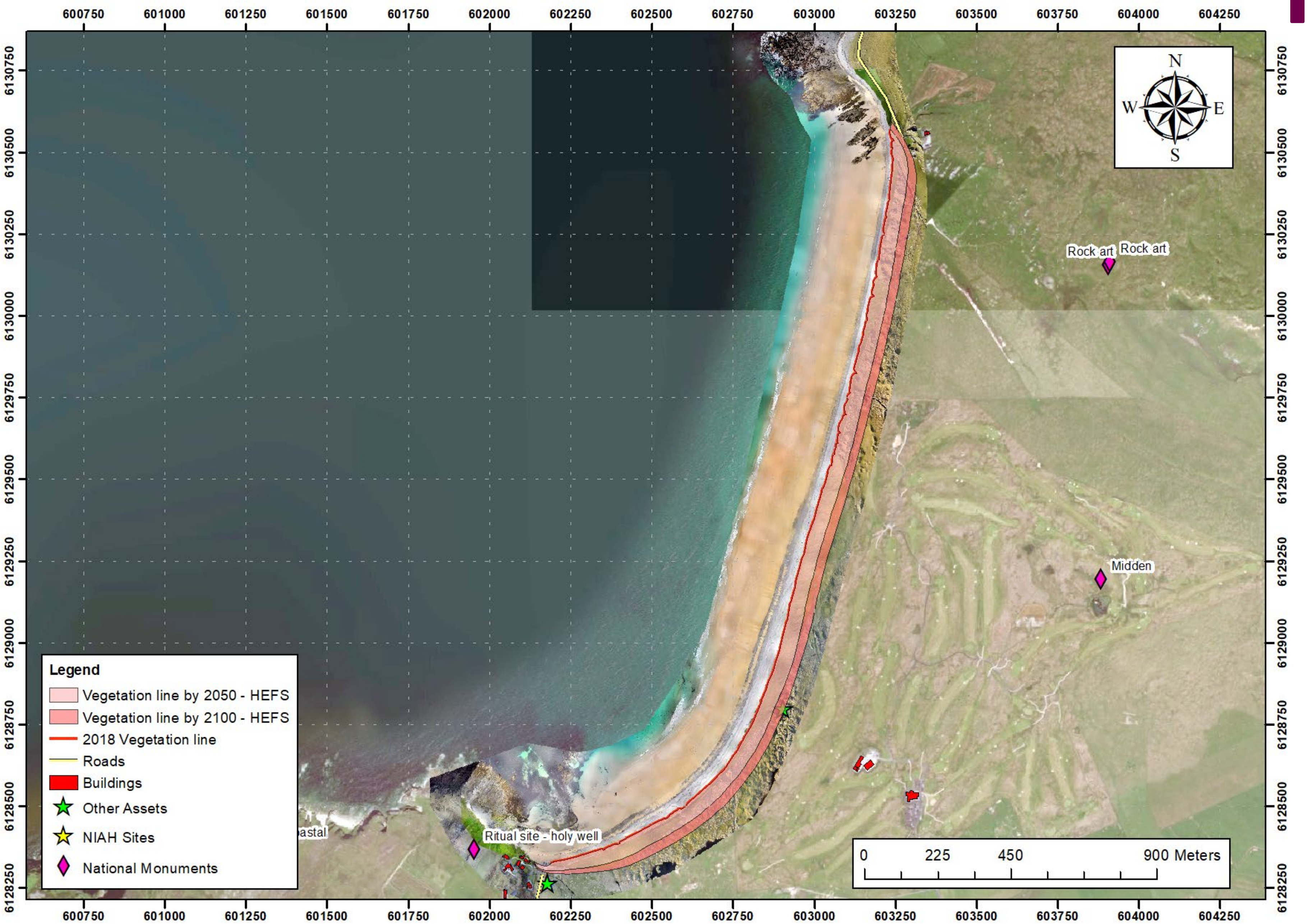

Figure 7.7: Predicted coastal change at Pollan Strand by 2050 and 2100 under the High End Future Scenario – i.e. SLR of +1.0m

7.3.4 Coastal change at Lagg beach

The projected extent of coastal retreat at Lagg Beach by 2050 and 2100 under the MRFS and HEFS climate change scenarios are presented in Table 7.7. The corresponding coastline evolution maps for each climate change scenario are presented in Figure 7.8 and Figure 7.9. Given that there is a significant difference between the projected erosion rates in able 7.7 the coastline evolution maps presented in Figure 7.8 and Figure 7.9 should be interpreted with a high degree of caution.

This is particularly relevant at Lagg beach as it is well established that the morphological processes in this area are governed by a complex exchange of sediment between the estuary, the beach and dunes that function on a multi-decadal cyclical basis (see Section 1.2.3). As such, it should be noted that the projected erosion rates and coastline evolution maps presented in this Section are considered highly conservative. It is RPS' opinion that these projections represent close to a "worst-case scenario" future rates of coastal erosion are likely to be much lower.

Table 7.7: Predicted coastal retreat at Lagg beach by 2050 and 2100 using the Equilibrium Profile and Historical Trend Analysis method

Timescale	Equilibrium Profile / Bruun Rule		Historical Trend Analysis	
	MRFS	HEFS	MRFS	HEFS
Retreat by 2050 [m]	152	254	17	34
Retreat by 2100 [m]	245	409	28	55

Despite these highly conservative projections, it will be seen from Figure 7.8 and Figure 7.9 that under the MRFS only the minor road that effectively provides access to Lagg beach is affected by coastal retreat. Under the HEFS it will be seen that the dune *could potentially* retreat as far back as St. Mary's Catholic Church. Elements of this church and graveyard are designated as a NIAH site and a National Monument (see Section 8.4). However, RPS would again stress the conservative nature of this coastline evolution projection based on the caveat above.

A summary of the assets at risk under the relevant climate change scenarios and epochs is presented in Table 7.8 below.

Table 7.8: Assets at risks at Lagg beach by 2050 and 2100 under MRFS and HEFS coastal retreat scenarios

Asset	MRFS Coastal Change		HEFS Coastal Change	
	By 2050	By 2100	By 2050	By 2100
Loss of land	226,239m^2	538,456m^2	348,367m^2	729,254m^2
Buildings	0	0	0	1
Roads	153m	626m	375m	698m
Cultural Heritage	0	0	0	Potential loss of St. Marys Church
Other	n/a	n/a	n/a	n/a

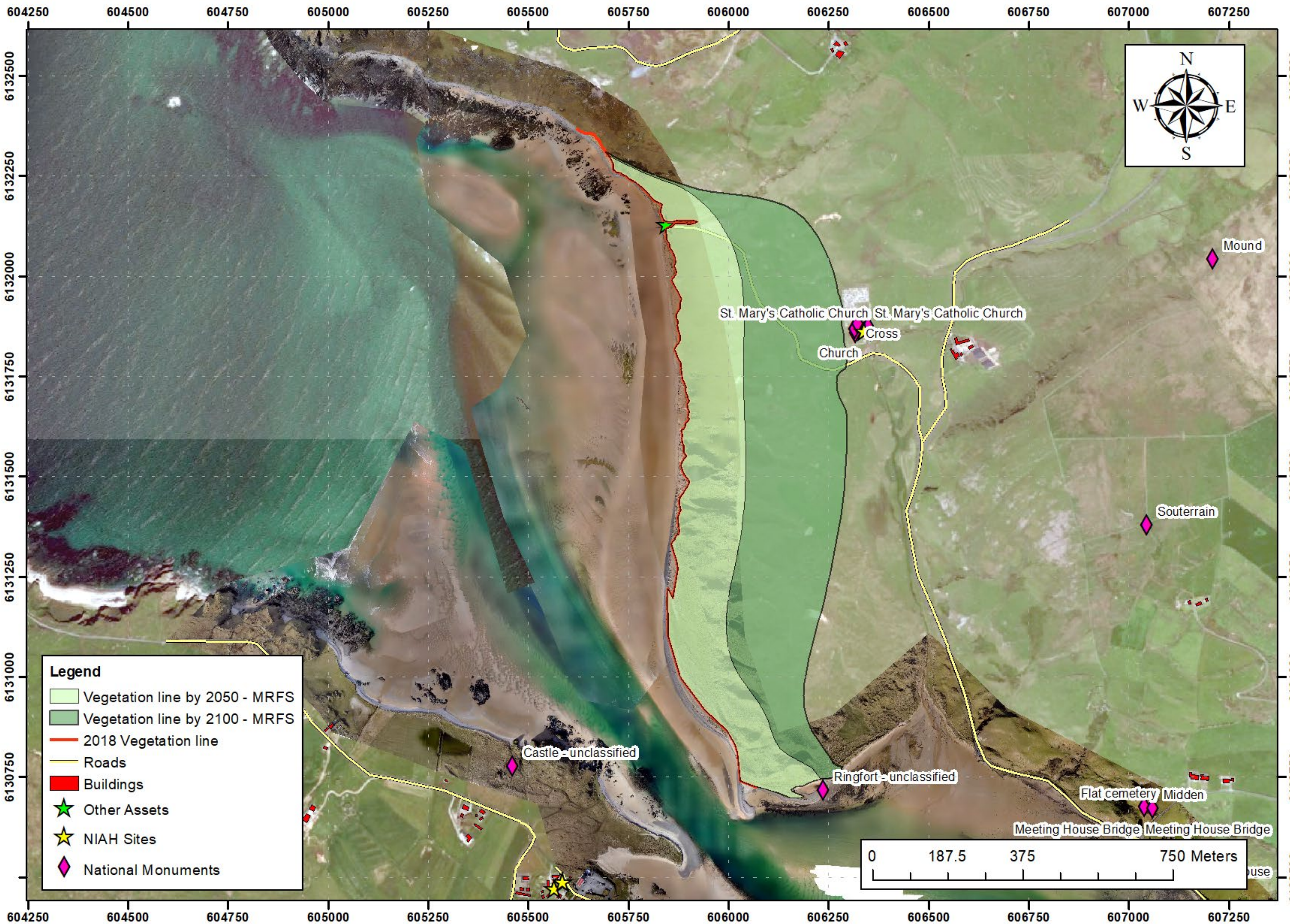

Figure 7.8: Predicted coastal change at Lagg Beach by 2050 and 2100 under the Medium Range Future Scenario – i.e. SLR of +0.5m

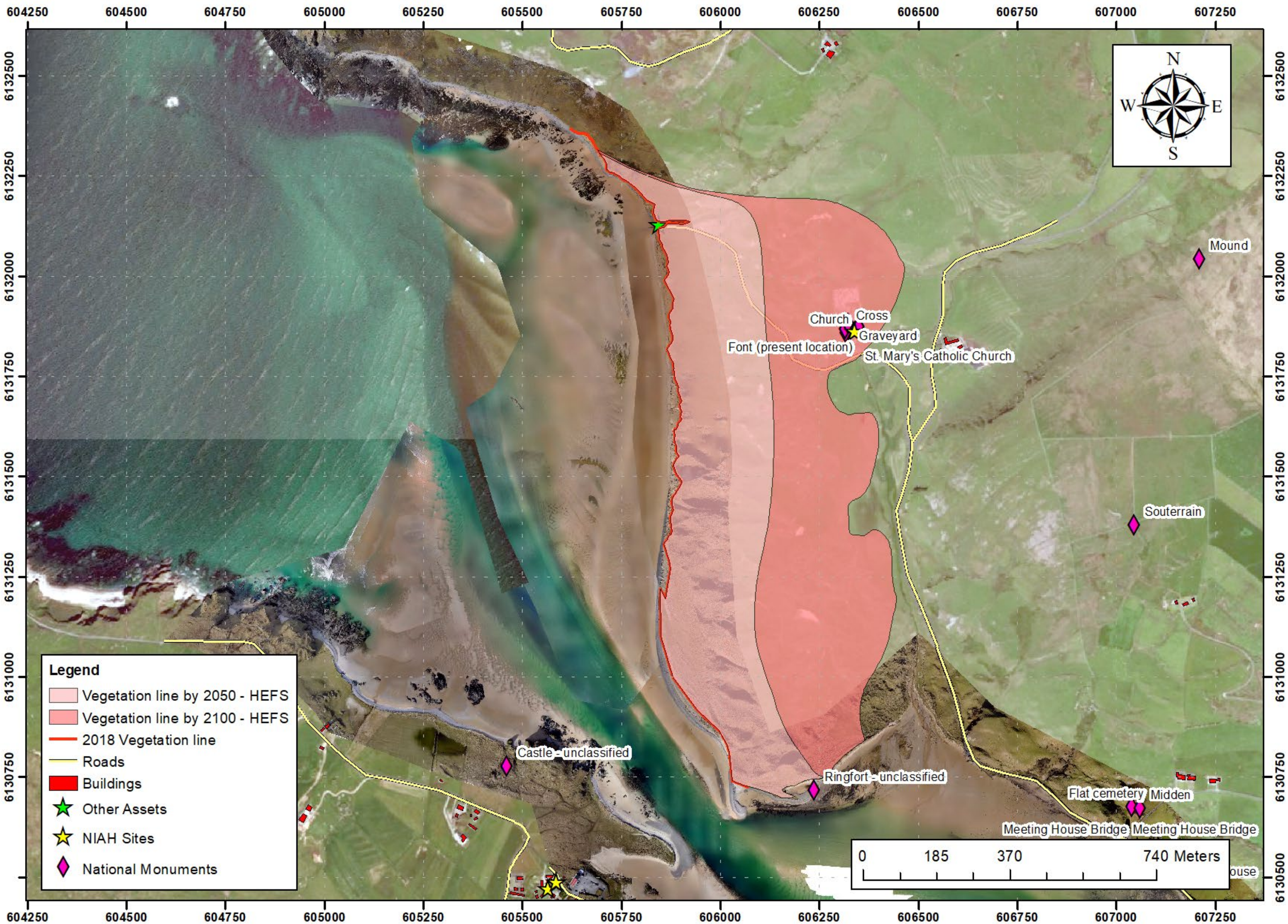

Figure 7.9: Predicted coastal change at Lagg Beach by 2050 and 2100 under the High End Future Scenario – i.e. SLR of +1.0m

7.3.5 Coastal change at Binbane Coast

The projected extent of coastal retreat at Binbane by 2050 and 2100 for the MRFS and HEFS climate change scenarios are presented in in Table 7.9. It should be noted that based on the available geological information it was determined that the maximum extent of erosion could be achieved by 2050 irrespective of the climate change scenario. As such only one coastline evolution map has been presented in this Section – this is presented Figure 7.10.

Table 7.9: Predicted coastal retreat at Binbane coast by 2050 and 2100 using the Equilibrium Profile and Historical Trend Analysis method

Timescale	Equilibrium Profile / Bruun Rule		Historical Trend Analysis	
	MRFS	HEFS	MRFS	HEFS
Retreat by 2050 [m]	31	52	17	34
Retreat by 2100 [m]	51	85	28	55

The main asset at risk of future coastal erosion is a localised section of the minor road that runs parallel to Binbane coast. The area of land affected by future coastal retreat will be limited by the underlying geology which is comprised primarily of hard rock. The assets at risk along the Binbane coast are summarised in Table 7.10 below.

Table 7.10: Assets at risks at Binbane coast by 2050 and 2100 under MRFS and HEFS coastal retreat scenarios

Asset	MRFS Coastal Change		HEFS Coastal Change	
	By 2050	By 2100	By 2050	By 2100
Loss of land	24,017m^2	24,017m^2	24,017m^2	24,017m^2
Buildings	0	0	0	1
Roads	409m	409m	409m	409m
Cultural Heritage	0	0	0	0
Other	Loss of access to sport facilities			

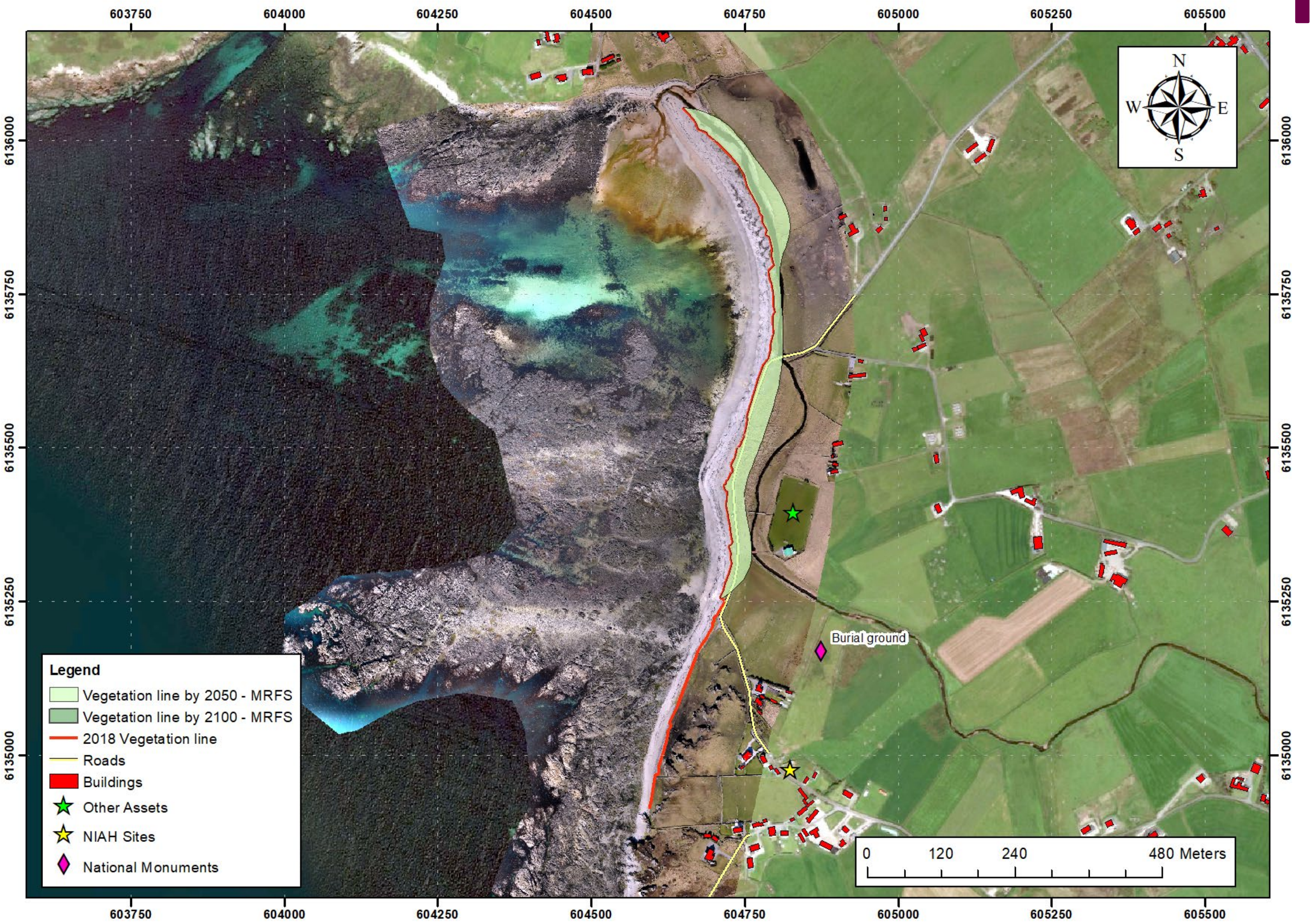

Figure 7.10: Predicted coastal change at Binbane coast by 2050 and 2100 under the Medium Range Future Scenario – i.e. SLR of +0.5m

8 PRELIMINARY ENVIRONMENTAL ASSESSMENT

The study area includes a number of areas of high ecological value, containing a variety of habitats and species of conservation concern that are protected under European and National designations. There are also several areas designated for the protection of water quality and cultural heritage assets. A desktop study was carried out to identify those areas which have been designated for the protection of these features. These designated areas are summarised in Sections 8.1 to 8.4 below.

8.1 European/International Designations

As illustrated in Figure 8.1 there is one Special Areas of Conservation (SAC) and two Special Protection Areas (SPAs) intersecting the study area and a further six SACs and three SPAs within 15km of the study area. A description and the relevance of these sites are described in further detail in the following Sections of this report.

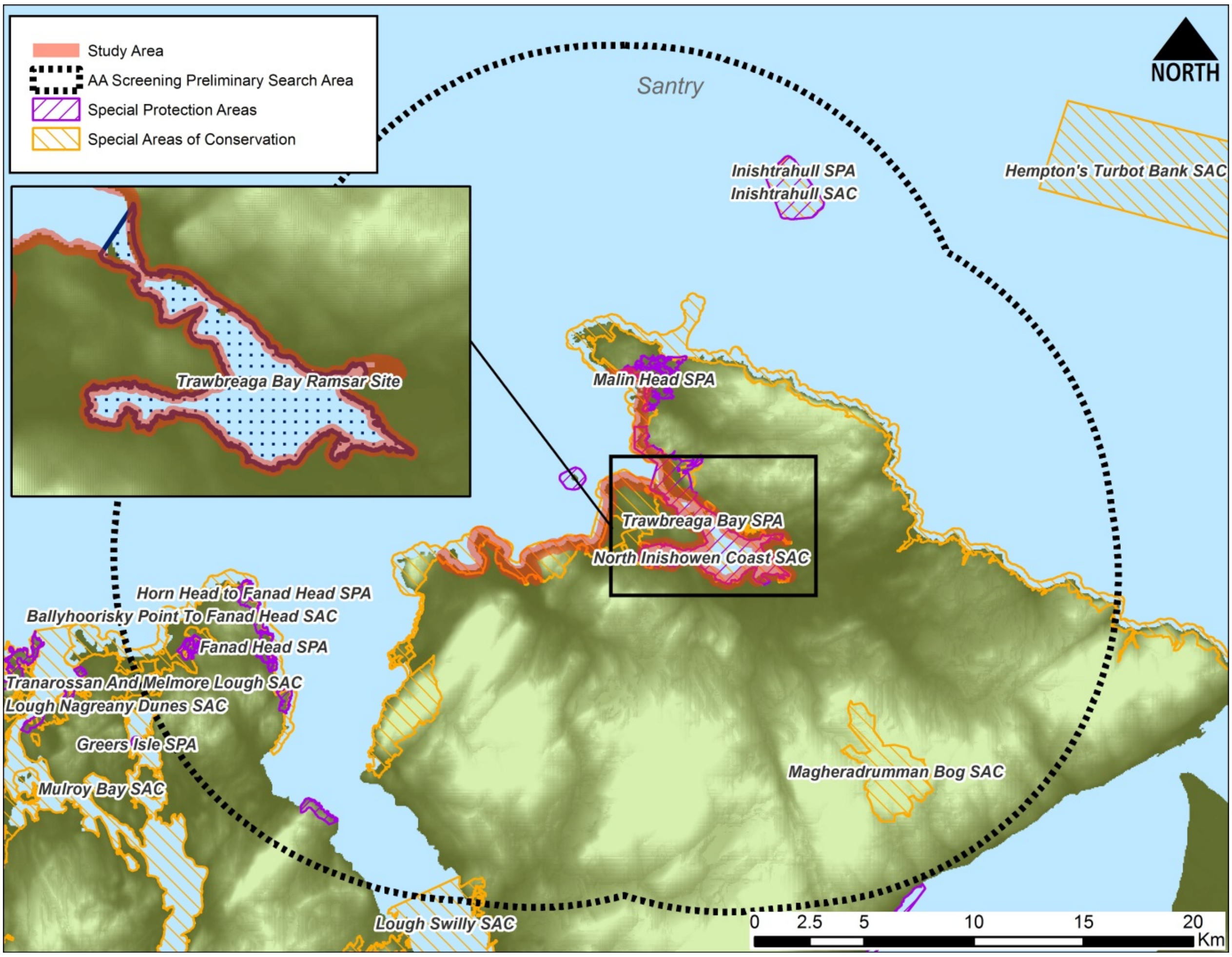

Figure 8.1: SAC, SPA and Ramsar Wetland sites surrounding the Study Area

8.1.1 Special Areas of Conservation (SACs)

Special Areas of Conservation (SAC) are prime wildlife conservation areas, considered to be important at a European as well as a National level. In Ireland, the majority of SACs are in rural areas, although a few sites reach into town or city landscapes, such as Dublin Bay, Cork Harbour and Wexford Harbour.

SACs are selected under the Habitats Directive for the conservation of a number of habitat types, which in Ireland includes raised bogs, blanket bogs, turloughs, sand dunes, machair (flat sandy plains on the north and west coasts), heaths, lakes, rivers, woodlands, estuaries and sea inlets. The Directive also affords protection to 25 species of flora and fauna, including Salmon, Otter, Freshwater Pearl Mussel, Bottlenose Dolphin and Killarney Fern. Collectively, these are known as Annex I habitats (including priority types which are in danger of disappearance) and Annex II species (other than birds).

8.1.2 Special Protection Areas (SPAs)

Special Protection Areas (SPA) are conservation areas which are important sites for rare and vulnerable birds (as listed on Annex I of the Birds Directive) and/or for regularly occurring migratory species. SPAs are designated under the ‘Birds Directive’ (Council Directive 2009/147/EC - codified version of Directive 79/409/EEC on the Conservation of Wild Birds, as amended).

Ireland’s SPA network encompasses over 5,700km² of marine and terrestrial habitats. The marine areas include some of the productive intertidal zones of bays and estuaries that provide vital food resources for several wintering wader species. Marine waters adjacent to breeding seabird colonies and other important areas for sea ducks, divers and grebes are also included in the network. The remaining areas of the SPA network include inland wetland sites important for wintering water birds and extensive areas of blanket bog and upland habitats that provide breeding and foraging resources for species including Merlin and Golden Plover.

Agricultural land also represents a share of the SPA network, ranging from the extensive farmland of upland areas where its hedgerows, wet grassland and scrub offer feeding and/or breeding opportunities for Hen Harrier to the intensively farmed coastal polder land where internationally important numbers of swans and geese occur. Coastal habitats including Machair are also represented in the network, which are of high importance for Chough and breeding Dunlin.

8.1.3 Ramsar Wetlands

Ramsar Sites are designated for the protection of wetland areas (which are important feeding habitats for birds) under the ‘Convention on Wetlands of International Importance’ which took place in Ramsar, Iran in 1971. In Ireland, all Ramsar sites have also been recognised as SPA and/or SAC areas and so are afforded protection by the European Communities (Birds and Natural Habitats) Regulations 2011.

There is one Ramsar site in the study area, Trawbreaga Bay, which is within the Trawbreaga Bay SPA.

8.1.4 OSPAR Marine Protected Areas

OSPAR Marine Protected Areas (MPA) sites are identified under the OSPAR Convention to protect the marine environment of the North East Atlantic. Ireland has identified a number of its SACs as OSPAR MPAs for marine habitats. Two of these MPAs occur in the waters surrounding County Donegal, but neither is within the study area. The nearest OSPAR MPA is at Mulroy Bay SAC, around 17km west of the study area.

8.2 National Designations

8.2.1 Natural Heritage Areas (NHAs) and proposed Natural Heritage Areas (pNHAs)

Natural Heritage Areas (NHAs) are designated under the Wildlife Act (1976 - 2000). They are considered as notable habitats which support animals or vegetation of importance.

There are 12 NHAs in County Donegal, of which four are on the Inishowen Peninsula, however none are coastal sites. The nearest NHA to the study area is Slieve Snaght Bogs NHA which is located approximately 6km south of Trawbreaga Bay.

Proposed Natural Heritage Areas (pNHAs) were published on a non-statutory basis in 1995, but have not since been statutorily proposed or designated. All pNHAs are subject to limited statutory protection, but are recognised for their ecological value by planning and licensing authorities. The pNHAs in the study area and its surroundings are shown in Figure 8.2.

There are 67 pNHAs in County Donegal, of which nine are on or adjacent to the Inishowen peninsula. One pNHA, North Inishowen Coast, intersects with the study area. A second pNHA, Glashedy Island, is located a short distance offshore from the study area.

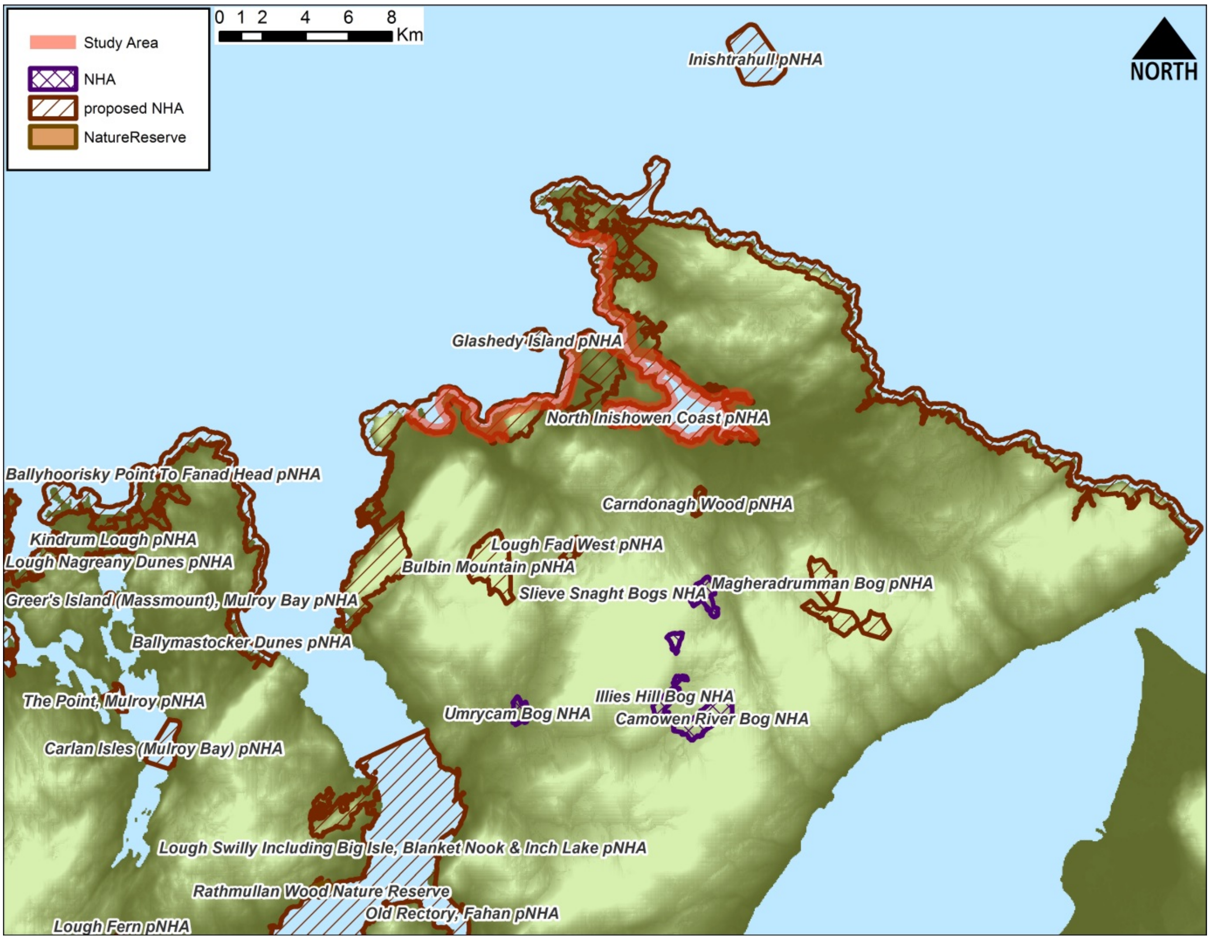

Figure 8.2: NHAs, pNHAs and Nature Reserves surrounding the Study Area

8.2.2 Other National Designations

- **Nature Reserves -** These sites are identified as being important habitats to support wildlife and are protected under Ministerial Order. There are seven nature reserves in Co. Donegal but none are located within the study area. The nearest nature reserve to the study area is Rathmullan Wood, located on the western shore of Lough Swilly, around 20km southwest of the study area.

- **National Parks** - These sites are established under the International Union for the Conservation of Nature and are areas identified as being not materially altered by human exploitation and occupation and where steps have been taken to prevent exploitation or occupation in respect of ecological, geomorphological or aesthetic features. There are no national parks on the Inishowen Peninsula.

8.3 Water Quality Designations – The Water Framework Directive (WFD)

The 'Water Framework Directive' (Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy) establishes a framework for the protection of all waters including rivers, lakes, estuaries, coastal waters and groundwater, and their dependent wildlife/habitats under one piece of environmental legislation. Specifically the WFD aims to:

- Protect/enhance all waters (surface, ground and coastal waters)
- Achieve "good status" for all waters by December 2015 (where technically feasible; in some areas extended deadlines to 2021 or 2027 apply)
- Manage water bodies based on river basins or catchments; and
- Involve the public.

The implementation of the WFD has included the identification and establishment of eight River Basin Districts throughout Ireland. The study area is located in the North Western River Basin District (RBD) which is an international RBD, shared with Northern Ireland.

River Basin Management Planning takes an integrated approach to the protection, improvement and sustainable management of the water environment. The planning process revolves around a six year planning cycle of action and review, so that every six years a revised river basin management plan is produced. In the first cycle of River Basin Management (2009-2015) each River Basin Management Plan described the classification results for its waterbodies and identified measures that can be introduced in order to safeguard waters and meet the environmental objectives of the WFD.

The North Western River Basin Management Plan (RBMP) (2009-2015) was developed to satisfy the requirements of the WFD and has classified all waterbodies according to their chemical, biological and hydromorphological status ranging from bad to high, based on monitoring data collected between 2007 and 2009. The RBMP aims to protect all waters within the district, and where necessary improve all waters so that they reach 'Good Ecological Status' by 2015 and avoid any deterioration in status. Extended deadlines to achieve good status, to either 2021 or 2027, are needed in some areas due to technical, economic, environmental or recovery constraints.

For the 2nd WFD Cycle 2015-2021, the Eastern, South Eastern, South Western, Western and Shannon River Basin Districts will be merged to form one national River Basin District with a corresponding National River Basin Plan. In relation to the North Western and Neagh Bann International River Basin Districts (IRBDs), a single administrative area will be established in the Republic of Ireland portion of these two IRBDs for the purpose of coordinating their management with authorities in Northern Ireland.

While this rearrangement will lead to efficiencies in relation to matters such as assessment and reporting, regionalised administrative structures will be put in place to support implementation (e.g. river basin district characterisation, the development of programmes of measures, enforcement, public consultation and awareness activities).

The most recent status of rivers, lakes, transitional and coastal waterbodies within the catchment area published at the end of the 2009-2015 monitoring cycle, are summarised below and shown in Figure 8.3.

The coastal waterbodies of Trawbreaga Bay and the Northern Atlantic Seaboard (HAs 40; 02) have 'unassigned' status for this period, meaning that there is insufficient confidence in the data collected to assign a status. However, these coastal waterbodies are considered to be 'not at risk' of achieving good ecological status by the deadline.

The river waterbody draining in to the Binbane coastal road area has been assigned 'good ecological status' and is 'not at risk' of deteriorating as shown in Figure 8.4. The smaller rivers and stream draining to the Five Finger Strand and Lagg areas of interest are not assigned a status but are reported as being under review for risk of not achieving good ecological status.

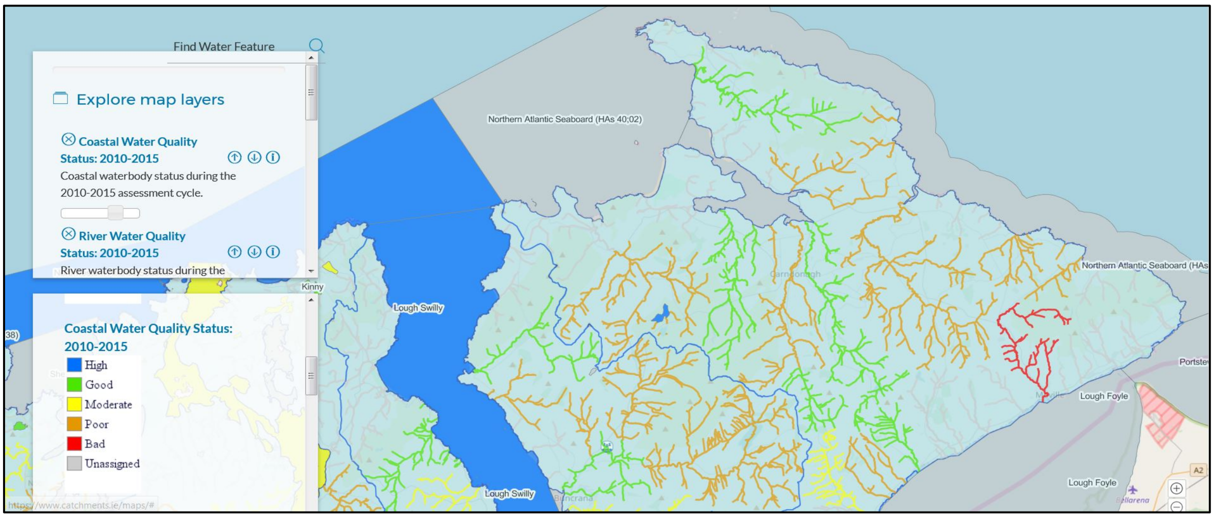

Figure 8.3: WFD River, Lake, Transitional and Coastal Waterbody Status 2010-2015 (courtesy of *www.catchments.ie/maps/*)

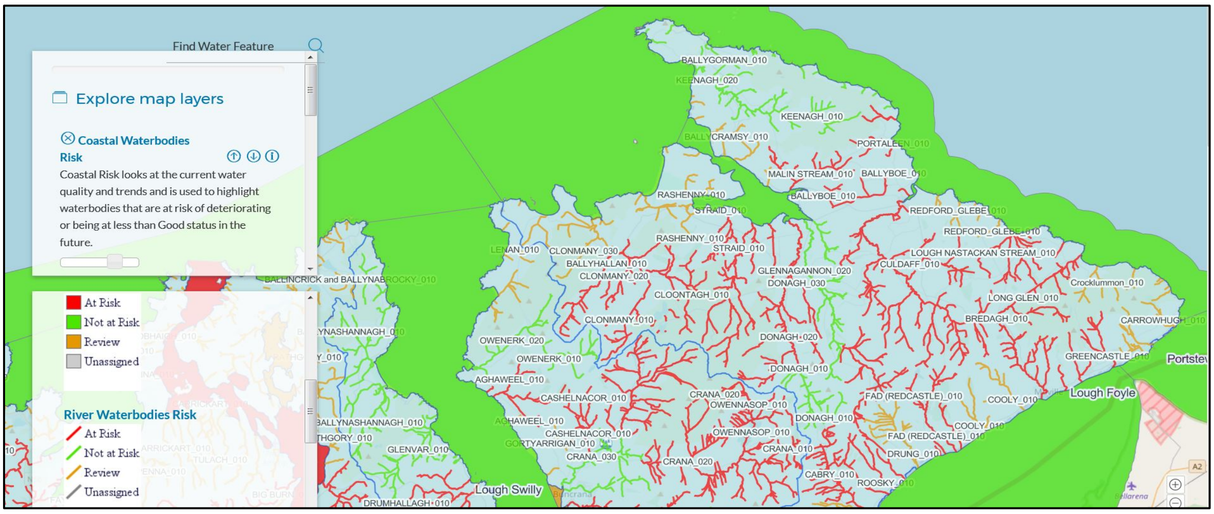

Figure 8.4: WFD River, Lake, Transitional and Coastal Waterbody Risk (courtesy of *www.catchments.ie/maps/*)

The river waterbodies draining into Trawbreaga Bay are a mixture of poor to good ecological status. Only two river waterbodies are deemed ‘not at risk’ of maintaining their current good ecological status with the remainder classified as either ‘at risk’ or under review.

The river waterbodies at Ballyliffin, Tullagh Bay and Rockstown Harbour have an unassigned status and are under review for risk.

Construction activity within the study area has the potential to impact water quality and morphological status and must therefore be sustainably managed. The majority of land surrounding the study area is generally used for agriculture (principally pasture or moor/heath grazing).

8.3.1 Register of Protected Areas (RPA)

In accordance with the requirements of the WFD and the associated national regulations, the EPA has compiled a Register of Protected Areas (RPA). The protected areas are identified as those requiring special protection under existing national or European legislation, either to protect their surface water or groundwater, or to conserve habitats or species that directly depend on those waters. The EPA is responsible for maintaining and updating the register as needed.

The various categories included in the RPA are outlined in Sections 8.3.2 - 8.3.4. Selected entries on RPA entries are shown in Figure 8.5.

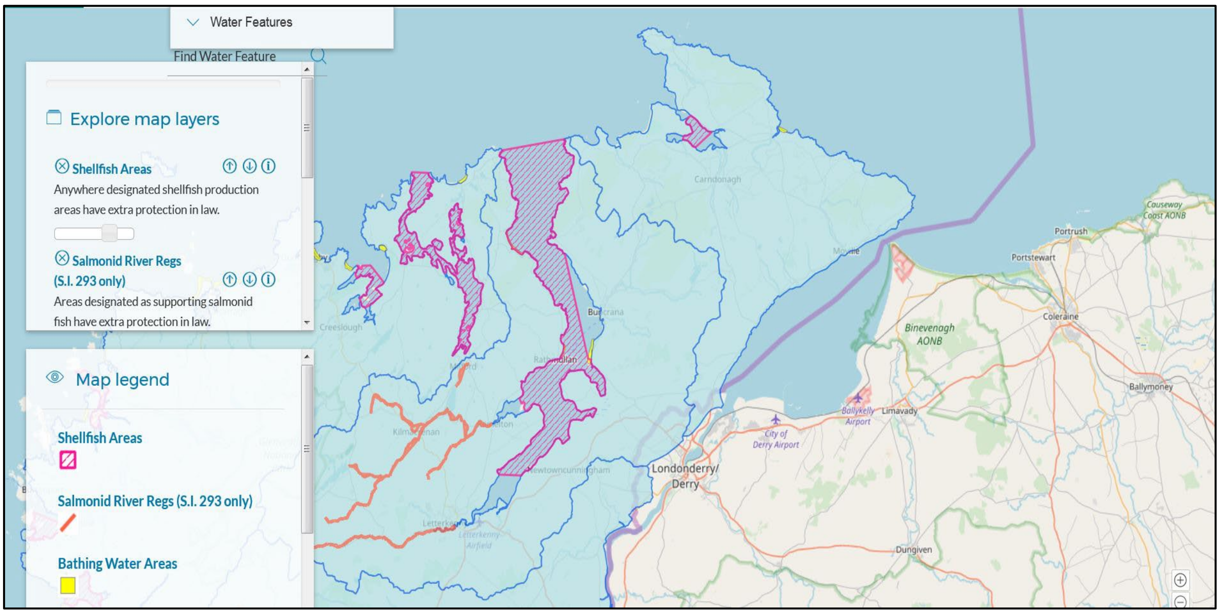

Figure 8.5: RPA entries around the Study Area (courtesy of *www.catchments.ie/maps/*)

8.3.2 Waters used for the Abstraction of Drinking Waters

Drinking water safeguard zones are designated areas which must be carefully managed to prevent the pollution of raw water sources (including groundwater) that are used to provide drinking water. The majority of groundwater in Ireland, including the catchment of East Inishowen, is included in the RPA. There are no rivers in Inishowen on the RPA however there is one lake, Lough Fad (Meendoran), which is around 6km south of Pollan Strand, Ballyliffin.

8.3.3 Areas designated to protect Economically Significant Aquatic Species

These are protected areas established under earlier EC directives aimed at protecting shellfish (79/923/EEC) and freshwater fish (78/659/EEC).

The Directive requires Member States to designate waters that need protection in order to support shellfish life and growth. It also sets physical, chemical and microbiological requirements that designated shellfish waters must either comply with or endeavour to improve. There are 64 sites in Ireland that are designated shellfish areas. Within the study area, part of Trawbreaga Bay has been designated as a Shellfish Area (Figure 8.5).

Certain rivers were designated under the EU Freshwater Fish Directive (78/659/EEC) (transposed into Irish law under S.I. No. 293/1988 - European Communities (Quality of Salmonid Waters) Regulations, 1988) as “salmonid waters”. The objective of this designation type was for the maintenance of water quality for salmon and trout freshwater species. The Freshwater Fish Directive has now been subsumed into the Water Framework Directive; however salmonid rivers remain on the register of protected areas. There are no rivers designated for salmonids on the Inishowen peninsula.

8.3.4 Areas designated for the Protection of Habitats or Species

These are areas designated for the protection of habitats or species where the maintenance or improvement of the status of water is an important factor in their protection. These are designated under the Birds Directive (79/409/EEC) and the Habitats Directive (92/43/EEC) and have been discussed previously in Sections 8.1.1 and 8.1.2.

8.3.5 Aquaculture and Fisheries

A number of sites within Trawbreaga Bay are licensed for aquaculture, with Oyster being the sole species cultivated via both extensive and intensive methods. The shellfish produced in Trawbreaga Bay are Class A from 01 December - 01 March (meaning they are able to go direct for human consumption) and Class B for the remainder of the year (meaning they must be depurated, heat treated or relayed to meet Class A requirements).

Data gathered by the Marine Institute in 2013 for Natura 2000 risk assessment shows that Trawbreaga Bay is dredged for cockles and the inshore area is pot fished for Lobster and Crab and line fished for Pollack and Mackerel.

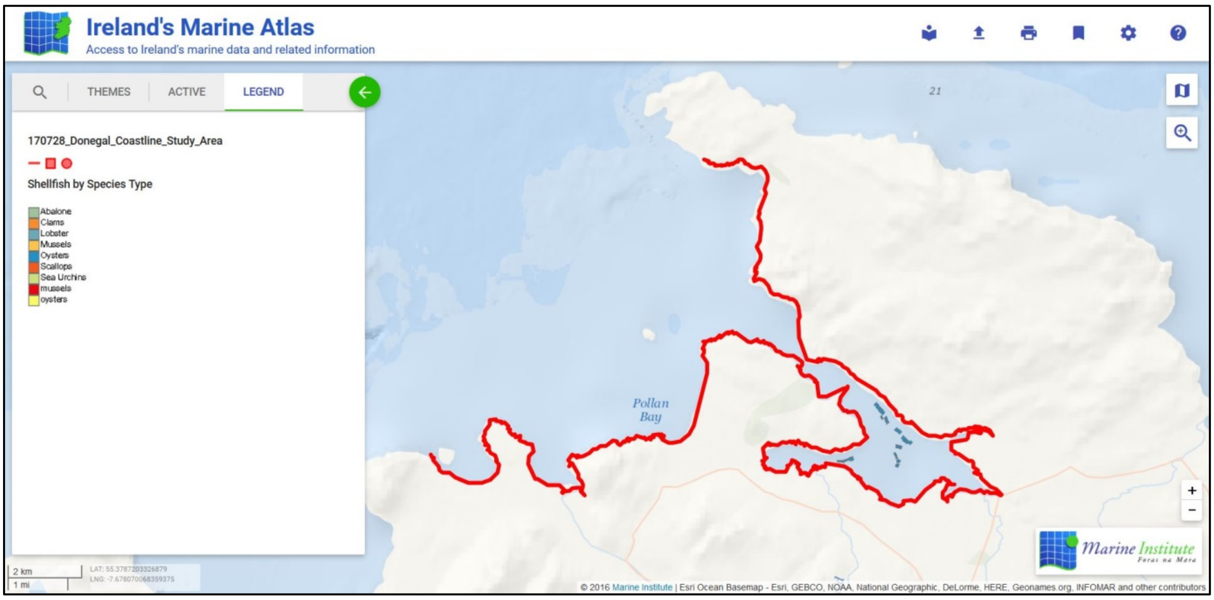

Figure 8.6: Aquaculture Licensed Sites 2017 from Marine Atlas (courtesy of *https://atlas.marine.ie/ DAFM Theme*)

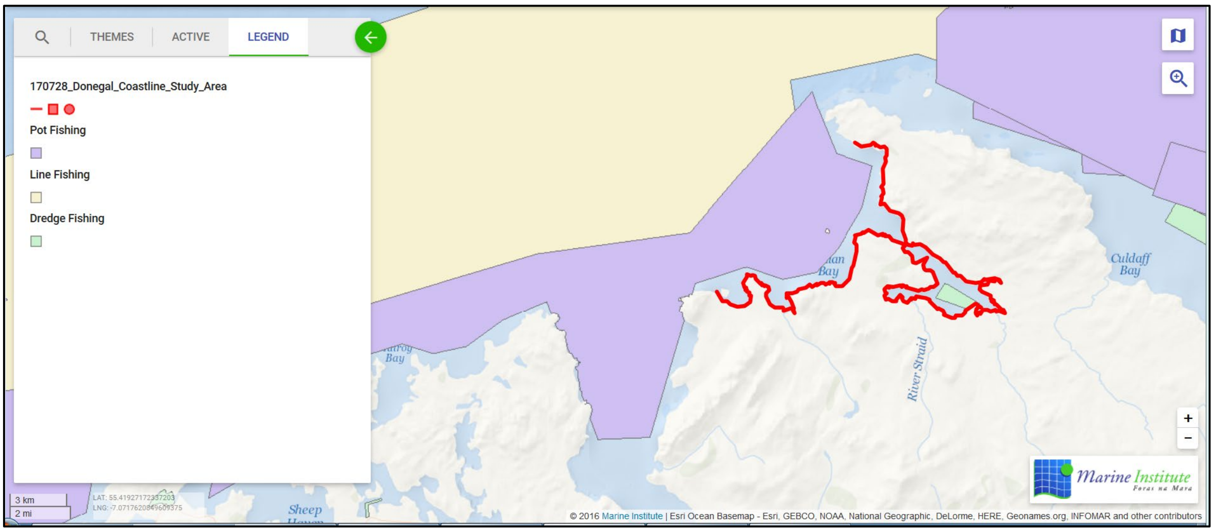

Figure 8.7: Inshore Fishing Activity (Marine Institute) 2013 from Marine Atlas (courtesy of *https://atlas.marine.ie/ DAFM Theme*)

8.4 Cultural Heritage

The implementation of coastal management measures has the potential to affect features of archaeological or architectural heritage value, e.g. altering views of ancient landscapes or causing damage to structures by collision, excavation or vibration during construction activities.

The study area and its surroundings host a variety of archaeological and architectural heritage sites which are afforded varying levels of protection under national legislation such as the National Monuments Acts (1930 to 2004) and the Planning and Development Act (2000) as amended. Figure 8.8 below shows the location of sites listed by the National Monuments Service as Records of Monuments and Places (RMP) and National Inventory of Architectural Heritage (NIAH).

Figure 8.8: Location of RMP and NIAH Sites within the Study Area

Records of Monuments and Places (RMP) – the National Monuments Service (www.archaeology.ie) holds responsibility for maintaining this inventory of sites of archaeological significance which pre-date the 18th Century (including records of those which historically have been destroyed). These sites are established under the National Monuments Acts. Figure 8.8, shows that the study area and its surroundings currently contains approximately 22 entries on the RMP. The entries are not located on any of the coastlines involved in this study.

The National Inventory of Architectural Heritage (NIAH) – this is a record of sites of architectural heritage importance in Ireland dating from the start of the eighteenth century up to the present day which is established under the Architectural Heritage (National Inventory) and Historic Monuments (Miscellaneous Provisions) Act, 1999. The National Inventory of Architectural Heritage also maintains an inventory of historic gardens and demesnes. Figure 8.8 presents unique records of either local or regional significance on the NIAH, of these 7 are located within 500m of the study area. These include 6 houses built between 1820 and 1915 and St Mary's Catholic Church. The Planning and Development Act 2000 requires Local Authorities to compile a "Record of Protected Structures" as part of the County Development Plan. These are structures, or part thereof, which are considered to be of architectural value. Many of these structures also appear on the NIAH list and can be water-related features such as bridges, weirs, walls and embankments.

Shipwrecks - Wrecks over 100 years old and archaeological objects found underwater are protected under the National Monuments (Amendment) Acts 1987 and 1994. Significant wrecks less than 100 years old can be designated by Underwater Heritage Order (UHO) on account of their historical, archaeological or artistic importance. The Shipwreck Inventory of Ireland includes all known wrecks for the years up to and including 1945 and approximately 12,000 records have been compiled and integrated into the shipwreck database thus far. An investigation on the position of wrecks located offshore of the study area showed several wrecks (including Saldanha, Lobella II and Emerald) which are located within a 20km radius.

8.5 Environmental Assessments

This section outlines the potential need for further environmental assessments or impact statements in relation to any proposed coastal protection works within the study area. Further environmental assessments required may include Strategic Environmental Assessment (SEA), Environmental Impact Assessment (EIA) and Appropriate Assessment (AA).

8.5.1 Strategic Environmental Assessment (SEA)

The Strategic Environmental Assessment (SEA) Directive (2001/42/EC) requires European Union (EU) member states to undertake SEA for certain plans and programmes. SEA is the process by which environmental considerations are required to be fully integrated into the preparation of plans and programmes. The SEA process is broadly comprised of the steps summarised in Table 8.1 below.

Table 8.1: Summary description of the main stages in the SEA process

Stage	Initial Review
Screening	Determines whether SEA is required for a Plan / Programme, in consultation with the designated statutory consultees.
Scoping	Determines the scope and level of detail of the assessment for the SEA, in consultation with the designated statutory consultees.
Environmental Assessment	Formal and transparent assessment of the likely significant impacts on the environment arising from the Plan / Programme, including all reasonable options. The output from this is an Environmental Report which must go on public display.
SEA Statement	Summarises the process undertaken and identifies how environmental considerations and consultations have been integrated into the final Plan / Programme.

Under the EPA Guidance the first step of the SEA Screening Process, Task 1.1, is a pre-screening check. This step involves the use of the decision tree presented in Figure 2 of the EPA publication "Development of Strategic Environmental Assessment (SEA) Methodologies for Plans and Programmes in Ireland". This decision tree allows for rapid screening-out of those plans and programmes that are clearly not going to have any environmental impact and screening-in of those that definitely do require SEA. Cognisant of this guidance it was found that an SEA would unlikely be required for this project as the final CERM plan only applies to a number of small scale, localised areas and will not form a statutory document that informs policy.

8.5.2 Environmental Impact Assessment (EIA)

The Fifth Schedule of the Planning and Development Regulations, 2001 (SI No 600 of 2001) sets out a comprehensive list of project types subject to Environmental Impact Assessment (EIA) for the purposes of the Regulations. Part II - Section 10(k) lists

"Coastal work to combat erosion and maritime works capable of altering the coast through the construction, for example, of dikes, moles, jetties and other sea defence works, where the length of coastline on which works would take place would exceed 1 kilometre, but excluding the maintenance and reconstruction of such works or works required for emergency purposes".

Any management option other than "No Active Intervention ('Do-nothing')" may fall under Schedule 5 Part II. Projects listed under part II require an EIA determination to be made about their likely significant environmental effects.

As a first step, an EIA screening should be undertaken for any proposed management option. The EIA screening report should include a review of any proposed management option including its plans/ design drawings, and an assessment of potential environmental impacts. Donegal County Council as the relevant competent authority should then evaluate the EIA screening report and assess the likelihood of the project in having a significant effect on the environment with reference to its scale, nature, location and context. Where it is concluded by Donegal County Council that there is a likelihood of significant environmental impacts, a brief report (or screening decision) that sets out the basis of the conclusions and explicitly states that an EIA is required should be prepared.

If it is concluded that an EIA is required, an EIA Scoping should then be undertaken by Donegal County Council, to determine the extent of issues to be considered in the assessment and reported in the Environmental Statement.

8.5.3 Appropriate Assessment (AA)

The Council Directive 92/43/EEC on the Conservation of Natural Habitats and of Wild Fauna and Flora, better known as "The Habitats Directive", provides legal protection for habitats and species of European importance. Articles 3 to 9 provide the legislative means to protect habitats and species of Community interest through the establishment and conservation of an EU-wide network of sites known as Natura 2000.

Articles 6(3) and 6(4) of the Habitats Directive set out the decision-making tests for plans and projects likely to have a significant effect on or to adversely affect the integrity of Natura 2000 sites (Annex 1.1). Article 6(3) establishes the requirement for AA:

"Any plan or project not directly connected with or necessary to the management of the [Natura 2000] site but likely to have a significant effect thereon, either individually or in combination with other plans or projects, shall be subjected to appropriate assessment of its implications for the site in view of the site's conservation objectives. In light of the conclusions of the assessment of the implications for the site and subject to the provisions of paragraph 4, the competent national authorities shall agree to the plan or project only after having ascertained that it will not adversely affect the integrity of the site concerned and, if appropriate, after having obtained the opinion of the general public."

Article 6(4) states:

"If, in spite of a negative assessment of the implications for the [Natura 2000] site and in the absence of alternative solutions, a plan or project must nevertheless be carried out for imperative reasons of overriding public interest, including those of a social or economic nature, Member States shall take all compensatory measures necessary to ensure that the overall coherence of Natura 2000 is protected. It shall inform the Commission of the compensatory measures adopted. "

In Ireland, European sites, include Special Protection Areas (SPAs), designated under the Conservation of Wild Birds Directive (79/409/ECC) as codified by Directive 2009/147/EC (EU Birds Directive), and Special Areas of Conservation (SACs) are established under the Habitats Directive for habitats and species.

Donegal County Council, in its role as the Competent Authority, is obliged to examine the likely significant effects, individually or in combination with other plans and projects, of the proposal on European sites in light of their specific qualifying interests/special conservation interests and conservation objectives. Donegal County Council should first undertake a screening for Appropriate Assessment that addresses and records the reasoning and conclusions in relation to Article 6(3) of the Habitats Directive which is outlined above.

European sites that have the potential to be affected by the proposed works have been identified as part of this preliminary environmental assessment. All European sites located within 15km of the study area are presented in Figure 8.1. A 15km buffer zone has been chosen as a precautionary measure, to ensure that all potentially affected European sites are included in the screening process, which is in line with *Appropriate Assessment of Plans and Projects in Ireland – Guidance for Planning Authorities* produced by the Department of the Environment, Heritage and Local Government. As shown in Figure 8.1, the study area is located within 15km of seven SAC sites and five SPA sites.

Due to the location of the 5 sites in relation to the designated sites, any management option other than “No Active Intervention (‘Do-nothing’)” will have to undergo the process of Appropriate Assessment.

8.6 Recommendations

8.6.1 Strategic Environmental Assessment

Cognisant guidance published within the EPA’s publication “Development of Strategic Environmental Assessment (SEA) Methodologies for Plans and Programmes in Ireland” RPS concluded that an SEA would unlikely be required for this project as the final CERM plan only applies to a number of small scale, localised areas and will not form a statutory document that informs policy.

8.6.2 Appropriate Assessment

As highlighted above, the proposed site is situated within and adjacent to a number of SAC and SPA sites. Any management option other than “No Active Intervention (‘Do-nothing’)” will therefore have to undergo the process of Appropriate Assessment.

8.6.3 Environmental Impact Statement

Fifth Schedule of the Planning and Development Regulations, 2001 (SI No 600 of 2001) sets out a comprehensive list of project types subject to Environmental Impact Assessment (EIA) for the purposes of the Regulations. Section 10(k) lists

“Coastal work to combat erosion and maritime works capable of altering the coast through the construction, for example, of dikes, moles, jetties and other sea defence works, where the length of coastline on which works would take place would exceed 1 kilometre, but excluding the maintenance and reconstruction of such works or works required for emergency purposes”.

As the 1km threshold for Section 10(k) is exceeded by all five coastlines included in this study, an EIA determination would be required by the competent authority (Donegal Co. Co) for any coastal management option other than “No Active Intervention (‘Do-nothing’)” .This will require the preparation of an EIA screening report to ascertain whether the project’s effects on the environment are expected to be significant.

8.7 Stakeholder Consultation

As per the scope of the project brief, RPS undertook a preliminary consultation by engaging with key statutory stakeholders in relation to the development of the various coastal erosion management plans for the five areas included in this study. In April 2019, RPS sent a consultation letter (see Figure 8.9 below) alongside a draft version of Interim Report 2 to:

- The Manager of the Development Applications Unit (DAU) within the Department of Culture, Heritage and the Gaeltacht;
- The Office of Public Works (OPW);
- The Environmental Protection Agency (EPA);

The only response received during this preliminary consultation process came from the EPA who queried if the requirements of the SEA Directive had been considered as part of this study. Sections 8.5 and 8.6 of this document address this comment.

To Whom It May Concern:

RPS have been appointed by Donegal County Council to develop a **Coastal Erosion Risk Management (CERM) Plan** for the Donegal coastline between Slodden Port and Binbane Head on the western side of the Inishowen peninsula. In particular, five individual sites located on this peninsula, Rockstown Harbour, Tullagh Bay, Pollen Strand, Five Finger Strand and the Binbane Coast road were identified for consideration in this study.

In brief, the objectives of this study are to undertake a detailed coastal erosion risk management investigation and to develop an appropriate plan to best manage the risks identified to human health and life (social), the environment, cultural heritage and economic activity and to further assess and investigate the feasibility of the management plan option(s) and measure(s) being recommended.

For your information RPS have included a copy of the draft of Interim Report 2. This report describes the findings of work packages 1 – 8 as defined in the OPW's guidelines for undertaking CERM studies and includes the following elements:

- Historical Review;
- Assessment of Existing Coastal Processes and Coastline Evolution;
- Current and Future Scenario Coastal Change Mapping; and
- A Risk Assessment
- Preliminary Environmental Assessment; and
- Options & Feasibility Assessment

The high level options considered as part of this study included No Active Intervention (i.e. 'do nothing'), Managed Realignment, Hold the Line and Advance the line. Where relevant, RPS may also consider a range of typical Hard and Soft Engineering options that could potentially be used to 'Advance, Hold or Realign the Line' during the development of the final Coastal Erosion Risk Management Plan. The ultimate aim is to develop a management plan that best manages the risks identified to human health and life (social), the environment, cultural heritage and economic activity.

To this end, RPS would like to offer your organisation the opportunity to comment or provide input into the work done to date and in particular the Options & Feasibility Assessment phase of the study. I trust the attached draft of Interim Report 2 will provide sufficient background information, however if you should require further information or clarification on any matter please feel free to contact me by email at Kristopher.calder@rpsgroup.com or by telephone on 028 9066 6094.

In order to comply with the Project Programme we would be grateful if you could reply as soon as reasonably possible but by no later than 19th April 2019. Thank you in advance for your attention to this matter.

Figure 8.9: Example of consultation letter sent to key statutory stakeholders

9 OPTIONS AND FEASIBILITY ASSESSMENT

9.1 Background

An assessment of the threat of coastal erosion along the Donegal coastline between Slodden Port and Binbane Head has considered five sites likely to be affected by coastal erosion; these sites are Rockstown Harbour, Tullagh Bay, Pollan Strand, Lagg Beach and Binbane Coast Road. As described in Section 7 the extent of coastal retreat and the associated threat from coastal erosion varies at each site due to prevailing coastal conditions, the physical setting of each site and also the underlying geology.

Based on the information presented in the previous sections of this report RPS examined the feasibility of a range of measures to mitigate the threat of erosion/damage associated with extreme storm events at all sites. The assessment was based on the latest Flood and Coastal Risk Management Appraisal Guidance (FCERM) issued by the Environment Agency. This guidance provides a methodology to undertake effective assessments. In principle the main objectives of this assessment were to:

- Consider all possible management options and measures
- Consider approximate costs of both capital and longer
- Consider all the above for short (2025), medium (2050) and long (2100) term scenarios
- Ensure any options recommended;
    - Are operationally robust
    - Minimise economic risk
    - Minimise risk to human health and life
    - Minimise risk to, or enhance, social amenity
    - Minimise risk to environmental pollution
    - Avoid damage to, and where possible enhance the flora and fauna of the study area
    - Avoid damage to, and where possible enhance landscape character and visual amenity within the study area
    - Avoid damage to, or loss of features of cultural heritage importance and their setting and heritage value within the study area

The main purpose of the options and feasibility assessment was to identify a suitable coastal management policy for all the sites of interest. Four key issues that were addressed in the appraisal of such policies are presented below;

- Coastal processes, including the historic and future evolution of the coastline;
- The natural environment, including the implications of the Habitat's Directive and biodiversity targets on shoreline management;
- Current and future land use, including current and future development proposals, agricultural and forestry issues, ports and harbour operations, aggregate and other dredging operations, recreational and tourism; and
- Existing coastal defences, including the purpose and ownership/responsibility for defences, the condition, performance and residual life of existing defences and other factors such as the availability of beach re-nourishment material to meet the present and future needs.

As no key policy driver has been previously identified for the coastline between Slodden Port and Binbane Head, RPS conducted an initial screening process to briefly review the technical feasibility and economic justification of all generic management options including 'Hold the Line', 'Advance the Line', 'Managed Realignment' and 'No Active Intervention'. These generic policy options are described below (FCDPA3):

- **Hold the Line**

  This option involves Improving or maintaining the standard of protection provided by the existing defence line. This policy includes situations where works or operations are undertaken in front of and behind the existing defences (e.g. beach re-nourishment, additional toe protection, construction of offshore breakwaters to control beach response etc.), to improve or maintain the standard of protection provided by the existing line of defence.

- **Advance the Line**

  This involves building new defences on the seaward side of the original defences in order to improve the standard of protection that was provided by the original defences.

- **Managed Realignment**

  This option involves allowing the coastline to move backwards (or forwards) from its present position, with management to control or limit such movement, and typically involves new protection structures further inland, creating a new or 'set back' line of protection. In terms of coastal erosion, this setback will dictate a minimum distance from the shoreline for new buildings. For coastal flooding, it will state a minimum elevation above mean sea level for development.

- **No Active Intervention (i.e. 'Do Nothing')**

  Where there is an existing defence, walk away; cease all maintenance, repairs and similar activities immediately. Where there is no existing scheme, do nothing; do not intervene in natural processes.

The output of this initial screening process is presented in Table 9.1.

Table 9.1: Initial review of coastal protection policies

Policy	Initial Review
Hold the Line	To be appraised for some sites. Will mitigate the threat of erosion to Ballyliffin Golf Club, residential properties and tourist amenities in the general area. May reduce beach width and therefore amenities in regions where implemented.
Advance the Line	No benefits at any of the sites. Potential environmental impacts would result from the development of seaward defences
Managed Realignment	To be appraised for some of the sites. Could create a buffer zone and facilitate long term natural coastal processes and give relevant stakeholders time to adapt and realign.
No Active Intervention (NAI)	To be appraised for some sites. Will facilitate long term natural coastal processes and protect the natural environment. Potential long term economic gains. Potential loss of amenities to various stakeholders.

Following the outcome of the screening process RPS investigated the Hold the Line, Managed Realignment and No Active Intervention (NAI) policies for the shorelines of the affected areas.

Before considering either of the active management options of Hold the Line or Managed Realignment, the NAI policy was assessed in order to understand the potential changes and threats to the coastline likely to result from the current and future coastal processes if left unchecked. This provided a consistent baseline against which to compare the benefits of possible interventions. The quantification of the impact of adopting a NAI strategy was based on an understanding of historical erosion at the study sites, the coastal processes of the area (i.e. future coastline evolution) and the impact of future climate change, particularly sea level trends as projected by the IPCC.

Based on the potential erosion risk to the five sites of interest identified in Section 7 the impact of adopting the NAI option has been assessed for each site for the short (2025), medium (2050) and long (2100) term timescales. This baseline assessment considers the impact of the NAI approach on various assets including residential property, roads and infrastructure, environmental features and important recreational assets. The output of this assessment is summarised in Table 9.2.

Table 9.2: Summary of potential consequence of implementing a NAI policy at each of the five sites of interest

Site	Potential Impact
Rockstown Harbour	By adopting a NAI approach, erosion may lead to damage to a boat store and several residential buildings. The coastal road (which is used to access several residential buildings) may be undermined in several locations.
Tullagh Bay	By adopting a NAI approach, erosion will potentially lead to the loss of several residential buildings and a substantial portion of a caravan park.
Pollan Strand	By adopting a NAI approach, erosion could potentially affect Ballyliffin Golf Club resulting in the potential loss of a parcel of land comprised of hinterland, rough and green. Having hosted a series of major tournaments, most recently the Irish Open in 2018, this course is of local importance. Additionally, a road which leads to a residential building could be undermined.
Lagg Beach	By adopting a NAI approach, erosion could result in the potential loss of St Mary's Chapel under the high end future climate change scenario (HEFS). This Chapel is highly unlikely to be affected by 2100 under the Medium Range Future Scenario (MRFS). Built in 1784, it is the second oldest Catholic church still in use in Ireland. It is a registered monument under the National Inventory of Architectural Heritage (NIAH) and is protected under the Record of Monuments and Places (RMP). Adopting a NAI approach coupled with a shoreline monitoring programme could be a viable option over the short term. Data from this programme could be used to inform a more robust assessment of the morphological processes at this site.
Binbane Coast Road	By adopting a NAI approach, there will be some minor coastal erosion. The extent of the erosion is limited by the presence of hard rock in the underling strata. This minor erosion could undermine a portion of a road which runs parallel to the coastline for 500m.

9.2 Preliminary Options Appraisal

Each of the high level policy options that were described and reviewed in 9.1 are comprised of numerous individual management measures that could be implemented to mitigate the risk of coastal erosion. A summary of the potential coastal management measures is presented in Table 9.3.

RPS therefore undertook an appraisal to identify a range of potential management measures that could be implemented at each of the five sites of interest regardless of effectiveness, potential environmental impacts or cost. The outcome of this appraisal is detailed in Table 9.4 below which outlines the long list of potential management measures that could be implemented at each of the sites.

Table 9.3: Potential coastal management measures

Potential Measure	Applicable for			Construction Type
	Tidal Flooding	Wave Overtopping	Erosion	Hard/Soft/Mixed
Seawalls	✓	✓	✓	Hard
Revetments		▲	✓	Hard
Embankments	✓	▲		Hard
Maintenance	▲	▲	▲	Mixed
Groynes			✓	Mixed
Detached breakwaters		▲	✓	Mixed
Headlands		▲	✓	Mixed
Perched beaches			✓	Mixed
Cove			✓	Mixed
Dune stabilisation (including re-profiling, hay bales, fencing, re-planting etc.)	✓	▲	✓	Soft
Nourishment	▲	▲	✓	Soft
Managed realignment	✓	✓	✓	Soft
Do nothing	✓	✓	✓	Soft

Key	
Applicable	✓
Applicable in some cases	▲
Not applicable	

Table 9.4: Appraisal of potential management measures for the sites of interest

High Level Policy	Management Measure
No Active Intervention	Do nothing and allow the existing natural coastal processes to continue
Managed Realignment	Sacrifice a portion of the hinterland and identify a distance to a coastal feature within which all/certain types of developments are prohibited (i.e. a lateral setback). Additionally begin to establish a plan to move vulnerable assets away from the shoreline
Hold the Line	Beach re-nourishment
Hold the Line	Dune/shoreline management
Hold the Line	Implement repairs to existing defences as and when necessary
Hold the Line	Upgrade existing sea defences
Hold the Line	Construct a rock armour revetment
Hold the Line	Construct a sea wall
Hold the Line	Install gabion baskets
Hold the Line	Construct a nearshore breakwater

For each site the list of potential management measures detailed in Table 9.4 was screened to ensure the proposed options meet the following criteria;

- The broad cost of capital construction and ongoing maintenance of the proposed measure has the potential to be financially viable;
- The proposed measure is technically viable and likely to be effective; and
- The proposed measure will not have a significant negative impact on the natural environment including the existing coastal process and will therefore not impact negatively on any nearby environmentally designated areas

Aside from technical effectiveness, it is also imperative to develop the most sustainable interim coastal protection works as possible. The Brundtland commission (1987) recommends critically examining issues relating to development and the environment in context of the three pillars of sustainability. These pillars are generally divided into the following three categories; environmental sustainability, social sustainability and economic sustainability.

In the context of the Slodden Port to Binbane Head study area, environmental issues include the potential to significantly impact the existing coastal processes and subsequently impact the European and nationally designated environmental sites across the study area. In this instance amongst the most pressing social issues is the increased threat of coastal erosion to numerous properties located at Rockstown Harbour and Tullagh Bay, to Ballyliffin Golf Course and to the St Mary's Chapel behind Lagg Beach. Finally, it is also important to consider the financial implications of coastal protection measures as even interim coastal protection works can demand both an expensive initial capital and maintenance/removal cost. These pillars of sustainability that need to be considered when assessing potential coastal protection measures are summarised in Figure 9.1.

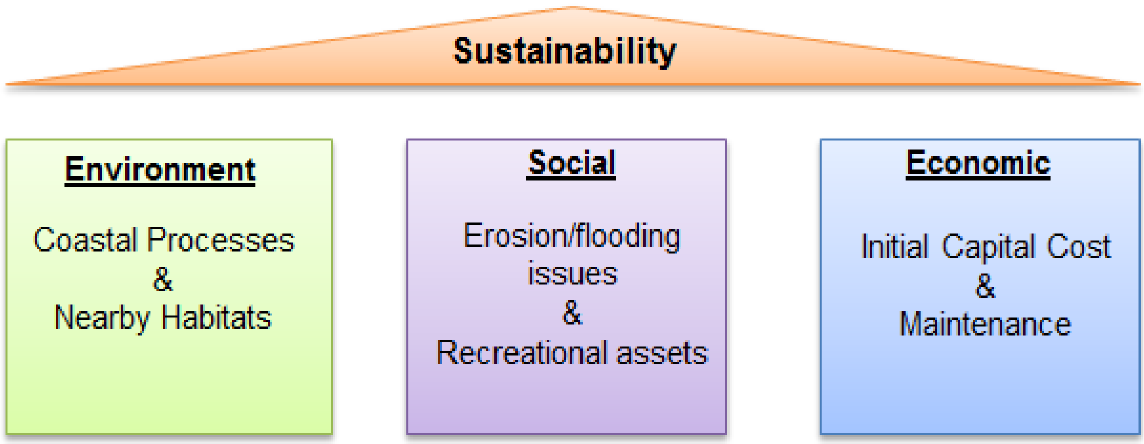

Figure 9.1: The pillars of sustainability that highlight critical issues of any development

Where a measure failed to meet any of these criteria it was rejected, the remaining management measures form a viable shortlist of potential management measures for each of the sites. The options rejected based on the criteria described above was the construction or nearshore breakwaters or upgrading existing sea defences.

The erosion risk management measures shortlisted for further consideration for Rockstown Harbour, Tullagh Bay, Pollan Strand, Lagg Beach and Binbane Coast Road are presented in Table 9.5 to Table 9.9 respectively.

Table 9.5: Erosion risk management measures shortlisted for further consideration at Rockstown Harbour

	High Level Policy	Management Measure
Rockstown Harbour	No Active Intervention	Do nothing and allow the existing natural coastal processes to continue with a shoreline monitoring programme in place
	Managed Realignment	Sacrifice a portion of the hinterland and control future development to create a buffer zone, facilitate long term natural coastal processes and give relevant stakeholders time to adapt and realign
	Hold the Line	Dune/shoreline management
	Hold the Line	Construct a rock armour revetment

Table 9.6: Erosion risk management measures shortlisted for further consideration at Tullagh Bay

	High Level Policy	Management Measure
Tullagh Bay	No Active Intervention	Do nothing and allow the existing natural coastal processes to continue
	Managed Realignment	Sacrifice a portion of the hinterland and control future development to create a buffer zone, facilitate long term natural coastal processes and give relevant stakeholders time to adapt and realign
	Hold the Line	Dune/shoreline management
	Hold the Line	Construct a rock armour revetment

Table 9.7: Erosion risk management measures shortlisted for further consideration at Pollan Strand

	High Level Policy	Management Measure
Pollan Strand	No Active Intervention	Do nothing and allow the existing natural coastal processes to continue with a shoreline monitoring programme in place
	Managed Realignment	Sacrifice a portion of the hinterland and control future development to create a buffer zone, facilitate long term natural coastal processes and give relevant stakeholders time to adapt and realign
	Hold the Line	Dune/shoreline management
	Hold the Line	Construct a rock armour revetment
	Hold the Line	Construct a seawall
	Hold the Line	Install gabion walls

Table 9.8: Erosion risk management measures shortlisted for further consideration at Lagg Beach

	High Level Policy	Management Measure
Lagg Beach	No Active Intervention	Do nothing and allow the existing natural coastal processes to continue with a shoreline monitoring programme in place
	Managed Realignment	Sacrifice a portion of the hinterland and control future development to create a buffer zone, facilitate long term natural coastal processes and give relevant stakeholders time to adapt and realign
	Hold the Line	Dune/shoreline management
	Hold the Line	Construct a rock armour revetment
	Hold the Line	Construct a seawall
	Hold the Line	Install gabion walls

Table 9.9 : Erosion risk management measures shortlisted for further consideration at Binbane

	High Level Policy	Management Measure
Binbane Coast Road	No Active Intervention	Do nothing and allow the existing natural coastal processes to continue with a shoreline monitoring programme in place
	Managed Realignment	Sacrifice a portion of the hinterland and control future development to create a buffer zone, facilitate long term natural coastal processes and give relevant stakeholders time to adapt and realign
	Hold the Line	Dune/shoreline management
	Hold the Line	Construct a rock armour revetment
	Hold the Line	Construct a seawall
	Hold the Line	Install gabion walls

9.3 Multi-Criteria Analysis of Erosion Risk Management Options

At some of the sites the links between the natural coastal processes, habitat diversity and land use are complex. Therefore a multi-criteria analysis (MCA) was adopted to objectively and systematically assess the potential coastal erosion management options that were short listed for each site in Table 9.5 - Table 9.9. The assessment criteria used in the MCA are presented below;

Technical Effectiveness:

A measure that effectively manages the risks from coastal erosion identified in Section 7 will score highly. A measure that requires a low level of mechanical or human intervention will also score well. A measure that would result in significant adverse effects elsewhere along the shoreline will score poorly.

Environmental Acceptability:

A good environmental acceptability score for a measure comes from likely maintenance of the 'favourable' status of nearby environmentally designated sites. Examples of environmental benefits vary, however increased habitat diversity and increased extent of existing habitats are aspects of a measure that will score well. The assessment also needs to consider requirements to maintain European sites in favourable status, if applicable.

Economic:

This criterion will score well if a measure minimises the risk of erosion to property or other built assets. The effect of each measure on transport infrastructure will also be considered if applicable.

Social:

This criterion is difficult to score as stakeholders have diverse needs and opinions depending on their use of the shoreline and hinterland. This will consider the impact of any proposal on human health and life. A measure that is universally condemned, negatively impacts on the use of existing amenities or presents a serious risk to human health or life will score poorly.

Other:

This criterion will consider any other aspects that may influence the implementation of coastal management measures, including associated risks and uncertainties. This may include, but is not limited to, change in physical conditions (due to uncertainty in the understanding of coastal processes), unforeseen changes such as accelerated climate change or changes in government guidance or legislation.

The weight assigned to each criterion and the specific scoring system for each criterion is reflective of the techniques recommended by the OPW and can be found in Appendix 1.

Following scoring for each criterion, a weighted score was then calculated for each measure. All measures with a positive MCA percentage score were carried forward to the final stage of the process; the identification of the preferred measures. The output from the MCA analysis for Rockstown Harbour, Tullagh Bay, Pollan Strand, Lagg Beach and Binbane Coast Road are presented in Table 9.10 to Table 9.14 respectively.

Table 9.10: Multi-Criteria Analysis (MCA) of the high level coastal management options available for Rockstown Harbour

			Coastal Management High Level Policy					
			No Active Intervention		Hold the Line		Managed Realignment	
Criteria	**Objective**	**Relative Weight**	**Score**	**Weighted score**	**Score**	**Weighted score**	**Score**	**Weighted score**
Technical Effectiveness	Level of mechanical or human intervention	5	5	25	1	5	3	15
	Health and safety	5	5	25	1	5	3	15
Economic	Minimise economic risk	1	0	0	0	0	0	0
	Minimise risk to transport infrastructure	2	-1	-2	1	2	-1	-2
Social	Minimise risk to health and life including properties	1	-1	-1	0	0	-1	-1
Environmental Acceptability	Avoid damage to designated sites of importance	5	0	0	-1	-5	0	0
	Protect landscape character	1	0	0	-1	-1	0	0
Other	Other future changes	1	0	0	-1	-1	0	0
		MCA Weight Score	47		5		27	

Table 9.11: Multi-Criteria Analysis (MCA) of the high level coastal management options available for Tullagh Bay

			Coastal Management High Level Policy					
			No Active Intervention		Hold the Line		Managed Realignment	
Criteria	Objective	Relative Weight	Score	Weighted score	Score	Weighted score	Score	Weighted score
Technical Effectiveness	Level of mechanical or human intervention	5	5	25	1	5	3	15
	Health and safety	5	5	25	1	5	3	15
Economic	Minimise economic risk	1	0	0	0	0	0	0
	Minimise risk to transport infrastructure	0	0	0	0	0	0	0
Social	Minimise risk to health and life including properties	1	-1	-1	0	0	-1	-1
Environmental Acceptability	Avoid damage to designated sites of importance	5	0	0	-1	-5	0	0
	Protect landscape character	1	0	0	-1	-1	0	0
Other	Other future changes	1	0	0	-1	-1	0	0
		MCA Weight Score	49		3		29	

Table 9.12: Multi-Criteria Analysis (MCA) of the high level coastal management options for Pollan Strand

			Coastal Management High Level Policy					
			No Active Intervention		Hold the Line		Managed Realignment	
Criteria	Objective	Relative Weight	Score	Weighted score	Score	Weighted score	Score	Weighted score
Technical Effectiveness	Level of mechanical or human intervention	5	5	25	1	5	3	15
	Health and safety	5	5	25	1	5	3	15
Economic	Minimise economic risk	3	-3	-9	1	3	0	0
	Minimise risk to transport infrastructure	0	0	0	0	0	0	0
Social	Minimise risk to health and life including properties	0	0	0	0	0	0	0
Environmental Acceptability	Avoid damage to designated sites of importance	5	0	0	-1	-5	0	0
	Protect landscape character	1	0	0	-1	-1	0	0
Other	Other future changes	1	0	0	-1	-1	0	0
		MCA Weight Score	41		6		30	

Table 9.13: Multi-Criteria Analysis (MCA) of the high level coastal management options available for Lagg beach

Criteria	Objective	Relative Weight	Coastal Management High Level Policy: No Active Intervention – Score	No Active Intervention – Weighted score	Hold the Line – Score	Hold the Line – Weighted score	Managed Realignment – Score	Managed Realignment – Weighted score
Technical Effectiveness	Level of mechanical or human intervention	5	5	25	1	5	3	15
	Health and safety	5	5	25	1	5	3	15
Economic	Minimise economic risk	1	0	0	0	0	0	0
	Minimise risk to transport infrastructure	2	-1	-2	1	2	-1	-2
Social	Minimise risk to health and life including properties	0	0	0	0	0	0	0
Environmental Acceptability	Avoid damage to designated sites of importance	5	0	0	-1	-5	0	0
	Protect landscape character	1	0	0	-1	-1	0	0
Other	Other future changes	1	-1	-1	-1	-1	-1	-1
MCA Weight Score			47		5		27	

Table 9.14: Multi-Criteria Analysis (MCA) of the high level coastal management options available for Binbane Coast Road

			Coastal Management High Level Policy					
			No Active Intervention		Hold the Line		Managed Realignment	
Criteria	Objective	Relative Weight	Score	Weighted score	Score	Weighted score	Score	Weighted score
Technical Effectiveness	Level of mechanical or human intervention	5	5	25	1	5	3	15
	Health and safety	5	5	25	1	5	3	15
Economic	Minimise economic risk	1	0	0	0	0	0	0
	Minimise risk to transport infrastructure	2	-1	-2	1	2	-1	-2
Social	Minimise risk to health and life including properties	0	0	0	0	0	0	0
Environmental Acceptability	Avoid damage to designated sites of importance	5	0	0	-1	-5	0	0
	Protect landscape character	1	0	0	-1	-1	0	0
Other	Other future changes	1	0	0	-1	-1	0	0
		MCA Weight Score	48		5		28	

9.4 Identification and Specification of the Preferred Risk Management Options

For all five sites management polices of NAI, Managed Realignment and Hold the Line scored positively. The different positive scores for each site indicate that each of the proposed high level policies have different advantages and disadvantages and therefore need to be carefully considered before being included in any proposed coastal erosion risk management plan.

A summary of the high level policies that scored positively during the MCA detailed in Section 9.3 is presented in Table 9.15 along with the preferred policy for each area. For all the sites, a policy of NAI scored highest and thus should be recommended along with a shoreline monitoring programme. For Lagg beach in particular, an ongoing shoreline monitoring programme would provide greater insight into the long-term cyclical coastal processes that govern the morphology of this beach and allow for a more robust assessment of erosion risk and better, more informed decision making over the long term.

Additionally, a policy of NAI has the advantage of retaining the natural landscape of the surrounding area which is of high importance especially around Ballyliffin golf course (Pollan Strand) and Lagg beach. Descriptions of the preferred high level policy and the proposed risk management measures for each site over the short, medium and long term are presented in the following Sections of this report.

Table 9.15: Positively scored high level policies from the MCA and the preferred policy for each study area

	Positive Scoring Policies			Preferred Policy
	Policy 1	Policy 2	Policy 3	
Rockstown Harbour	NAI	Managed Realignment	Hold the Line	NAI (potentially switching to Managed realignment)
Tullagh Bay	NAI	Managed Realignment	Hold the Line	NAI
Pollan Strand	NAI	Managed Realignment	Hold the Line	NAI or Managed Realignment
Lagg beach	NAI	Managed Realignment	Hold the Line	NAI
Binbane Coast Road	NAI	Managed Realignment	Hold the Line	NAI (potentially switching to Managed realignment)

9.4.1 Rockstown Harbour – No Active Intervention

Aside from a small parcel of land that runs parallel to the shoreline and localised sections of a minor road there are no assets at risk from coastal erosion under either the MRFS or HEFS climate change scenarios by 2100.

Due to the nature of this bay along with the rocky outcrops, climate change is not expected to result in a significant increase in prevailing wave energy however sea level rise as a result of climate change is likely to result in a gradual retreat of the shoreline.

Given the very limited threat of coastal erosion, RPS would recommend implementing a coastal management policy of **No Active Intervention (i.e. 'Do Nothing')** over the short, medium and long term. However, in order to gauge the potential impact of future climate change on the minor road in this area, RPS would also recommend implementing a **shoreline monitoring programme**. This would enable the Council to make a better informed, more robust decision about the medium to long-term management of this road. This policy may be revised to **Managed Realignment** based on the findings of the shoreline monitoring programme.

9.4.2 Tullagh Bay – No Active Intervention

As described in Section 7.3.2, despite the projected extent of coastal retreat there is actually very little in the way of tangible assets at risk from coastal erosion in Tullagh Bay. A parcel of land that runs parallel to the coast will likely be lost over the long-term as sea levels rise with future climate change, forcing the shoreline to retreat to maintain the existing profile. A caravan park situated in relatively close proximity to the shoreline may also be affected in the longer term under the high end future climate change scenario.

Given the very limited threat of coastal erosion, RPS would recommend implementing a coastal management policy of **No Active Intervention (i.e. 'Do Nothing')** over the short, medium and long term. This policy could be revised over the short to medium term if there is a significant change in coastal pressures during this period.

9.4.3 Pollan Strand – Managed Realignment & No Active Intervention

The main threat from coastal erosion at Pollan Strand is the potential impact on Ballyliffin Golf Club which is considered to be of high local importance in respect to the local tourism industry. Coastal retreat could impact operations by potentially compromising tees or greens situated on the fringe of the dune system. Aside from this risk, there are no other built assets or sites of cultural significance at risk of erosion.

Recognising the importance of Ballyliffin Golf Club whilst also considering the sustainability of any coastal management policy in respect to three pillars of sustainability described in Section 9.2, RPS would recommend implementing a policy of **Managed Realignment** over the short to medium term so that a policy of **No Active Intervention (i.e. 'Do Nothing')** could be implemented in the long term. This would enable Ballyliffin Golf Club to plan the long term reconfiguration of their renowned course whilst also creating a buffer zone to facilitate long term natural coastal processes. However, given that the area of land affected by this policy belongs to Ballyliffin Golf Club, the onus of planning the managed realignment would be on the Club as opposed to Donegal County Council.

A policy of Managed Realignment is intended to balance the interests of local stakeholders such as the Golf Club and of maintaining the integrity of the environment by allowing natural coastal processes to occur.

9.4.4 Lagg Beach – No Active Intervention

As described in Section 7.3.4, despite the extensive coastal retreat projected for Lagg beach there are in fact few assets at risk. Under the HEFS the main dune system could potentially retreat as far back as St. Mary's Catholic Church, elements of which are designated as a NIAH site and a National Monument. However, as noted in Section 7 of this report, these projections are considered highly conservative. It is RPS' opinion that these projections represent close to a "worst-case scenario" and that future rates of coastal erosion may well be much lower.

RPS would therefore recommended implementing a policy of **No Active Intervention (i.e. 'Do Nothing')** over the short to long term but coupling this policy with a robust **shoreline monitoring programme**. This would enable scientists and engineers to characterise the multi-decadal cyclical nature of the sediment transport regime in the area much more accurately and thus enable policy makers to make more robust and informed decision on a coastal management strategy in the medium and long term epochs.

9.4.5 Binbane Coast Road – No Active Intervention

The main asset at risk of future coastal erosion is a localised section of the minor road that runs parallel to Binbane coast. However, owing to the underlying geology of this area being hard rock, erosion is unlikely to affect the area to same extent as the other sites. RPS would therefore recommend implementing a policy of **No Active Intervention (i.e. 'Do Nothing')** over the short to long term but also establishing a **shoreline monitoring programme** over the short to medium term to determine if this policy should be revised to **Managed Realignment** in response to climate change.

10 COASTAL EROSION RISK MANAGEMENT PLAN

10.1 Summary of Plan Recommendations and Justification

The policy that consistently scored highest in the MCA for all sites within the study area was No Active Intervention (NAI). As described in Section 9.1, implementing a policy of NAI involves walking away and ceasing all maintenance, repairs and similar activities in areas where there are existing defences. In areas where there are no defences, NAI involves not intervening with natural process by doing nothing

From the outset it may appear that a policy of NAI is not suitable for the five study areas given that Section 7 found that the shoreline at each of these sites will be affected by coastal erosion. However, it is imperative to recognise that despite moderate to high rates of coastal erosion having been predicted to affect all of the study sites over the short to long term, there are in fact very few public or private assets at risk from this coastal erosion. Furthermore, it is well established that although defence schemes can be effective in reducing erosion in the short term, areas down drift of the protected region can be more severely affected, suffering higher rates of erosion due to an imbalance in sediment supply in the longer term. It is therefore important to adopt and implement a coastal management policy that balances economic, social and environmental issues of today without imposing problems on future generations.

Table 10.1: Summary of plan recommendations and justification for Rockstown Harbour

Study Area	Rockstown Harbour
Plan	The long-term plan for this area is to promote a naturally functioning coastline, with minimal human interferences. This will allow the coastline to dynamically respond to prevailing weather conditions and on-going climate change. As localised sections of the coastal road in this area could potentially be affected by coastal erosion over the medium to long term, RPS would recommend implementing a shoreline monitoring programme to determine if this policy should be revised from NAI to managed realignment in response to climate change. The management plan should be updated every 5yrs to take account of monitoring in the intervening period. There are no existing coastal defence structures in this area and few socio-economic assets that could justify the construction of any new defence works.
Short term (Present day to 2025)	The policy option is to allow natural coastal processes to continue to occur uninterrupted, i.e. allow the coastline to evolve in response to on-going climate change through a policy of No Active Intervention. The shoreline monitoring programme should be used to gauge the threat of future climate change and determine whether the existing policy of NAI should be revised to manage realignment in the medium to long-term.
Medium term (2025 to 2050)	Subject to the findings of the shoreline monitoring programme, possibly change the policy option from No Active Intervention to Managed Realignment
Long term (2050 to 2100)	Subject to the findings of the shoreline monitoring programme, possibly change the policy option from No Active Intervention to Managed Realignment

Table 10.2: Predicted implications of the preferred management plan for Rockstown Harbour

Time	Property and Built Assets	Landscape	Nature Conservation	Amenity and Recreational Use
Short term (Present day to 2025)	▪ No loss of private properties ▪ Minor loss of agricultural land	▪ Naturally functioning coast maintained	▪ Integrity of nearby environmentally designated sites ▪ Maintain the quality of the natural landscape	▪ Beach maintained
Medium term (2025 to 2050)	▪ No loss of private properties ▪ Further loss of agricultural land ▪ Potential localised undermining of coastal road	▪ Naturally functioning coast maintained	▪ Integrity of nearby environmentally designated sites ▪ Maintain the quality of the natural landscape	▪ Beach maintained
Long term (2050 to 2100)	▪ No loss of private properties ▪ Further loss of agricultural land ▪ Potential localised undermining of coastal road (no likely impact to local access) ▪ Potential loss of small pier on the western extent of the bay	▪ Naturally functioning coast maintained	▪ Integrity of nearby environmentally designated sites ▪ Maintain the quality of the natural landscape	▪ Beach maintained

Table 10.3: Summary of plan recommendations and justification for Tullagh Bay

Study Area	Tullagh Bay
Plan	The long-term plan for this area is to promote a naturally functioning coastline, with minimal human interferences. This will allow the coastline to dynamically respond to prevailing weather conditions and on-going climate change. There are no existing coastal defence structures in this area and few socio-economic assets that could justify the construction of any new defence works.
Short term (Present day to 2025)	The policy option from the present day is to allow natural coastal processes to continue to occur uninterrupted, i.e. allow the coastline to evolve in response to on-going climate change through a policy of No Active Intervention. This policy will facilitate the operation of a naturally functioning. There will be a loss of some land which is comprised primarily of agricultural land.
Medium term (2025 to 2050)	No change in policy option of No Active Intervention
Long term (2050 to 2100)	No change in policy option of No Active Intervention

Table 10.4: Predicted implications of the preferred management plan for Tullagh Bay

Time	Property and Built Assets	Landscape	Nature Conservation	Amenity and Recreational Use
Short term (Present day to 2025)	▪ No loss of private properties ▪ Minor loss of agricultural land	▪ Naturally functioning coast maintained	▪ Integrity of nearby environmentally designated sites ▪ Maintain the quality of the natural landscape	▪ Beach maintained
Medium term (2025 to 2050)	▪ No loss of private properties ▪ Further loss of agricultural land ▪ Potential localised undermining of coastal road	▪ Naturally functioning coast maintained	▪ Integrity of nearby environmentally designated sites ▪ Maintain the quality of the natural landscape	▪ Beach maintained
Long term (2050 to 2100)	▪ No loss of private properties ▪ Further loss of agricultural land ▪ A caravan park situated within the hinterland may be lost to coastal erosion. ▪ The layout of this caravan park could be easily re-configure to account for future coastal erosion	▪ Naturally functioning coast maintained	▪ Integrity of nearby environmentally designated sites ▪ Maintain the quality of the natural landscape	▪ Beach maintained

Table 10.5: Summary of plan recommendations and justification for Pollan Strand

Study Area	Pollan Strand
Plan	Alongside the extensive dune system at the Fiver Finger Strand, the dune system along this length of shoreline provides a vital sediment source for the region as a whole. This area is also designated at a European Level owing to the presence of fixed coastal dunes. The plan for this area is to therefore continue to promote a naturally functioning coastline, with minimal human interferences by promoting a policy of managed realignment. This would allow the coastline to dynamically respond to prevailing weather conditions and on-going climate change and ensure that the conservation objectives of the North Inishowen Coast SAC are maintained. Based on a suitable managed realignment strategy having been implemented over the short to medium term, RPS would recommend implementing a policy of NAI over the medium to long term. RPS would recommend implementing a shoreline monitoring programme to determine if this policy should be revised in response to climate change. The management plan should be updated every 5yrs to take account of monitoring in the intervening period. There are some partially buried piecemeal defences along this coastline, however under a policy of managed realignment, it is recommended to cease all future maintenance of these defences. There are a number of assets at the southern extent of the Strand that are unlikely to be affected by erosion owing to the underlying geology.
Short term (Present day to 2025)	The policy option is to create a buffer zone where natural coastal processes can to continue to occur uninterrupted. Given that the area of land affected by this policy belongs to Ballyliffin Golf Club, the onus of planning the managed realignment based on the findings presented in this report would be on the Club as opposed to Donegal County Council. This policy would enable a naturally functioning coastline to operate and is complimentary to the management objectives of the North Inishowen Coast SAC and other nearby environmental designations.
Medium term (2025 to 2050)	If a suitable managed realignment strategy was implemented over the short term to create a suitable buffer zone, RPS would recommend implementing policy of No Active Intervention over the medium to long term. This would promote the natural coastal processes within this sediment cell. The management plan should be updated every 5yrs to take account of monitoring in the intervening period.
Long term (2050 to 2100)	No change in policy option of No Active Intervention The management plan should be updated every 5yrs to take account of monitoring in the intervening period.

Table 10.6: Predicted implications of the preferred management plan for Pollan Strand

Time	Property and Built Assets	Landscape	Nature Conservation	Amenity and Recreational Use
Short term (Present day to 2025)	▪ No loss of private properties ▪ Minor loss of agricultural land ▪ Ballyliffin Golf Course realigned to facilitate future climate change and associated coastal processes	▪ Naturally functioning coast maintained ▪ Supply of sediment to local sediment cell maintained	▪ NAI complementary to conservation objections of North Inishowen Coast SAC ▪ Maintain the quality of the natural landscape	▪ Beach maintained
Medium term (2025 to 2050)	▪ No loss of private properties ▪ Further loss of agricultural land ▪ Mitigated impact to Ballyliffin Golf Course if successfully realigned	▪ Naturally functioning coast maintained ▪ Supply of sediment to local sediment cell maintained	▪ NAI complementary to conservation objections of North Inishowen Coast SAC ▪ Maintain the quality of the natural landscape	▪ Beach maintained ▪ Mitigated impact to Ballyliffin Golf Course if successfully realigned
Long term (2050 to 2100)	▪ No loss of private properties ▪ Further loss of agricultural land ▪ Potential localised undermining of coastal road ▪ Mitigated impact to Ballyliffin Golf Course if successfully realigned	▪ Naturally functioning coast maintained ▪ Supply of sediment to local sediment cell maintained	▪ NAI complementary to conservation objections of North Inishowen Coast SAC ▪ Maintain the quality of the natural landscape	▪ Beach maintained ▪ Mitigated impact to Ballyliffin Golf Course if successfully realigned

Table 10.7: Summary of plan recommendations and justification for Five Finger Strand

Study Area	Five Finger Strand
Plan	The complex exchange of sediment between the estuary, the beach and the dune system means that the extensive dune system in this area is a vital sediment source to the wider area. Academic research has also established that the sediment in this area is re-worked between the ebb tidal delta and wider system on a multi-decadal scale. The long-term plan for this area is to therefore promote these natural coastal processes with minimal human interferences by implementing a policy of No Active Intervention. In order to better understand these long-term cyclical processes and gauge the threat of future coastal erosion, RPS would strongly recommend an on-going beach monitoring programme. This programme could potentially be developed and/or implemented in conjunction with local university groups who have experience in monitoring this coastal system. There are some piece meal hard defences at the entrance to and inside Trawbreaga Bay, however these defences have negligible impact to the coastal processes along the main dune system. The erosion assessment presented in Section 7.3.4 found that St. Mary's Catholic Church could potentially be a risk from coastal erosion under the HEFS by 2100. However, given the conservative nature of the erosion assessment, a policy of NAI coupled with an on-going shoreline monitoring programme was considered to be the most sustainable management policy available.
Short term (Present day to 2025)	The policy option is to establish a robust shoreline monitoring programme and allow natural coastal processes to continue to occur uninterrupted through a policy of No Active Intervention. This would facilitate the existing multi-decadal cyclical coastal processes to continue to occur whilst creating an extensive database of information relating to coastal processes to occur. This information would enable policy makers to make a more informed decision in the future in respect to erosion management policy for this area. A policy of NAI will enable a naturally functioning coastline to operate and is complimentary to the management objectives of the North Inishowen Coast SAC and other nearby environmental designations.
Medium term (2025 to 2050)	Subject to the findings of the shoreline monitoring programme, no change in policy option of No Active Intervention
Long term (2050 to 2100)	Subject to the findings of the shoreline monitoring programme, no change in policy option of No Active Intervention St. Mary's Catholic Church could potentially be a risk from coastal erosion under the HEFS by 2100. However, this was based on a very conservative assessment. The complex coastal processes of the Inishowen peninsula are such that the future rates of coastal erosion may be much lower than those reported in Section 7.3.4.

Table 10.8: Predicted implications of the preferred management plan for Five Finger Strand

Time	Property and Built Assets	Landscape	Nature Conservation	Amenity and Recreational Use
Short term (Present day to 2025)	▪ No loss of private properties ▪ Potential undermining of minor road used to access beach	▪ Naturally functioning coast maintained ▪ Supply of sediment to local sediment cell including Trawbreaga bay maintained ▪ Potential partial loss of internationally recognised dune system	▪ NAI complementary to conservation objections of North Inishowen Coast SAC ▪ Maintain the quality of the natural landscape ▪ Long-term cyclical coastal processes uninterrupted	▪ Beach maintained ▪ Potential impact to the minor road used to access beach
Medium term (2025 to 2050)	▪ No loss of private properties ▪ Potential further undermining of minor road used to access beach	▪ Naturally functioning coast maintained ▪ Supply of sediment to local sediment cell including Trawbreaga bay maintained ▪ Potential partial loss of internationally recognised dune system	▪ NAI complementary to conservation objections of North Inishowen Coast SAC ▪ Maintain the quality of the natural landscape ▪ Long-term cyclical coastal processes uninterrupted	▪ Beach maintained ▪ Potential impact to the minor road used to access beach
Long term (2050 to 2100)	▪ No loss of private properties ▪ Potential further undermining of minor road used to access beach ▪ Potential loss of St. Mary's Catholic Church (although considering highly unlikely given conservative assessment)	▪ Naturally functioning coast maintained ▪ Supply of sediment to local sediment cell including Trawbreaga bay maintained ▪ Potential loss of internationally recognised dune system	▪ NAI complementary to conservation objections of North Inishowen Coast SAC ▪ Maintain the quality of the natural landscape ▪ Long-term cyclical coastal processes uninterrupted	▪ Beach maintained ▪ Potential impact to the minor road used to access beach

Table 10.9: Summary of plan recommendations and justification for Binbane coast

Study Area	Binbane coast
Plan	As the underlying geology in this area is comprised primarily by hard rock this area is not expected to be affected by the same pressures of coastal erosion as experienced at the other sites. Based on this information, the long term plan for this site is No Active Intervention. It should be noted however that a policy of managed realignment also scored relatively highly in the Multi-Criteria Analysis reported in Section 9.3. RPS would therefore recommend monitoring the on-going risk at Binbane (particularly from sea level rise) over the short to medium term to determine if the policy should be revised from NAI to Managed Realignment for the localised section of Binbane coast where the minor road may be affected. The management plan should be updated every 5yrs to take account of monitoring in the intervening period.
Short term (Present day to 2025)	The policy options to allow natural coastal processes to continue to occur uninterrupted, i.e. allow the coastline to evolve in response to on-going climate change through a policy of No Active Intervention. There are a number of localised regions where coastal erosion may affect the structural integrity of a local road, however a shoreline monitoring programme should be established to determine if this is likely to be an issue.
Medium term (2025 to 2050)	Subject to the findings of the shoreline monitoring programme, possibly change the policy option from No Active Intervention to Managed Realignment
Long term (2050 to 2100)	Subject to the findings of the shoreline monitoring programme, possibly change the policy option from No Active Intervention to Managed Realignment

Table 10.10: Predicted implications of the preferred management plan for Binbane coast

Time	Property and Built Assets	Landscape	Nature Conservation	Amenity and Recreational Use
Short term (Present day to 2025)	▪ No loss of private properties ▪ Potential minor loss of agricultural land	▪ Naturally functioning coast maintained	▪ Integrity of nearby environmentally designated sites ▪ Maintain the quality of the natural landscape	▪ Shingle/cobble beach area protected
Medium term (2025 to 2050)	▪ No loss of private properties ▪ Further loss of agricultural land ▪ Potential undermining of coastal road	▪ Naturally functioning coast maintained	▪ Integrity of nearby environmentally designated sites ▪ Maintain the quality of the natural landscape	▪ Shingle/cobble beach area protected ▪ Potential access issues due to undermining of coastal road
Long term (2050 to 2100)	▪ Potential impacts to Binbane road area highly likely to have been arrested by 2050 irrespective of climate change scenario owing to underlying geology which is comprised primarily of hard rock.			

10.2 Shoreline Monitoring Programme

The following Section of this report describes the rational and benefit of implementing a shoreline monitoring programme at the sites that were assessed as part of this study. A high level assessment of the requirements of a potential programme are also presented in Section 10.2.2.

10.2.1 Background

The coastline is an important habitat, amenity and natural defence against coastal pressures such as erosion and flooding. Managing this sensitive natural resource requires a careful balance between environmental considerations and coastal management responsibilities. Data gathered as part of an effective shoreline monitoring programme can be essential in achieving this target.

Shoreline monitoring is a term broadly used to describe the collection, storage and analysis of information about coastal processes and how the coastal zone responds to spatially and temporarily varying forcing factors including but not limited to storm events, coastal development and climate change. Monitoring provides important quantitative information used to identify changes, rates of change and trends in the evolution of key variables. This data is required to make informed coastal management decisions.

Accurate and repeatable coastal data is essential for timely and informed decision making. Many strategic studies throughout Europe, including Shoreline Management Plans (SMPs) in the UK, depend on reliable historic data as well as up-to-date information. However, unlike the UK, there are no regionally coordinated or integrated approaches to shoreline monitoring in Ireland. As such, despite the good practices of many local authorities, shoreline monitoring in Ireland tends to be centred on localised problems, individual beach management schemes, academic studies or occasionally a more strategic approach to beach management. There are a number of issues with Ireland's ad-hoc approach to shoreline monitoring at present, these issues include but are not limited to:

- Inconsistencies in the type of data collected;
- Inconsistences in survey methods;
- Lack of metadata to verify the origin and quality of data; and
- Lack of data before or after significant storm events which are generally of greatest interest to coastal managers and policy makers.

In absence of a regionally coordinated or integrated approach to shoreline monitoring and for the reasons set out above, RPS would reiterate the findings of recent academic research undertaken in the study area which highlighted the need for regular monitoring of coastal systems due to their complex inter-storm characteristics and variability (Guisado-Pintade *et al.*, 2018). Furthermore, RPS would recommend that the relevant management strategies identified in Section 9.4 should be reviewed on a five year cycle based on the findings of the any future long term shoreline monitoring programme.

10.2.2 Shoreline monitoring programme for the study area

The precise details of the data that need to be collected as part of a shoreline monitoring programme will depend upon the specific site and its character, consequently a preliminary assessment of the site is often necessary to design a suitable data-collection programme. However, given RPS' knowledge of the site and existing information gaps, RPS would recommend establishing a programme that at minimum includes monitoring of the evolution of beach profiles, by gathering topographic data/LIDAR data, bathymetric data and aerial photography. Any future shoreline monitoring programme should be undertaken regularly enough to pick up seasonal scale behaviour and planned with any on-going or planned research.

Guidance on the Channel Coastal Observatory coastal group's website provides a good basis from which to develop the scope of a potential shoreline monitoring programme for Donegal County Council. However, it should be noted that actual specification of survey methods, frequency of monitoring and resolution of data is beyond the scope of this particular study and that the following information should only be used for indicative purposes only.

10.2.2.1 Beach Profile / Topographic Data

All shoreline monitoring programmes should include topographic surveys, although the frequency and method of survey required varies. In most cases the data collected serves both operational requirements e.g. scheme development and operational maintenance, and strategic requirements.

A risk framework extracted from the Channel Coastal Observatory website is presented in Table 10.11 below and indicates the frequency and spatial distribution of survey required for different levels of risk. The technical specifications of the beach profile / topographic data should be fined tuned to each individual site for example by following the guidelines published in the Environment Agencies' "National Standard Technical Specifications for Surveying Services" document.

In general, baseline surveys should be conducted to a consistent standard at all sites, typically based on a combination of beach profiles at 50m intervals, plus shore parallel lines. The spatial interval of subsequent beach profile surveys could potentially be increased to 100m – 300m depending on the coastal management strategy, beach exposure and morphological form of the area. In the case of the Slodden Port to Binbane study area the actual survey methods together with the spatial and temporal resolutions of the beach profile / topographic surveys should be developed further through a more detailed shoreline monitoring scoping study.

Table 10.11: Typical temporal intervals for topographic information

Frontage Category	Land-based topographic surveys	Detailed spot height (baseline) survey	Post-storm survey (>1:1yr event)
High risk management sites	Bi-annual	Annual	Call-off
Hold the line or Managed Realigned, high exposure	Bi-annual	5 Years	Call-off
Hold the line or Managed Realigned, low exposure	Annual	5 Years	Call-off
No Active Intervention, accessible beach	Annual	5 Years	Call-off
No Active Intervention, inaccessible site	Lidar	None	None

10.2.2.2 Bathymetry data

Traditionally, bathymetric data has been gathered with a single beam echo sounder, gathering one profile line at a time. This provides relatively poor spatial resolution and may fail to identify large and potentially important seabed features, even when the line spacing is fairly close (50m). For this reason the main focus of bathymetry survey programmes has shifted towards the use of swath (multi-beam) techniques i.e. 100% seafloor coverage. However, this method can be inefficient in shallow water and areas where there is complex bathymetry and shallow banks such as the ebb tidal delta at Five Finger Strand. Consequently it is likely that the surveying method for this area will be limited to single beam bathymetry. Ideally, hydrographic surveys should extend offshore by between 0.5-1km, depending on anticipated beach profile closure depth. As a general guide, changes to the bathymetry in water depths greater than about 10m-15m have little impact on wave conditions.

In most instances full surveys should typically be repeated every five years at all relevant sites. More detailed surveys may occasionally be required in high-risk areas such as Lagg Beach whereby the position of the ebb-tidal delta is known to change constantly based on a complex exchange of sediment between the estuary, the beach and dunes, and the ebb delta (O'Connor *et al*., 2011).

Bathymetry data should be recorded relative to the same datum as topographic surveys across the whole region. Baseline surveys will typically be generated at a spatial interval of 50m, although this too will vary according to local bathymetry.

10.2.2.3 Aerial Photography

Aerial photography is widely used in many shoreline monitoring programmes as the data collected provides an excellent analytical medium which can be used conveniently in combination with other types of georeferenced survey information. In particular, aerial images provide the opportunity for valuable interpretation of morphodynamic changes measured by georeferenced profile data. This enables coastal managers to examine large scale changes in the nearshore region and easily assess coastal erosion and accretion. More recently, aerial photography has been combined with LIDAR (LIght Detection And Ranging) and other aerial topographic survey techniques. These systems can produce very accurate geo-referenced elevation data that can then in turn be used to develop Digital Terrain Models (DTMs).

RPS would recommend surveying the entire shoreline of each monitoring area at least once every 5 years and possibly annually if there are particular concerns. Aerial surveys would preferably be undertaken using LIDAR or similar technology. Recent research (Guisado-Pintado *et al*., 2019) has already demonstrated the ease at which high quality point cloud data can be collected at Lagg beach using UAV technology and the versatile range of applications the data can be used for.

10.2.2.4 Extent of survey areas

When designing a potential shoreline monitoring programme it is important to ensure that sufficient coverage is achieved, particularly during the initial surveying campaign as this data will be used as a baseline for subsequent assessments. Although defining the exact extent of a potential shoreline monitoring scheme is beyond the scope of this study, RPS would recommend ensuring any monitoring programme covers the areas illustrated in Figure 10.1.

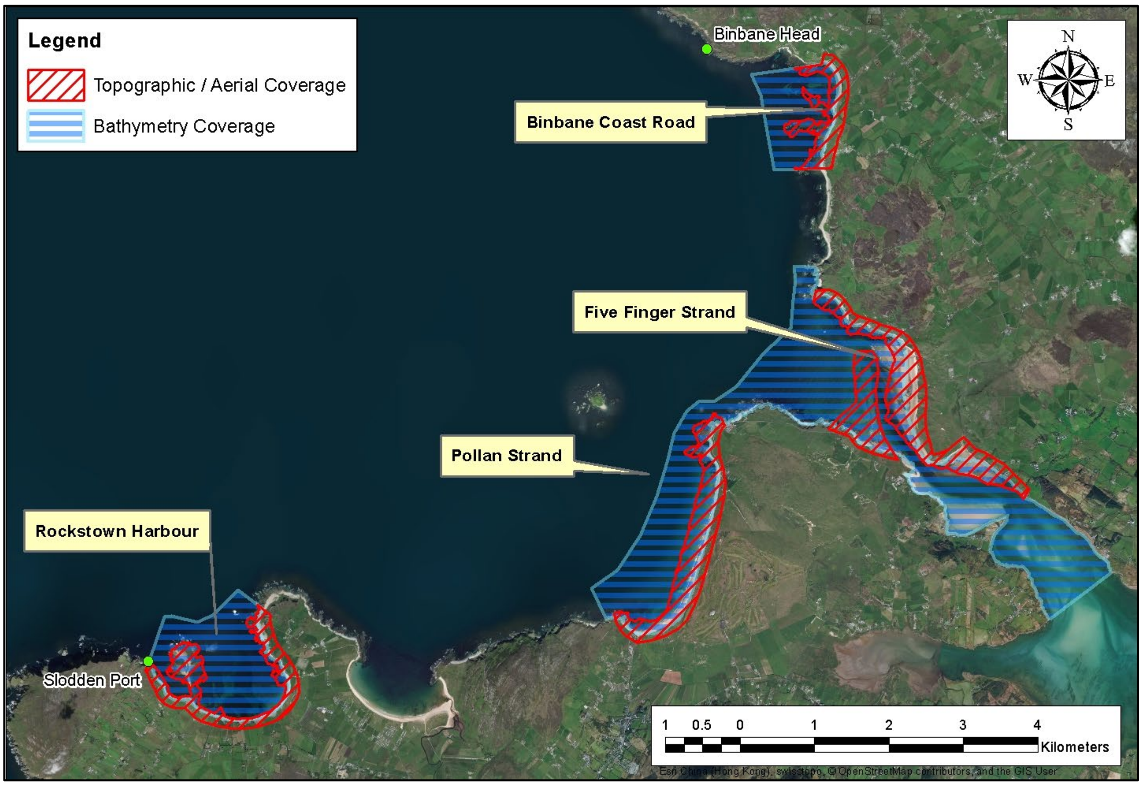

Figure 10.1: Proposed coverage of a shoreline monitoring scheme for the Slodden to Binbane area

11 ECONOMIC ASSESSMENT

An economic assessment of costs and benefits of proposed management measures is normally a key part of any Coastal Flooding Erosion Risk Management Plan. Typically this assessment takes into account both the initial capital and future maintenance costs of measures over the design life of the preferred options or scheme and is undertaken in accordance with guidance documents published by the Flood Hazard Research Centre (FHRC) publication. The fundamental basis of all economic assessments is that all of effects and benefits of an option can be defined in terms of its monetary value. An option is considered to be 'justified' if the benefits outweigh the costs (i.e. the benefit cost ratio is greater than one).

However, this somewhat unusual in that the preferred policy option for all five sites is "No Active Intervention" meaning that there are no initial capital or future expenditure requirements associated with implementation of the preferred management policies[1,2]. As the benefits associated with No Active Intervention cannot defined in terms of monetary value, it is therefore not possible to undertake an economic assessment of the preferred option for any of the five sites.

It is important to note that the policy of No Active Intervention was identified as the preferred policy for each of the sites primarily due to consideration of environmental and technical effectiveness as opposed to economic factors (see the Multi-Criteria Analysis in Section 9.3). That is to say, a policy of "No Active Intervention" would still have scored highest and been the preferred policy even if the other policies had scored full marks in the economic criteria described in Section 9.3.

The high level shoreline monitoring scheme that has been recommended for Rockstown Harbour, Pollan Strand, Five Finger Strand and Binbane coast has no direct economic benefit that can be considered in a cost benefit analysis. As described in Section 10.2 the main benefit of a shoreline monitoring scheme will be to measure and record high quality field data that can then in turn be used to gauge the impact of on-going climate change on the coastal processes within the study area. This will in turn inform further coastal research and better define complex coastal systems such as those at Five Finger Strand which are known to be governed by multi - decadal cyclical processes. Ultimately, the data gathered from a well-defined shoreline monitoring programme will enable policy makers to make much more robust and sustainable decisions relating to coastal management with a higher degree of confidence during future reviews of the Slodden Port to Binbane Head CERM Plan.

[1] No Active Intervention is the preferred policy from the present day to short term for all sites except the Pollan Strand whereby an initial policy of Managed Realignment has been recommended. As the area of land affected by this policy is owned by Ballyliffin Golf Course, the onus will be on the Club to plan and implement any potential realignment to the course. As such, this policy has not been assessed as part of this Economic Assessment.

[2] In some areas the initial policy of No Active Intervention may be revised in response to the findings of the shoreline monitoring programme. Economic Assessments have not been undertaken to account for these potential shifts in policies as it is not possible to predict the findings of the shoreline monitoring programmes or determine when a shift in policy may occur. Any economic assessment on these alternative policy options would therefore be highly speculative and based on uncertain assumptions.

12 CONCLUSION

RPS were commissioned by Donegal County Council to develop a Coastal Erosion Risk Management (CERM) plan for five individual sites situated on the Donegal coastline between Slodden Port and Binbane Head on the western side of the Inishowen peninsula. These sites included Rockstown Harbour, Tullagh Bay, Pollen Strand, Five Finger Strand (otherwise known as Lagg Beach) and the Binbane Coast road.

One of the primary drivers of this CERM study was the loss of a small carpark which was used to access the popular Five Finger Strand in January 2016. An assessment undertaken by RPS found that the loss of this carpark was driven primarily by heavy rainfall which occurred during storm Desmond and subsequent drainage issues as opposed to arduous offshore storm conditions. Met Éireann described this storm event as "highly abnormal" owing to the exceptional level of rainfall which resulted in Malin Head reporting its wettest December since 1885.

Coastal Processes

A historical analysis of coastal change across the study area found that all sites except Lagg beach demonstrated very little movement of the shoreline and could be classified as dynamically stable; fluctuating about a mean position in response to specific storm events. Conversely, historical records demonstrated that the northern extent of Lagg beach has been retreating landward since 1995, whilst the southern extent of Lagg beach, has experienced significant accretion over the same period. These changes reflect the complex exchange of sediment between the estuary, the beach and dunes, and the ebb delta as reported by O'Connor et al., 2011.

Further to the historical assessment, RPS also undertook extensive hydraulic modelling of the coastal processes at each of the five sites during "typical" and extreme storm event conditions. Output from these model simulations found that:

- Tidal choking at the narrow tidal inlet at Lagg Point is likely to result in a gradual increase in bed levels within Trawbreaga Bay due to the asymmetric transport of suspended bed material.
- All sites could experience a significant increase in wave energy under future climate change conditions whereby sea levels could rise by up to +1.0m.
- The shorelines at Pollan Strand, Lagg beach and Binbane coast are all orientated very close to the natural equilibrium orientation whereby the transport of sediment is on average close to zero.
- Rockstown Harbour and Tullagh Bay are classic horseshoe embayment beaches flanked by rocky headlands that limit the longshore transport of sediment to form sediment sub-cells.

Erosion Risk

Based on a very conservative assessment of the erosion risk across the five sites which represents a "worst case scenario" RPS identified notable erosion risk at all five of the sites. The extent of coastal retreat by 2100 ranged between 11m and 50m depending on the future climate change scenario adopted at four of the sites. At Lagg beach potential shoreline retreat was found to be as high as *c.*400m by 2100 under the HEFS climate change scenario. However, this is based on a conservative assessment and it is RPS' opinion that the future rates of coastal erosion at Lagg beach will be significantly lower.

Despite these conservative erosion assessments and projected rates of shoreline retreat a subsequent risk assessment found that there are in fact very few assets at risk from erosion. At Rockstown Harbour, Tullagh Bay and Binbane it was found that very localised sections of minor coastal roads could potentially be affected over the long term depending on how climate change affects sea levels and the prevailing coastal processes in the intervening period.

At Pollan Strand the main risk is the potential impact on Ballyliffin Golf Club whereby several tees or greens on the fringe of the dune system could be impacted by coastal erosion. Aside from this risk, there are no other built assets or sites of cultural significance at risk of erosion.

The site identified at most risk from coastal erosion was Lagg beach. Under the high end future climate change scenario it was found that the dune system could potentially retreat as far back as St. Mary's Catholic Church, elements of which designated as a NIAH site and a National Monument. However, as noted previously, these projections are considered highly conservative owing to the fact that they do not include the natural multi-decadal sediment feedback systems than are the main driver of long-term coastal morphology in this area.

Options and Feasibility Assessment

An options and feasibility assessment was undertaken for each of the study sites. The policy that consistently scored highest in this assessment was "No Active Intervention" (NAI). Implementing a policy of NAI involves ceasing all maintenance, repairs and similar activities in areas where there are existing defences and not intervening with natural process by doing nothing in areas where there are no defences.

Managed realignment was also identified as a potential policy option at Rockstown Harbour, Pollan Strand and Binbane. However, given that there were few assets currently at risk at Rockstown Harbour and Binbane RPS recommended implementing a shoreline monitoring programme to monitor coastal erosion and inform the review of the management policies at these sites after five years.

The recommendation for Pollan Strand is to continue to promote a naturally functioning coastline by promoting a policy of managed realignment. This would enable the coastline to dynamically respond to various pressures including climate change and ensure that the conservation objectives of the North Inishowen Coast SAC are maintained. Based on a suitable managed realignment strategy having been implemented over the short to medium term, principally re-configuring parts of Ballyliffin Golf Course to ensure it would remain playable, a policy of NAI could then be implemented over the medium to long term.

It is RPS' opinion that the coastal erosion projections for Lagg beach represent close to a "worst-case scenario" and that the future rates of coastal erosion at Lagg beach will be significantly less due to the complex reworking of sediment in this area. RPS therefore recommend implementing a policy of No Active Intervention in this area while establishing a robust shoreline monitoring programme. This would enable coastal managers to define this coastal system with confidence and thus develop the most robust and sustainable coastal management strategy possible for this area over the long term.

In absence of a regionally coordinated or integrated approach to shoreline monitoring, RPS have outlined the basis of a potential shoreline monitoring programme for the study area. However, the requirements of a potential shoreline monitoring programme should be refined in a more detailed scoping study.

Economic Assessment

The fundamental basis of all economic assessments is that all effects and benefits of an option can be defined in monetary terms. An option is considered to be 'justified' if the benefits outweigh the costs (i.e. the benefit cost ratio is greater than one). However, as the preferred policy option for all sites except Pollan Strand is "No Active Intervention" there are no initial capital or future maintenance costs associated with any of the policies. Additionally the benefits associated with No Active Intervention cannot defined in monetary terms, hence it is not possible to undertake an economic assessment of the preferred option for any of the five sites. It is important to note that the policy of No Active Intervention was primarily identified as the preferred policy for each of the sites due to environmental and technical effectiveness factors as opposed to economic factors.

Furthermore, the shoreline monitoring scheme that has been recommended for Rockstown Harbour, Pollan Strand, Five Finger Strand and Binbane coast has no direct economic benefit that can be considered in a cost benefit analysis. The main benefit of a shoreline monitoring scheme is to obtain and record high quality field measurements. Ultimately, the data gathered from a well-defined shoreline monitoring programme can enable policy makers to make much more robust and sustainable decisions relating to coastal management with a high degree of confidence.

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14 APPENDIX 1

Multi-Criteria Scoring Guidance

Weighting Guidance

Criteria	Objective	Relative Weight
Technical Effectiveness	Level of mechanical or human intervention	Weight of 5 applied
	Health and safety	Weight of 5 applied
Economic	Minimise economic risk	5 where annual damages exceed €5 million 4 where annual damages are between €1 million and €4.99 million 3 where annual damages are between €0.5 million and €1 million 2 where annual damages are below €0.5 million 1 where there are no annual damages
	Minimise risk to transport infrastructure	5 where major transport infrastructure is at risk 4 where significant transport routes are at risk 3 where regionally important infrastructure route are at risk 2 where minor/local transport routes are at risk 1 where negligible impacts to transport infrastructure 0 no infrastructure assets at risk
Social	Minimise risk to health and life including properties	5 where the number of residential properties at risk is greater than 500 4 where the number of residential properties at risk is between 250 than 499 3 where the number of residential properties at risk is between 100 and 249 2 where the number of residential properties at risk is between 10 and 49 1 where the number of residential properties at risk is between 1 and 10 0 where no residential properties are at risk
Environmental Acceptability	Avoid damage to designated sites of importance	5 where an internationally important site is present and potentially affected 4 where a nationally important site is present and potentially affected 3 where legally protected species/species of conservation concern are present/likely to be present and potentially affected 2 where a site of local importance is present and potentially affected 1 where there are no designated sites or known records of legally protected species/species of conservation concern, but habitats are present that could be affected 0 no sites, habitats or species at present that could be affected
	Protect landscape character	5 where landscape is designated as an internationally/nationally important landscape and potentially affected 4 where landscape character type is designated at a county level as highly sensitive and/or exceptional/high value and potentially affected 3 where landscape character type is designated at a county level as moderate sensitivity and/or medium value; protected views as low sensitivity and/or medium value; protected views present that could be affected 2 where landscape character type is designated at a county level as low sensitivity and or/low value and potentially affected 1 where there is no landscape sensitivity/value, but landscape features/views are important at a local level and potentially affected 0 where there is no specific designation, and no landscape value/sensitivity
Other	Other future changes	Weight of 1 applied

Scoring Guidance

Criteria	Objective	Relative Weight
Technical Effectiveness	Level of mechanical or human intervention	5= No future maintenance requirements over the life of options (Approximately 50yrs) 3= Limited future maintenance requirements over life of option 1=Medium future maintenance requirements over life of option 0= Regular future maintenance required (approximately every 5 years) -1=Significant maintenance requirements
	Health and safety	5= No health and safety risk to construction workers 3= Limited health and safety risk to construction workers 1= Medium health and safety risk to construction workers 0= Significant health and safety risk to construction workers -1= Very significant health and safety risk to construction workers
Economic	Minimise economic risk	5= All economic damages removed 3= Significant reduction in economic damages 1= Limited reduction in economic damages 0= No increase in economic damages -1= Potential for limited increase in economic damages -3= Potential for increase in economic damages -5=Potential significant increase in economic damages
	Minimise risk to transport infrastructure	5= All transport routes protected from any risks 3= Risks reduced to a significant number of transport routes 1= Risks reduced to a number of transport routes 0= No increase in the number of transport routes at risk -1= Potential for impacts on a limited number of transport routes (either directly or indirectly) -3= Potential for impacts on a number of transport routes (either directly or indirectly) -5= Potential impacts on a significant number of transport routes (either directly or indirectly)
Social	Minimise risk to health and life including properties	5= All residential properties protected from the risk of erosion. All high vulnerability properties protected from risk of erosion. 3= Risk reduced to a significant number of residential properties and o high vulnerability properties 1= Risk reduced to a limited number of residential properties and high vulnerability properties 0= No increase in the number of residential properties at risk -1= Potential for impacts on a limited number of residential properties (either directly or indirectly) and high vulnerability properties -3= Potential for impacts on an a number of residential properties (either directly or indirectly) and high vulnerability properties -5= Potential for impacts on a significant number of residential properties (either directly or indirectly) and high vulnerability properties
Environmental Acceptability	Avoid damage to designated sites of importance	5= Improvement in conservation status of designated sites; increase in population sixes and/or extent of suitable habitat supporting target species; and/or, increase in extent of riverine, wetland and coastal habitats 3= Potential for habitat enhancement within designated sites. 1= Potential for localised habitat enhancement 0= No deterioration in the conservation status of designated sites; no net increase in population sizes and/or loss of extent of suitable habitat supporting target species; and/or, no net loss of or permanent damage to existing riverine, wetland and coastal habitats -1= Potential for impacts on designated sites and their features, and/or damage to and/or loss of existing riverine, wetland and coastal habitats and associated species, although limited by the already modified nature of the channel/shoreline or by the localised nature of the option -3= Potential for impacts on designated sites and their features, and or/damage to and/or loss of existing riverine, wetland and coastal habitats and associated species -5= Potential for a significant effect on designated sites which may lead to deterioration of the conservation status; significant loss of habitats and associated species
	Protect landscape character	5= Improvement to visual amenity into/from designated areas 3= Opportunities identified to enhance visual amenity and landscape character in wider area 1= Opportunities identified to enhance visual amenity and landscape character in the local area 0= No adverse impacts on landscape character; and/or, no deterioration in quality of views into/from designated areas -1= Adverse change in local landscape character, although severity of impact reduced by use of demountables or low height of defences, impact is temporary, the fact that existing defences in this area or landscape is designated as being of low sensitivity -3= Adverse change in local landscape character within a landscape designated as being of medium to high sensitivity -5= Significant adverse change in landscape character across a wide area; significant change in views into/from landscapes designated as being of medium to high sensitivity
Other	Other future changes	3= Option will not be affected by future coastal processes or political circumstances 1= Option highly unlikely to be affected by future coastal processes or political circumstances 0= Option unlikely to be affected by future coastal processes or political circumstances -1 = Option may be affected by future coastal processes or political circumstances -3 = Option likely to be affected by future coastal processes or political circumstances