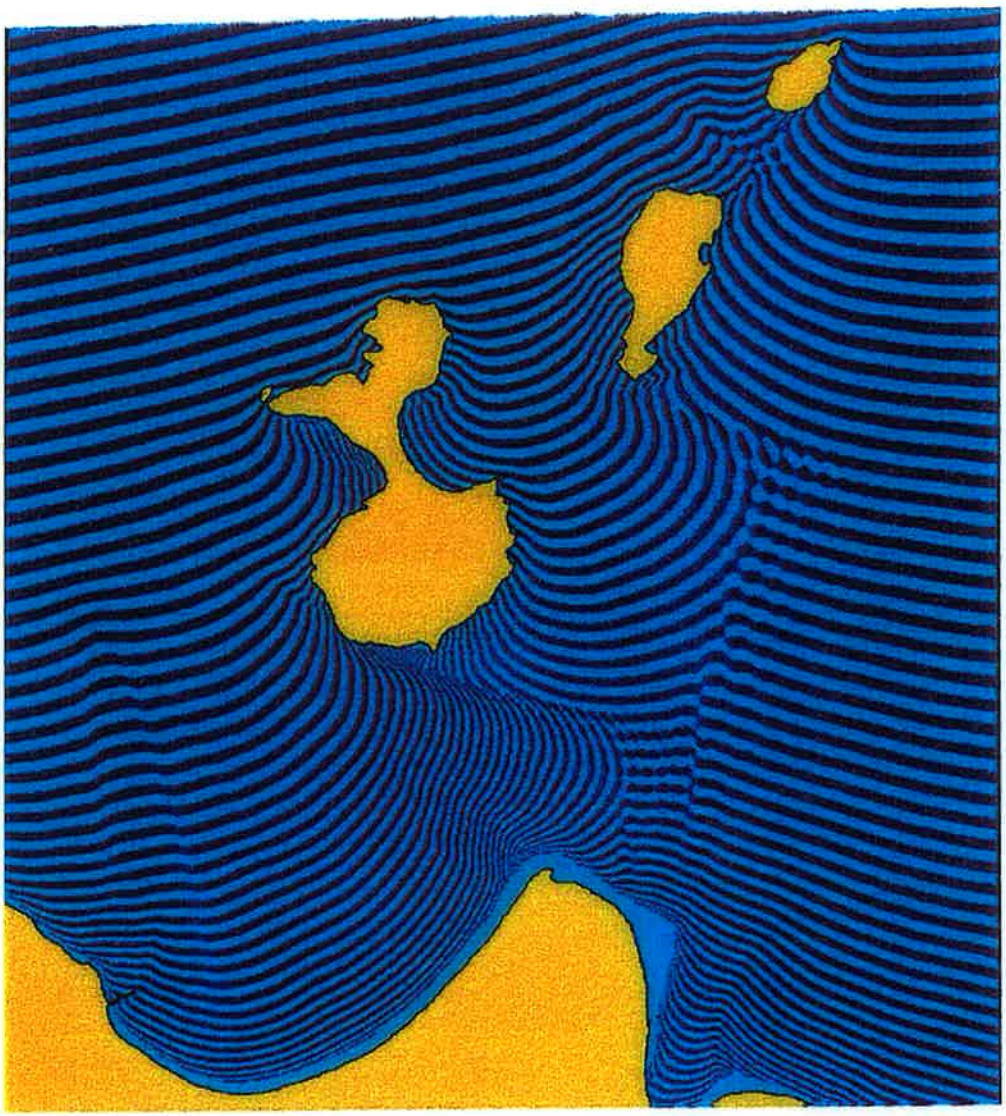
DONEGAL COUNTY COUNCIL

Magheraroarty Coastal Study



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1.0INTRODUCTION

The Magheraroarty beach is located in north west Donegal and is backed by the Dooey Peninsula which separates Inishbofin and Ballyness Bays.

Magheraroarty Pier has been construction on the southern shore of Inishbofin Bay at the south western end of Magheraroarty Beach. The pier is the main summer access point for the ferry to Tory Island.

The Dooey Peninsula and Ballyness Bay are environmentally important because of their varied habitat with specific wildfowl and botanical interest. The beach and adjoining area is also important for recreation and amenity.

There is concern that erosion of the beach material is threatening the stability of the sand dunes that form the back lands to the beach which act as defences for the whole of the Ballyness region. At the same time there is pressure for extension/dredge channel to give access at all stages of the tide to the Magheraroarty Pier and also for new pier works on Inishbofin Island.

The Department of the Marine, on behalf of the Donegal County Council, commissioned Kirk McClure Morton to investigate the coastal regime of Inishbofin and Ballyness Bays to enable the problem of coastal erosion to be evaluated and to examine the effects of any development of Magheraroarty and Inishbofin Piers.

The study was required to establish the coastal regime in Inishbofin Bay and Ballyness Bay including tidal variations, wave climate, littoral processes and beach and dune movements.

Options for coastal protection complete with an economic and environmental appraisal were required including consideration of the "do nothing" option.

Proposal for the improvement of the berthing facility at Magheraroarty for the Tory Ferry to give access under all tidal conditions were to be considered including the effects on the coastal processes of the area. Alternative

arrangements for new piers on Inishbofin were included in the coastal study.

The study was extended to include the investigation of a proposed causeway between Inishbofin Island and the end of the Dooey Peninsula.

In addition the specific items noted above, the study was to provide information on sediment process to assist the County Council and the University of Ulster with the LIFE project of the area.

2.0 STUDY AREA

Inishbofin Bay is formed between the northerly facing coast, east of Bloody Foreland, Inishbofin Island and the barrier beach/dunes system of the Dooey Peninsula (see Figure 1).

Ballyness Bay is a sheltered inlet protected by the barrier beach with its tidal entrance, running north between the Hook and Drumnatinny Point.

Magheraroarty lies at the proximal end of the Dooey Peninsula and has a tidal restricted pier which is the main summer access for the Tory Island Ferry Service.

The coastline to the west of Magheraroarty is rocky with discontinuous gravel storm beaches fronting eroded stoney till cliffs.

To the north north east of Magheraroarty the Dooey Peninsula sweeps round to the Otter Beg Spit and the Cloghan or Ford where access can be gained to Inishbofin at a very low spring tide.

The Dooey Peninsula is composed of aeolian sand deposited on a gravel basement. The west facing beach is a wide shallow beach with a narrow zone of ephemeral dune in front of the main ridge.

The nature of the frontal ridge of the dune system varies along the shore. Close to Magheraroarty Pier the gravel basement is exposed and the dune ridge is a low machair like zone which is dissected by shallow blowouts resulting from human recreational activities.

The frontal ridge of the dunes increase in height north eastwards out towards Peninsula Point. There area several significant blowouts which are distributing sand into the backland areas.

Behind the frontage ridge the dune structure is complex. The dominating feature is the giant bare sandhill which rises to about 30 m Ordnance Datum. The western face of the sand hill has a mild slope while the east face is steep.

To the east of the entrance to Ballyness Bay the frontal ridge of the dunes is well formed without any significant blowouts. The beach is narrower and less dissipative than the west facing beach in Inishbofin Bay. The dunes at Drumnatinny Point are considerably lower than the Dooey Sand Hill.

Ballyness lies behind the Dooey Peninsula with a mutual flood/ebb channel entrance throat. Inside the entrance there is a well developed flood delta system leading to extensive flat sandy intertidal areas with pronounced ebb tidal channels. Erosion of the back side of the Dooey peninsula has resulted in embayments and the formation of dune islands at high tide.

The Dooey Peninsula and Ballyness Bay area are particularly important ecological sites. The area is a proposed Natural Heritage Area and proposed Special Area of Conservation under the EU Habitat Directive.

3.0 HISTORICAL REVIEW

3.1 Formation of the Dooey Peninsula

John Shaw in his Phd Thesis "Holocene Coastal Evolution, Co Donegal" undertook considerable research into the historical formation of the Dooey Peninsula and Ballyness area of Co Donegal. Sections of this work, undertaken under the supervision of the late Professor Bill Carter, University of Ulster, have been used in this chapter to give a historical perspective to this study.

Based on an examination of exposed gravel and dunecrete ridges, Shaw suggested that the evolution pattern of the Dooey Peninsula as shown in Figure 2. After examining the effects of Holocene relative sea level change in the area, Shaw concluded that gravel basement of the spit was in place some 4,000-5,000 years ago. The source of the material is thought to be the coastline to the west which although rocky today had more extensive stone till cliffs at that time. As the material was sorted by wave action the fine material was removed to sediment sinks offshore, allowing gravel deposition to dominate during the rapid construction phase. However there is some evidence of aeolian sand also being fed ashore at the same time. As the spit grew the tidal and wave currents would have been altered. Vertical growth of the barrier occurred after the gravel frame had been established when minerogenic sand fed ashore was augmented by biogenic carbonate.

3.2 Recent Changes

A 1714 map of H. Moll indicates that the Dooey Peninsula was an Island at that time. While the accuracy of the map is unknown, it may well be correct as the Admiralty Survey of 1858 shows that the sand dunes terminated about 1 kilometre to the east of the site of Magheraroarty Pier with a low gravel ridge connecting the south west end of the dunes to Magheraroarty.

Figure 3 shows the changes in the Ballyness area from 1834 to 1977. While the seaward outline of the Peninsula has been relatively stable, erosion

within Ballyness Bay produced a considerable enlargement of the intertidal areas and formed a series of islands.

A significant change in the position of the large sandhill occurred during the period. In 1834 the sandhill was situated close to the distal end of the peninsula. By 1905 the hill was in a similar position but erosion within the estuary had begun to form embayments. The 1954 data shows that the great sandhill had migrated some 500 metres along a line 70° true north.

The 1977 aerial photograph, Figure 4 shows a similar location for the feature indicating that migration was arrested at the entrance throat to Ballyness Bay with sand washing into the channel and being distributed into the ebb delta.

The level of the great sandhill appears to be declining, a view supported by evidence from older residents of Inishbofin. This large sand body became unstable in historic times and may eventually disappear.

It is also interesting to note from historic records that the harvesting of marram grass on the peninsula appears to have made the frontal ridge more unstable, leading to the great number of blowouts seen along the frontal ridge today.

Possible changes in the nearshore bathymetry of Inishbofin Bay were assessed by undertaking a limited hydrographic check survey in the autumn of 1996 and comparing the results with Admiralty Survey of 1858. The recent check surveys showed similar results to those of the 1858 survey indicating that they had seen little change in the nearshore bathymetry of the Bay. This result is not surprising since much of the seabed of Inishbofin Bay consists of rock and stone outcrops with only small areas of finer sediments present within Inishbofin Bay.

4.0 COASTAL PROCESSES

The physical processes controlling the distribution and movements of sediment were investigated using state-of-the-art mathematical modelling techniques.

As part of the study, Kirk McClure Morton employed hydrodynamic wave and tidal computer models for the north western coast of Ireland. These models were used to provide information on the wave activity and tidal currents expected in Inishbofin and the Ballyness area.

The hydrodynamic models provided the base data required for input to a suite of littoral zone process computer models, MIKE 21/LITPACK, developed by DHI, Denmark. These models were designed to evaluate beach movements along mobile coastlines. The computer models were capable of estimating sediment transport in waves and currents, longshore sediment transport, 2-D sediment transport as well as cross shore storm profile development.

4.1Site Location and Exposure

The Admiralty chart of the area, Figure 1 shows the location of Inishbofin Bay, Inishbofin Islands and Ballyness.

Inishbofin Bay is open to the west and north west, however, due to the effect of refraction and diffraction, waves approaching the Irish Coast from south west through to north east can enter the Bay. Although the Inishbofin Island group give shelter to the Ballyness entrance area, waves approaching this region from the west can reach the beach; albeit in a highly transformed condition.

4.2Wave Climate

4.2.1Offshore Wave Climate

Data from the UK Meterological Office wave data model for a point 55.25° North 08.46° West as shown in Figure 5 was used to establish the offshore wind and wave climate. Swell and wind wave heights, periods and directions together with wind data were obtained for every 3 hours for three years 1994, 1995 and 1996.

The offshore wave roses are given in Figure 6, 7 & 8 and a typical annual wave trace is given in Figure 9.

It will be noted that the majority of all waves and large waves come from the west to north western sector. While the frequency of large waves from the north and north east is much less than from the west north west, waves of 5-6 metres height from the north to north east directions occur from time to time.

A statistical analysis of the wave records was also undertaken to determine the extreme wave conditions. Based on the three years of data it calculated that at the offshore point the 1 in 50 year wave climate would have a significant wave height of 12.5 metres and period of approximately 16 seconds. A typical annual storm would have a significant wave height of 8.7 m and period of 12 seconds.

4.2.2Inshore Wave Conditions

The inshore wave climate at four locations in Inishbofin Bay and Ballyness entrance were calculated using the latest spectral analysis techniques in conjunction with a fully computerised combined refraction and energy dissipation analysis. Three dimensional transformation matrices were developed to enable the 3 hourly inshore wave records for each point to be established from the offshore data. Details of the techniques used are given in Appendix A.

The locations of the four inshore points together with the fifth point at the entrance to Inishbofin Bay are shown in Figure 10.

Typical annual wave roses (1994) for each of the four inshore locations are shown in Figures 11 to 14. Compared to the offshore wave climate the spread of the wave directions in the inshore areas is very narrow, particularly at Site 2 where the waves are strongly influenced by Inishbofin Island. The reduction in wave height from offshore to inshore can also be seen in the typical winter wave trace shown in Figure 15. Where peak offshore wave height of approximately 10 metres were reduced to 5 metres at Site 1.

The significant wave height during a 1:50 year storm is predicted to be about 7.8 m at Site 1.

Due to the complex shape of study area the wave patterns will vary significantly along the shoreline as the waves are modified by the Inishbofin Island group.

In order to be able to investigate the influence of wave driven currents, the wave climate around the area was modelled using MIKE 21 PMS model. This model take account of wave diffraction as well as refraction, shoaling, bed friction and wave breaking.

Since wave currents are most significant during major wave events, typical gale conditions were simulated in the analysis. Wave directions of 285, 300, 320 and 015 degrees were investigated to give the spread of wave directions which can approach Inishbofin Bay.

Wave pattern diagrams are shown in Figures 16 to 22 and accord with the information from the annual wave climate transformation, i.e. the wave direction within Inishbofin Bay are very similar for a variety of offshore wave directions from the west or north westerly sector. The effects of tidal levels on the penetration of waves between Inishbofin Island and Peninsula Point can also be seen from the wave pattern diagrams.

4.3 Tidal Regime

4.3.1Tidal Flows

The tidal flow regime in the Magheraroarty region is complicated by the presence of the Inishbofin Island group and by the Ballyness estuary. Tidal flows of 2 knots are noted on the chart to the north of Bloody Foreland, Inishbeg Island and Temlebreaga Head. In the entrance channel to Ballyness tidal currents approach velocities of about 2 m/s. In Inishbofin Bay the currents are generally weak.

The tidal flow regime of the coastal study area was established using a suite of hydrodynamic computer modes, TIDEWAY-2D developed by Hydraulics Research Ltd.

The set up of the hydrodynamic model required an accurate digital ground model of the bathymetry of the Magheraroarty region to be developed. A bathymetric base data set was created from Admiralty Chart No. 2752, Admiralty Source Data Sheet No. 29 for North West Ireland and results from a hydrographic survey of Inishbofin Bay completed by Kirk McClure Morton in September 1996. All the depths in the base set were converted to a common chart datum before being digitised.

A base model covering the area between Bloody Foreland, Horn Head and Tory Sound with a 90 m grid spacing was created. A patch reduced the spatial resolution to 30 m in order to accurately define the tidal flow characteristics within the area of interest.

The tidal flow calculations were based on the solution of the two-dimensional depth integrated flow equations for shallow water using implicit finite difference techniques based on the Crank Nicholson method. The resulting tidal flow regime predicted by the computerised hydrodynamic model is presented in the form of a typical ebb and flood mean tidal flow patters corresponding to 3 to 9 hours after high water in Figures 23 to 24. The length and direction of the vectors are proportional to the magnitude of the current velocity at each nodal point in the grid.

The results of the current meter survey, completed as part of this study, in the entrance channel to Ballyness Harbour were used to validate the model. Close agreement was attained between the model and the field measurements showing the model predictions were representative of the tidal flows in the Magheraroarty region. Details of the model setup and implementation are presented in detail in Appendix A.

Data from the TIDEWAY tidal model was also used as boundary conditions for a MIKE 21 HD fine grid (7.5 m) Flow Model so that the tidal currents could be combined with wave currents to examine the movement of sediments. Typical flood and ebb vector plots are shown in Figure 25 to 26.

4.3.2 Tidal and Storm Surge Levels

The tidal levels have been derived from the Admiralty tidal tables based on Galway as the standard port. The tidal levels at Inishbofin Bay are calculated as follows:

	Chart Datum	O.D. Poolbeg
H.A.T	4.3 m	4.7 m
Mean High Water Spring	3.9 m	4.3 m
Mean High Water Neaps	3.0 m	3.4 m
Mean Low Water Neaps	1.5 m	1.9 m
Mean Low Water Spring	0.4 m	0.8 m
L.A.T.	-0.1 m	0.3 m

As the wave heights that can approach the shoreline are influenced by water depth an extreme tidal analysis was undertaken taking account of storm surges. The technique used was based on the UK Department of Energy Offshore Installations manual. The 1 in 50 year extreme water level was calculated to be 5.01 m CD which is equivalent to 5.41 m OD Poolbeg.

Analysis of the conditions which cause extreme storm surges show that the conditions which produce high water levels also produce storm wave

events. It was therefore concluded that it would be prudent to assume that the 1:50 storm event could occur with a 1:50 extreme water level

4.4Sediment Transport

4.4.1Sediment Transport computer simulations

The sediment movement expected along the mobile coastline at Magheraroarty was analysed using a suite of littoral zone process computer models, MIKE 21/LITPACK, developed by DHI, Denmark.

The sediment transport models utilize the results of the hydrodynamic models describing the nearshore wave climate and tidal flow regime together with beach survey data and particle size analyses of the sediments present within the study area.

The MIKE 21 suite of programs contain modules which enable the simulation of wave driven currents and sediment transport. The effect of Islands, Piers and other structures can be taken into account within the analysis. The LITPACK package was used to model cross-shore sediment transport and beach profile development.

The MIKE 21 model was set up using data from the beach surveys of autumn 96, and other surveys undertaken on behalf of the Admiralty. These data sets were supplemented by a comprehensive set of sediment particle size analyses defining the nature and grading of the sediments along the shoreline and intertidal zones of the beach. Grading curves typical of the surface sediments on the beach are presented in Figures 27, 28 and 29. Grading curves for sand at the toe of the dunes are presented in Figures 30 and 31.

A detailed description of the technique and assumptions used to evaluate the sediment transport is presented in Appendix B.

4.4.2Existing Coastal Regime

As noted previously the dominant wave direction is from the west to north west sector. The layout of the coastline beaches, estuary and islands dictates the wave pattern along the shoreline and the littoral currents.

The wave driven currents resulting from the west to north west waves approaching the area (Figures 16 to 20) are shown in Figures 32 to 37.

Figures 32, 33 and 34 show the wave driven currents at high tide for the wave directions of 285°, 300° and 320°. It will be seen that irrespective of the wave direction in the west to north west sector, the flow patterns within Inishbofin Bay are broadly similar. There is a strong wave driven current from the west along the shoreline from Bloody Foreland which sweep round the Magheraroarty beach towards the Otter Beg Spit. This drift round the bay then flow west along the southern side of the spit. At the same time there is a littoral current along the southern shore of Inishbofin Island which at high water passes by the northern side of the Otter Beg Spit.

Simulation of the conditions at mid tide, when tidal currents are also taken into account, Figures 35 and 36 and at low tide, Figure 37, shows that the general pattern of drift is broadly consistent with the high tide pattern.

With north and north easterly waves the currents are different from the westerly conditions as shown in Figures 38, 39 and 40. In this case the littoral currents flow from the north east across the Cloghan or Ford particularly at high water and with the ebb tide.

At the entrance channel to Ballyness Bay sediment is distributed into the flood and ebb deltas by the strong currents. Sand avalanching from the sand hill into the entrance channel moves seawards in the throat and onto the ebb delta. With westerly waves there is some by passing of sediment to the east while with north and north easterly waves the position is reversed.

In general sediments move along the shoreline from the west and are carried onto Magheraroarty Beach particularly at its outer part toward the Otter Beg Spit. The prevailing westerly winds blow sand which has been deposited on the beach into the dune system of the Dooey Peninsula. Sand from the peninsula is carried from the dune system into the ebb channels in Ballyness Bay and transported to the ebb delta system from where it is transferred to the beach. The giant sandhill is an important feature in this sediment transport process and there is evidence that its size is decreasing and may eventually disappear.

5.0 ENVIRONMENTAL APPRAISAL

The Dooey Peninsula and Ballyness Bay area within a proposed natural Heritage Area and a proposed candidate Special Area of Conservation. See Figure 41.

The sandflats, shallow bays, fixed sand dunes and machairs are all EU annexed habitats. The dunes and sandflats at Dooey Point are considered to be of national importance while the waterfowl interest is considered to be of regional importance. The presence of Croncrake in the proposed NHA greatly increases the ecological importance of the site.

As part of the study an ecological appraisal was undertaken of the Ballyness Bay and Dooey Peninsula area. The environmental assessment included an expert-eye appraisal of flora and fauna, undertaken in October 1996, with additional information obtained from literature and personal communication with statutory and non-statutory consultees. Details of the appraisal are given in Appendix C.

While the Dooey Peninsula itself may be lacking in flora diversity, behind the dunes at Drumnatinny are areas of wet and sandy grassland of the machair variety. Areas of saltmarsh, grassland and heath around Ballyness Bay add further flora diversity to the overall area.

Ballyness Bay is of importance for wintering waterfowl with regionally important numbers of birds. The most important loafing area is the backstrand of Dooey especially along the middle and eastern stretch near the dune islands. Dominant species include Ringed Plover, Brent Goose, Red Breasted Merganser, Sanderling and Wigeon. The Bay is the only Golden Plover site of consequence in NW Donegal, with a maximum of 600 birds being recorded in October 1992. A small flock of Long-tailed Duck has been sighted in Inishbofin Bay (the Port Marsh). This is quite important in the Irish context.

Otter, Irish Hare, Common Seal and Grey Seal are annexed species under the Habitats Directive.

Otter has been signed on Dooey Peninsula and Fox on the eastern edge of Drumnatinny. An unconfirmed sighting of Irish Hare has also been reported.

A small population of Common Seals use the Bay with haul out sites located on the central sand barrier and western side of the outflow. A breeding colony of Grey Seals occur at Inishbofin.

Since the Dooey Peninsula and Ballyness Bay is a proposed candidate SAC, any defence works or pier construction must be undertaken so that there is no risk of endangering the nature of the habitats which ae all covered by the EU habitat directive.

6.0 COASTAL EROSION

6.1 Erosion in Inishbofin Bay

The line of the frontal ridge of the dunes in Inishbofin Bay has been relatively stable over recent years. However, there are significant blowouts along the ridge (see Plates 1 and 2). In the northerly section of the ridge, these blowouts have possibly resulted from the harvesting of marram in former times when the material was used for roofing etc. These blowouts feed sand from the beach to the rear areas of the dunes.

At Magheraroarty Pier end of the dune ridge blowouts result from human recreational pressure. Vehicle access (see Plate 3) and pedestrian traffic are causing damage to the vulnerable part of the dunes which is leading to erosion in this area, Plate 4.

Significant changes in Magheraroarty beach are predicted to occur during extreme storm events. The model simulations of the changes in beach profile at the centre of the bay during a 1 in 50 storm are shown in Figures 42 and 43. Sand is drawn away from the dune and upper beach and deposited in the nearshore area. It is predicted that some 10 m of dunes would be eroded during such an event. The lowering of the beach levels will however be restricted by the gravel basement which will become exposed with the loss of sand.

At the southern end of the beach the gravel basement is already exposed. During extreme storm events the low dunes on top of the shingle beach may be eroded and gravel washed over the ridge of the underlying shingle.

Magheraroarty Pier is acting as a groyne and retaining gravels on the storm beach to the west of the pier (Plate 5). The model simulations show the some 1,100 m^3/year would be transported along the upper beach if the pier structure was not in place. The effect of the pier has been to cause erosion to east of the Pier, Plate 6, due to the loss of shingle supply to the area.

6.2 Erosion at the North of the Dooey Peninsula

As can be seen in Plates 7 to 10 the north eastern and eastern side of the bare sandhill on the Dooey Peninsula is being eroded by wave and current action. This is part of the natural processes of the area where sand from the hill is eroded into ebb delta of the Ballyness Bay entrance. Any attempt to protect the eastern face of the sandhill would have an effect on the whole regime of the area.

6.3 Erosion in Ballyness Bay

At high tide strong south and south easterly winds can generate waves of up to 0.5 m significant wave height along the Ballyness Bay side of the Dooey Peninsula. Over the last hundred and fifty years these waves, together with the tidal flows have resulted in erosion leading to an increase in the intertidal area and the formation of sandhill islands. The continuing rate of erosion will be dependant upon the amount of sand being supplied to the rear of the dunes by the prevailing westerly winds.

6.4 Coastal Protection Measures

The whole of the Dooey Peninsula and Ballyness is a proposed NHC/cSAC. Any attempt to alter the natural process to provide protection would be counter productive in that they would almost certainly upset the dynamic sediment transport regime that governs the habitat of the area.

If due to global warming there is increased storminess and sea level rise then it is expected that there will be erosion of the dune line as the system adjusts to the variation in wave climate. Attempting to prevent such a change at this site would be very expensive and doomed to failure in the long run.

While the "do nothing" option is recommended in relation to the main erosion mechanisms, there are areas where human activity is resulting in erosion and compensating measures should be undertaken. The construction of Magheraroarty Pier has obstructed the movement of shingle along the upper beach. It is therefore suggested that shingle

should be mechanically bypassed and placed on the storm beach to the east of the pier so that the supply of shingle to the gravel ridge in this area is maintained.

Human recreational activity is damaging the dunes particularly the low dunes at the Magheraroarty Pier end of the system. Vehicular traffic should be prevented from accessing this fragile environment and consideration should be given to making specific pedestrian access points unto the beach with timber walkways to prevent further damage to these dunes.

7.0 MAGHERAROARTY PIER EXTENSION

7.1 Existing Pier

The existing pier at Magheraroarty was constructed in the late 1970's on the site of a former pier. The pier (Plates 11 and 12) is of reinforced concrete construction and extends some 18.5 metres down to low water spring tides.

The pier is the main summer access point for the Tory Island Ferry as well as providing facilities for local fishing boats and access to Inishbofin.

7.2 Improved Berthing Facilities

The ferry to Tory Island has been improved in recent years. Now with the construction of a new all tide berth at West Town, Tory, underway there is a need for improved berthing on the mainland.

Magheraroarty is the operators preferred location for the summer ferry service. The operator requires a berth accessible at all stages of the tide and with a degree of shelter so that the ferry can operate from Magheraroarty most of the time in summer.

From the wave pattern diagram Figures 16 to 22, it will be seen that the existing pier provides little shelter and an L shaped extension will be required with a depth of 3 metres at LAT.

7.3Pier Extension and Dredged Channel

To provide the facilities required, the pier at Magheraroarty must be extended and, depending upon the length of the extension, a dredged access channel provided.

The provision of a very short extension from the end of the exiting pier would involve a dredging channel of some 300 metres in length and up to 3 metres deep. While the existing berth is protected from the high littoral currents, by Magheraroarty Point, see Figure 33, a dredged channel

would be in the path of the main littoral currents feeding into Inisbofin Bay. Such a channel is likely to silt up in a relatively short space of time.

Alternatively the Pier may be extended so that only a small depth of dredging is required, see Figure 44. The berth for the ferry would be along the outer L where, as can be seen in Figures 45 to 49, it would be sheltered from direct wave attack. The estimated cost of this pier extension and berth is IR£4.4 million.

7.4Environmental Implications of Pier Extension

A 240 metre pier extension was investigated in the coastal process models. The littoral currents for various wave directions are shown in Figures 50 to 55. These may be compared with the same conditions for the present pier, Figures 32 to 40.

Generally the pier extension has little or no effect on the littoral processes for the northern half of the Magheraroarty beach. However there are noticeable changes in the littoral currents on the southern half of the beach for some of the wave directions. In view of the importance of the ecology of the Dooey Peninsula and the Ballyness area, it is considered that a conservative view should be taken with regard to changes in the coastal processes. Thus it is considered that an extension to Magheraroarty Pier is not advisable due to its likely effect on the coastal process of the southern half of Magheraroarty beach.

Due to the presence of Magheraroarty Point to the west of the Pier an extension of about 50 metres with dredging of not greater than 1 metre depth could be provided at Magheraroarty without the risk of significant environmental impact. This would provide improved facilities for local boats serving Inishbofin Island.

7.5Alternative Locations for the Tory Island Ferry Berth

Magheraroarty Pier is an attractive venue for the Tory Island ferry due to its short journey time and the fact that the island can normally be seen by visitors approaching Magheraroarty by road.

Curran Port further to the west of Magheraroarty is a possible venue for a new berth. Curran Port is a rocky bay with a steep shingle storm beach. Although the bay looks as if it would be sheltered it is more exposed than Magheraroarty. Due to the rocks in the Bay there is limited manoeuvring room. The cost of providing a new pier would be greater than the extension of Magheraroarty. This site is not favoured by the ferry operators.

The pier at Port na Blah is used at times by the Tory Island Ferry. Road access and visitor attractiveness is good at Port na Blah but the pier is not accessible at all stages of the tide and the site is exposed to northerly winds. The journey time to Tory is only marginally shorter than from the main ferry base at Bunbeg.

8.0 INISHBOFIN PIER

8.1 Existing Pier

The existing pier on Inishbofin Island is situated on the southern shore to the west of Cloghan or Ford. The pier, Plate 13, is relatively short, is tidally restricted, and the end section is subsiding. The pier acts as a small groyne and retains some shingle on its western side.

8.2 Proposed New Pier

A proposed new pier is to be located some 150 metres to the west of the existing pier. This new pier would be some 200 metres long with 2 metres of water along its outer section at low tide, Figure 56.

The wave patterns and wave heights around the pier are shown in Figures 57 to 64. It will be seen that the pier would give shelter from the westerly waves. However at high tide a low swell can be diffracted around the north of Inishbofin Island and approach the site of the new pier from the north east direction. Similarly the eastern side of the pier will be exposed to north easterly waves at times of high to mid tide.

As with the existing pier, it is expected that the new pier will act as a groyne and retain shingle on the western side of the root of the pier. However, as can be seen from Figures 50 to 55 the proposed pier will not significantly alter the littoral currents outside the immediate area of the pier. The construction of this pier is not expected to alter the stability of the beach or dunes at Dooey Peninsula and Ballyness. Scour protection will be required around the tip of the pier due to the deflection of the littoral currents in this area.

The estimated cost of construction of this proposed pier is IR£2.4 million.

8.3Toberglassan Bay

The proposed new pier on the south of the Island would not provide a sufficient area of shelter to allow 50 fishing boats to be moored in the area throughout the summer. Local fishermen requested the investigation of a new structure at the north end of Toberglassan Bay to provide this facility.

Toberglassan Bay is located on the north eastern side of Inishbofin opposite Inishdooey. The bay has a sand beach exposed at low tide backed by a steep shingle storm beach. The northern shore of the bay is rocky, Plate 14.

The location of the proposed pier is shown in Figure 65. Figures 66 to 71 show the wave pattern and wave heights for a range of wave directions indicating that the structure would provide shelter from most directions.

The proposed structure would have no significant effect on the coastal processes of the general area although within Toberglassan Bay it would cause a redistribution of the beach sand. Material would be moved to the northern end of the beach due to the clockwise wave current drift created within the bay by the new pier.

While the pier would provide shelter there are no roads or other infrastructure on this part of the Island which is within the proposed NHA.

The estimated cost of construction of this pier/breakwater is IR£3.0 million.

9.0 INISHBOFIN CAUSEWAY

9.1 Proposed Causeway

Mains water and electricity services are not currently available on Inishbofin Island. There are plans to provide electrical connections to the Island, probably by laying a cable across the Cloghan or Ford. Investigation of the feasibility of also providing access to the island via a causeway at Cloghan or Ford was therefore included in the study.

The proposed causeway embankment would be constructed along the line of the Cloghan or Ford from Inishbofin Island to Peninsula Point. The embankment would be protected by rock armour slopes on both sides of the embankment. The level of the top of the causeway would be between +6 m to +8 m CD depending on the nature of the causeway surface and the degree of overtopping to be permitted during storms.

The estimated cost of the causeway is IR£5 - 6 million excluding the cost of any connecting roadworks along the Dooey Peninsula.

9.2Effect of Causeway on Coastal Processes

The typical gale wave pattern with the causeway in place are shown in Figures 72 to 77 and wave heights, Figures 78 to 81. The effect on the littoral drift patterns are shown in Figures 82 to 89 and on the tidal flows only in Figures 90 and 91.

Comparing these diagrams with the ones for the existing situation, Figures 32 to 40 and 25 to 26, it will be seen that the construction of the causeway cuts off the tidal flow and wave driven currents across the Cloghan or Ford.

With north and north easterly waves a build up of sand on the northern side of the causeway at the Inishbofin Island is to be expected. During westerly gales the Causeway causes increased outflowing currents from the northern part of Magheraroarty beach which would alter the form of the

Otter Beg Spit. The causeway construction would also result in a reduction in the sediment supply to the northern side of Peninsula Point.

The construction of the causeway will significantly change the littoral currents and therefore sediment transport regime of Magheraroarty beach and the Dooey Peninsula. In view of the interlinking of the sediment movements between the west facing beach, north facing beach, the dunes and Ballyness Bay, the modelling study shows that the construction of the causeway to Inishbofin Island is likely to affect the balance of the entire system.

10.0 CONCLUSIONS AND RECOMMENDATIONS

10.1 General

The Dooey peninsula and Ballyness Bay form a particularly important ecological area which is a proposed NHA and cSAC. The sediment transport system is complex but in general sediments move along the shoreline from the west and are carried onto Magheraroarty Beach particularly at its outer part towards the Otter Beg Spit. The prevailing westerly winds blow sand which has been deposited on the breach into the dune system of the Dooey Peninsula. Sand from the peninsula is carried from the dune system into the ebb channels in Ballyness Bay and transported to the ebb delta system from where it is transferred to the beach.

10.2Coastal Erosion

While the line of the frontal ridge of the dunes of the Dooey peninsula has been relatively stable over recent years erosion is taking place along the eastern side of the giant sandhill. This is an important feature in the sediment transport process of the area and erosion of the sandhill should not be prevented. The sandhill became unstable in historic times and may eventually disappear.

The model study predicts that erosion of the frontal ridge will occur during major storm events. Any increase in storm numbers and intensity due to global warming will result in erosion of the dune line as the system adjusts to the variation in the wave climate. It is not desirable nor practical to attempt to prevent such an adjustment.

There are two areas where human activity is resulting in erosion and where action should be taken. Magheraroarty Pier is obstructing the movement of shingle along the upper beach leading to coastal erosion to the east of the pier. Mechanically bypassing the shingle is recommended to mitigate the effects of the pier.

Damage is being caused to the low dune system at the southern end of Magheraroarty beach due to recreational activity. It is recommended

that timber path access points onto the beach should be created to prevent blowouts forming in these dunes. Details outlined in the ECOPRO Manual should be adopted for these access paths.

10.3Magheraroarty Pier

Magheraroarty Pier is the main summer access point for the Tory Island ferry as well as providing facilities for local fishing boats and access to Inishbofin. The ferry operator would like the pier to provide access to all stages of the tide as well as providing more shelter for summer operations.

A deep dredged channel with a small pier extension or a major pier extension with a small amount of dredging will be required to provide access for the ferry at all stages of the tide.

Significant littoral currents cross the line of a proposed channel into Magheraroarty Pier. Thus it is expected that a suitable dredged channel would silt up relatively quickly.

A major pier extension and new berth will interfere with the wave driven currents in the area and it is likely to alter the sediment process on the souther part of Magheraroarty Beach.

In view of the ecological importance of the area and the cost of a major pier extension for the ferry service, it is recommended that an all tide berth is not provided for the ferry at Magheraroarty. A small extension (50 m) with limited dredging could be provided to improve facilities for local boats without the risk of significant environmental damage.

10.4Inishbofin Pier

A new 200 m long pier located, some 150 metres to the west of the existing pier at Inishbofin has been examined as part of the study. The new pier would provide increased shelter and greater operating depths for vessels servicing Inishbofin Island.

The construction of the pier is not expected to significantly alter the stability of the beach or dune system of the Dooey Peninsula. Scour protection will be required around the tip of the new pier due to the presence of strong wave driven currents in the area during westerly gales.

An alternative pier/breakwater location has been proposed at the northern end of Toberglassan Bay to provide facilities for 50 foot fishing boats. The investigation shows that a pier/breakwater at this location would provide shelter from most directions and would have little impact on the overall sediment transport regime of the area. Some local redistribution of sand in the bay would occur following the construction of the pier.

There is no road access or other services available to the Toberglassan Bay area of Inishbofin Island and the Island is included in the proposed NHA.

10.5Inishbofin Causeway

The study included the investigation of the feasibility of providing a causeway from Inishbofin to Peninsula Point.

The model study showed that the construction of a causeway would significantly alter the sediment transport pattern around the northern part of Magheraroarty beach and Otter Beg Spit. It is considered that there is a significant risk that the building of a causeway would alter the dynamic balance of the sediment transport system of the area and therefore the construction of such a causeway is not recommended.

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APPENDIX A

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A1.0 INTRODUCTION

A detailed wave climate assessment was undertaken for the coastal study area using state-of-the-art computational modelling techniques. The objectives of the study were:

1. To determine the wave climate at coastline for input into the sediment transport models.

2. To establish the extreme wave conditions for the design of any coastal protection structures.

Data from the UK Meteorological Office wave data mode was used to assess the offshore wave climate. Swell and wind wave data were derived for every 3 hours for the period December 1993 to November 1996.

The inshore wave climate at the approaches to Magheraroarty and Ballyness were calculated using the latest wave spectral techniques in conjunction with a fully combined refraction and energy dissipation analysis. The models were capable of accurately predicting the reduction of wave energy of storm waves generated in the Atlantic as well as the locally generated waves across the direct fetches as they approach the shoreline.

The wave conditions around Magheraroarty pier, its adjoining beach and the beach outside Ballyness Bay were modelled using the parabolic mild slope equation model MIKE 21 PMS which is particularly suitable for computing wave fields in coastal areas with islands.

A2.0 EVALUATION OF THE OFFSHORE WAVE CLIMATE

A2.1 General

The offshore wave conditions were evaluated from wave records calculated using the Meteorological Office's wave prediction model as described by Golding (1980). This model calculates the wave climate at a series of grid points which cover the general areas of the North Atlantic. The model utilises meteorological data from which wind strengths, durations and directions can be calculated at the grid points. Hindcasting techniques are then used to calculate wave growth with time and spreading from each of the points. The wave climate at any grid point can then be calculated by superimposing not only the local waves but also those arriving from any of the other locations at that time.

Wave records for the period December 1993 to November 1996 in approximately 50 m depth of water off Tory Island were used as the base data for the study. Swell and wind wave heights, periods and directions for every 3 hours throughout the 36 month period.

A2.2 Extrapolation of Wave Records

The extreme wave conditions expected at the offshore site were estimated using the methods outlined in BS6349: Part 1: 1984. (British Standards Institution 1984).

The first step was to identify individual storm events within the data set available. An appropriate criteria was selected. In the case of Magheraroarty and Ballyness the significant wave height (Hs) had to exceed 3 m to be considered a storm and the end of the event was when the height dropped below 1.5 m. Having identified the appropriate storms, the maximum value of Hs in each event was recorded and then these values were ranked in descending order.

The next stage in the analysis was to plot the initial wave heights against their cumulative probabilities of occurrence, using an appropriate probability function. The object was to obtain a straight line from which an estimate of the extreme values could be extrapolated.

A Weibull distribution function was used in the analysis whereby a plot of ln(Hs - Hl) against lnln(1/Pn) yielded a straight line graph. Here Hl is defined as the lower limiting value of Hs.

H1 is essentially the cut-off value where all the storms with Hs equal to this value or above were taken. The value of H1 is selected by trial and error to give the line of best fit (i.e. the line whose r^2 value is closest to l) Pn is the probability that the wave height Hs is equalled or exceeded and is given by Equation l.

Equation 1 $Pn = \frac{n}{(n_x + 1)}$ n = Rank number

n_x = Total number of storm events

A graph is plotted of X against Y as given in Equations 2 and 3.

Equation 2 $X = lnln\ (1/Pn)$ Equation 3 $Y = ln\ (Hs - Hl)$

Points that deviate appreciably from the straight line trend are not included in the final regression analysis. These points are caused by storm events that have higher or significantly lower return periods than that of the total record length in which the events lie.

Having drawn the best fit line and calculated the equation, estimates of Hs for 1 in 50 and 1 in 100 year storms may be found.

Pn is also defined as in Equation 4. If To is known and the desired Return period Tr, Pn can then be calculated. The value of X can be found from Equation 2 and using the equation of the line the corresponding value of Y. Rearranging Equation 3 in the form as shown in Equation 5 enables the value of Hs to be found.

Equation 4 $Pn = \frac{T_o}{Tr(n_x + 1)}$ To = Length of Data Set in years

Tr = Return period in years

Rearranging $Y = ln(Hs-Hl)$ gives

Equation 5 $Hs = e^{Y} + Hl$

With Magheraroarty and Ballyness it was found that using a value of 4.75 m for Hl provided the best fit line with a regression coefficient of 0.9732.

Hs for a 1 in 50 year storm was then calculated at 12.4 m.

A2.3 Wave Time Series Plots

The offshore data set is presented in the form of Significant Wave Height, Period and Direction versus Time plots in Figures 9 and A1 to A2. The plots show that, in general, the wave activity is greater during the winter months compared to the summer.

A3.0 MODELLING THE INSHORE WAVE CLIMATE

A3.1 General

The inshore wave climate was derived by wave transformation modelling of the offshore wave data to the 10 metre contour off Magheraroarty and Ballyness. Using linear theory wave ray models developed at HR Wallingford a selection of wave events covering the entire range of the offshore dataset were used to establish the wave transformation function for all the wave events in the offshore wave climate.

The wave conditions at the beach were transformed from the 10 metre contour using the Buttjes and Janssen model which takes account of the non linear effects as waves travel into the shallow waters.

A3.2 Modelling the Seabed Characteristics

The offshore to inshore wave transformation analysis required the bathymetry around Inishboffin Bay, Ballyness Harbour and the adjoining area of the Irish Sea to be modelled accurately. This required a grid system to be set up over the entire region and the depth value at each nodal point input to a computer data base. Fourteen grids, with grid spacing varying from 200 m in offshore regions to 50 m in the area around Inishboffin Bay and Magheraroarty pier were used to accurately model the changes in depth. The data were obtained from Admiralty Charts and source data. All points were converted to the same datum, chosen as LAT (lowest astronomical tide level), before being entered into the computer.

The grid system used in the modelling process is illustrated in Figure A3.

A3.3 Offshore to Inshore Wave Transformation

The 3 hourly offshore wave records were scanned to identify the range of wave heights and periods contained in the data sets. 824 wave events were chosen which covered the complete range of the offshore wave climate. The 824 events were run inshore using back tracking and forward tracking wave model analysis. To each of four selected sites.

Back-Tracking Ray Model

The refraction model uses the concept of wave rays, that is, lines perpendicular to the wave crest which extend in the direction of wave advance. Although the wave rays naturally travel from the seaward edge of an area towards the land, it is extremely efficient computationally to initially use a "back-tracking" method. This technique consists of "projecting" rays seawards from the area of interest. This enables the determination of the period and direction of waves which can reach the site from an offshore location. A typical back-tracking ray model is presented in Figure A4.

Rays were projected from the 10 m depth contour off Magheraroarty and Ballyness Bay from 0° to 360°N in 0.25° intervals to ensure the detection of all wave rays which reached a specified offshore boundary. Fifteen wave periods were investigated per event, selected so that they corresponded to each frequency component of the relevant offshore wave spectra. The analysis therefore had to be repeated for each of the 824 wave events selected to cover the range of the offshore wave records at each of the four selected sites.

The results from this stage of the analysis take the form of a list of all those rays which connect the chosen sites to the offshore boundary. The wave period of each ray, its direction on leaving the sites and its direction at the offshore boundary are stored. Typically this list would contain information about several thousand rays.

For convenience, the list of wave rays which can reach the offshore boundary are converted to a matrix format which are called `transfer functions'. Each matrix column represents a period band (15 in total) and each row a sector of offshore wave directions (36 in total representing angular increments of 10°). The transfer functions contain all the information on how the seabed topography changes the wave direction at each period.

The state of the analysis allowed the determination of the inshore wave conditions, at the sites, for each selected wave event, taking into account refraction and shoaling only. No allowance was made, at this stage, for losses in wave energy due to frictional effects on the seabed. Most importantly, this model gave the directional spread of the waves approaching the sites. It also enabled the determination of the representative period, direction and height of offshore storm spectra, for use in the forward-tracking ray model.

Forward-Tracking Model

The next stage in the analysis was to run the forward-tracking ray model to determine energy losses due to friction on the seabed and wave breaking. Wave rays representing the significant wave height and energy period of each of the offshore spectrum were tracked from the offshore boundary to the sites.

Bed friction was modelled using the Bretschneider and Reid formulation (Bretschneider 1954). A global friction factor of 0.04 was used throughout the analysis.

Wave breaking was modelled using the empirical formulation of Weggel (Weggel 1972). A value of 0.75 was used to represent the fraction of energy above the breaking limit which is dissipated.

A3.4 Wave Transformation Matrices

The results of ray tracking mathematical models gave the transformation function for the inshore wave conditions at the approaches to the coastal zone during each of the 824 selected offshore wave events.

The transformation functions were placed in two matrices to enable the complete 3 hourly offshore record to be accurately transformed inshore. A 3 dimensional matrix based on wave direction, height and period was used to give the wave height attenuation relationship, while a 2 dimensional matrix based on wave direction and periods gave the wave direction transformation.

A special computer routine was written to establish the inshore wave condition for every offshore wave record by interpolating between the appropriate wave transformation functions in the matrices.

Results of the inshore wave modelling are given in Figure A5 to A7 as well as in Figure 15. These records show the complete yearly records as well as a typical winter climate.

A3.5 Shallow Water Transformations

The forward-tracking and back-tracking ray refraction models were capable of predicting the transformation of an offshore wave climate to points at the approaches to the

shoreline. However, the models which are based on small amplitude linear wave theory, were not considered capable of satisfactorily predicting the wave climate at the shoreline, due to the significance of non-linear effects of waves travelling in shallow water. An alternative approach was therefore adopted to calculate the transformation of the wave climate from the nearshore to the shoreline.

The wave analysis between the 10 metre depth contour and beach was undertaken using DHi's Mike 21/Litpack software. The wave model contained within the coastal process models included a description of refraction, bed friction, shoaling, wave breaking and calculation of radiation, bed friction, shoaling, wave breaking and calculation of radiation stress, gradients to enable wave setup to be considered. The model can be applied on complex coastal profiles including those with longshore bars. The Buttjes and Janssen wave model was used with irregular waves assuming a Rayleigh distribution about an H_{rms} wave height and model included the effects of directional spreading.

A3.6 Modelling the Wave Climate around Magheraroarty Beach, Inishboffin Island and beach outside Ballyness Bay

The wave conditions around Magheraroarty beach, Inishbofin Island and the beach outside Ballyness Bay were assessed for a variety of conditions using the MIKE 21 PMS model.

MIKE 21 PMS is a linear refraction-diffraction model based on a parabolic approximation to the elliptic mild slope equation. The model takes into account the effects of refraction and shoaling due to varying depth, diffraction along the perpendicular to the predominant wave direction and energy dissipation due to bottom friction and wave breaking. The model also takes into account the effect of frequency and directional spreading using linear superposition.

MIKE 21 PMS is based on a parabolic approximation to the elliptic mild slope equation. Several parabolic approximations are implemented in MIKE 21 PMS ranging from the simple approximation valid for small angles to the more sophisticated approximations valid for large wave angles (up to +/- 60°). The parabolic equation is solved using the Crank-Nicholson finite difference scheme.

The model was used to compute the wave field around the pier and the beaches at Magheraroarty and outside Ballyness Bay taking account of wave refraction, shoaling, breaking and diffraction perpendicular to the main wave direction.

The basic output data from the model was integral wave parameters such as the root mean square wave height, the peak wave period and the mean wave direction. Others output data which was obtained from the model was: radiation stresses and instantaneous surface elevations.

Wave conditions and radiation stresses (used in the calculation of wave induced currents) were required for the computation of littoral currents and erosion/deposition patterns around the pier and beaches.

Since wave currents are most significant during major wave events, typical gale conditions were simulated in the analysis. Wave directions of 285, 300, 320 and 015 degrees were investigated to give the spread of wave directions which can approach Inishboffin Bay.

The bathymetres of the PMS wave model is shown in Figure A8. The wave conditions at the boundary of this model were obtained by wave transformation from the offshore data point to a point at the entrance to Inishbofin Bay (Point 5, Figure 10) for the westerly/north-westerly section and to a point north of Inisbeg for the north/north-easterly directions.

Typical annual gale conditions were found to produce 6 m significant wave height with periods spectral peak periods of 10.5 seconds, at the entrances to Inishboffin Bay with wave directions ranging from $285^{o} - 320^{o}$. For the north-north-east directions the typical gale conditions gave conditions of 4.3 m significant wave height with spectral peak periods of 8 seconds at the PMS model boundary.

A3.7 Modelling the wave climate within Ballyness Bay

The wave climate which could erode the Dooey Peninsula within Ballyness Bay was assessed using a spectral wave windcasting analysis based on the shallow water equations of the Shore Protection Manual, 1984. The fetch lengths were based on the average of 9 radials at 3 degree interval over a 24 degree arc with a cosine to the 10th power directional spreading function for the wind input to the sea.

A4.0 TIDAL MODELLING

A4.1 Tideway 2D Model

A4.1.1 Tidal Model Set Up and Implementation

The tidal flow characteristics of the coastal study area were established using the suite of two-dimensional depth integrated hydrodynamic models, TIDEWAY – 2D, developed at Hydraulics Research Ltd.

The tidal computations were performed on powerful UNIX based SUN SPARC Workstations. The model flow results, which comprise water levels, velocities and discharges between each model element were stored in computer files at 12 minute intervals throughout the tidal cycle for subsequent processing.

The solution of a computer numerical model is required to be both stable, ie with no tendency for uncontrollable oscillations to occur, and accurate. In TIDEWAY 2D stability of the solution to the two-dimensional depth integrated flow equations is assured by the implementation of implicit finite difference techniques based on the Crank-Nicholson method.

Therefore, no constraints were placed on the size of the timestep used by the model due to the stability criterion. However, to maintain accuracy in the solution the timestep was limited to five times the stability limit had an explicit material method been used, Δt, where

$$\Delta t = \frac{\Delta s}{\sqrt{2\,g d_{max}} + V_{max}}$$

and	Δs	=	maximum grid spacing	(m)
	d_{max}	=	maximum water depth	(m)
	v_{max}	=	maximum velocity	(ms^{-1})
	g	=	acceleration due to gravity	(ms^{-2})

The timestep used for the Magheraroarty model was 6 seconds.

To prove the stability, the complete model was re-run for three tides. Tidal heights and velocities predicted after the second and third tides were compared and found to be identical showing that the model had given a stable solution.

The boundary conditions for the open boundaries of the main model were defined by tidal elevations and discharges. These were calculated for the same day as the current meter survey, using Admiralty Tide Tables and bathymetry data. The open boundaries of the models extended from Bloody Foreland and Horn Head to Tory Sound. These were chosen to be well away from the area of interest ensuring that boundary influences on model results would be insignificant.

In order to increase model resolution in the area of interest a patched model of 30 m grid spacing in the vicinity of Ballyness Harbour was dynamically linked to and run within the main model. The use of dynamically linked patching ensures that the correct flow is maintained between the patch and the main model and that there is the correct transfer of momentum and other properties at the patch boundary.

The hydrodynamic model can take account of fresh water inputs from rivers, however, in the case of the Magheraroarty model river inputs were not considered to be significant and therefore this facility was not employed in the modelling of Ballyness Harbour.

Friction due to seabed roughness affects mainly the amplitudes of the tides and currents. The effect of seabed roughness, f, in the model was calculated using the rough channel law.

$$f = C[\log_{10}(14.8\frac{d}{k_2})]^{-2}$$

where
k_s = roughness length (m)
d = water depth (m)

The roughness length is related to the size of the proturbences on the bed, either directly in the form of particle sizes or indirectly in the form of ripple lengths. A value of 0.03 m was chosen from the Magheraroarty model, which is representative of the sandy seabed in the region of interest.

The spatial distribution of the tidal currents is influenced by the bathymetry and the forces arising because of the friction as a fluid element moves through the surrounding fluid. The internal stress is proportional to the velocity gradient and the degree of turbulence and is represented by a single coefficient called the eddy diffusivity. In the case of the Magheraroatry model, an eddy diffusivity of 10 m^2s^{-1} was used.

A4.12 Verification of the Tidal Model

The final patched model was verified to ensure that the results from the hydrodynamic model provided an accurate representation of the tidal flow regime in the Magheraroarty area.

Flows predicted by the model were compared to hydrodynamic field measurements recorded during a marine survey completed as part of this study. The current meter site was in the channel at the entrance to Ballyness Harbour.

The verification procedure involves adjusting the values of model parameters, mainly bed roughness and turbulent diffusivity, until the model results are representative of the field survey observations.

A comparison between the model velocity results and the field results used to verify the hydrodynamic model are presented in Figure A9. The figure shows the depth averaged tidal current speed derived from the current measurements at the surface, intermediate depths and close to the seabed plotted against the model predictions.

The model results show that, at the current meter survey site, the model was able to predict the correct magnitude of the tidal current speed.

Tidal elevation data was also measured at both Magheraroarty and Ballyness Piers. At these two sites the tidal elevation curves predicted by the model were of the same magnitude and shape as the field measurements as can be seen in Figure A10.

Overall the hydrodynamic model was considered to be successfully verified by giving close agreement with the field survey observations.

A4.2 MIKE 21 HD Tidal Model

A MIKE 21 HD tidal model was employed to provide a source of tidal current vector which could be combined with the wave driven currents for sediment transport assessment.

A 22.5 grid model was used for the main model whose bathymetry is shown in Figure A11. In the area around Inishbofin Bay, a 7.5 m grid tidal vector spacing was used to provide data at the same grid points as the wave current simulations.

Boundary data for the MIKE 21 HD model were taken from the TIDEWAY 2D model described previously. A time step of 5 seconds and an edddy viscosity coefficient of 2 m^2/sec was used in HD model.

The MIKE 21 HD tidal model was run for both the existing bathymetry and for the bathymetry with the proposed causeway between Inishboffin Island and Peninsula Point in place so that the alterations in tidal flow conditions could be accurately assessed.

APPENDIX B

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B2.0 MODELLING OF THE SEDIMENT TRANSPORT REGIME

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B.1 COASTAL ZONE

B.1.1 Introduction

The LITPACK/MIKE 21 modelling system consists of a number of individual models each describing part of the process which determine the sediment movement on a coastline. The individual models are connected in order to achieve consistency in the calculations and to take advantage of the special features of each model.

The interaction of the different modules is shown in Figure B1 and a description of the models and their interrelationships is given below.

B.1.2 The Sediment Transport Model - STP

The "intra-wave period" sediment transport model STP forms the basic sediment transport description from combined wave and current action in all the LITPACK modules.

In combined waves and current the turbulence interaction in the near bed boundary layer is of importance for the bed shear stresses as well as for the eddy viscosity distribution. The basis for the sediment transport description is the model for turbulent wave-current boundary layers of Fredsoe (1984). The boundary layer is composed of two regions:

Close to the bed, turbulence and shear stress in the wave boundary layer vary within the wave period, giving rapidly changing bed concentration and turbulent diffusion coefficients.

Outside the wave boundary layer the mean velocity is described by a log-profile.

The increased turbulence level in the wave boundary layer retards the mean current, an effect which is expressed through an apparent wave roughness, k_w, being larger than the natural bed roughness k.

Outside the surf zone the net transport in pure wave motion occurs due to asymmetry in the near-bed orbital wave motion, the Lagrangian drift (a particle under a progressive wave follows unclosed trajectories) and the so-called streaming in the turbulent near-bed boundary layer.

Inside the breaker zone the near-bed current is directed offshore to compensate the onshore transport of water in the surface roller and that due to streaming and Lagrangian drift. This strong undertow leads to offshore transport in the surf zone.

The calculated velocity profiles have been compared with measurements from Svendsen et al (1987) (Figure B2) below.

Figure B2 Comparison between the velocity profile calculated by STP and measurements, in case of zero mean flow.

The total sediment load is split into bed load and suspended load, which are calculated separately. The transport of non-cohesive material as bed load is calculated according to the model presented by Engelund and Fredsoe (1976). Through subsequent developments this model has been extended to cover combined waves and current, and conditions in the surf zone. The bed transport is determined as a function of the bed shear stress through the dimensionless bed shear stress, θ:

$$\theta = U_f^2/(s-1)gd$$

s is the relative sediment density, g the acceleration of gravity, d the grain size and U_f is the shear velocity. The bed load transport is assumed to correspond to the instantaneous bed shear stress under unsteady conditions, eg under wave action.

The suspended load transport, q_s, is described through the sediment concentration C, which is determined from the vertical turbulent diffusion equation:

$$\frac{\partial C}{\partial t} = \frac{\partial}{\partial z}\left(\varepsilon_s \frac{\partial C}{\partial z}\right) + w\frac{\partial C}{\partial z}$$

t is time, z the vertical co-ordinate (zero at the bed), ε_s the turbulent diffusion coefficient and w is the settling velocity of the sediment. ε_s is taken to be equal to the turbulent eddy viscosity of the flow field. The near-bed boundary condition is given as bed concentration C_b at the level z = 2d. C_b is determined as a function of θ using the dynamic considerations of Bagnold (1954) that a certain sediment concentration is required near the bed in order to transfer the shear stress to the bed through grain-grain interaction.

The bed concentration, C_b, is only valid for the plane bed case, ie sheet flow, which is found for θ larger than about 0.8. At smaller θ values the bed is covered by wave ripples. The sediment transport model by Fredsoe et al (1985) has been modified to take the effect of wave ripples into account. The modification involves the bed concentration, turbulent diffusion and the bed roughness. The values of C_b and ε are based directly on the laboratory measurements of Nielsen (1979). The roughness expressed through the ripple dimensions as given by Raudkivi (1988). The sediment transport model converges gradually towards a plane bed description with increasing bed shear stress or mean current velocity.

Inside the surf zone, the wave energy is dissipated due to breaking, and the production of turbulence is very intense. This has been taken into account by use of a one equation turbulence model (Diegaard et al (1986)).

The suspended sediment transport q_s averaged over the wave period T is calculated as the product of sediment concentration and current (Hedegaard et. al. (1988)):

$$q_s = \frac{1}{T}\int_0^T \int_{2d}^{D} CU \; dydt$$

Furthermore, q_s may include contribution from the Lagrangian Drift and the undertow current, if these features are considered.

The suspended transport due to the Lagrangian drift and circulation current (undertow) is found on the basis of the mean velocity U, and mean concentration profile, C.

$$q_{s\ add} = \int_{2d}^{D} \overline{C}\ \overline{U}\ dy$$

The suspended sediment follows the water and the sediment transport is based on the Lagrangian flow velocity. U is thus taken as the sum of the Eulerian circulation current U and the Lagrangian drift velocity U_D obtained from the flow model.

Figure B3 shows a vertical mean sediment concentration profile calculated by STP, compared to full scale field measurements.

Figure B.3 Vertical Profiles of Mean Sediment Concentrations

The main results from STP are:

- bed load
- suspended load

in two directions in combined breaking or non-breaking waves and current.

B1.3 The Littoral Drift Model - LITDRIFT

LITDRIFT is a comprehensive deterministic numerical model which consists of two major parts:

- a hydrodynamic model
- a sediment transport model, STP

The hydrodynamic model includes a description of propagation, shoaling and breaking of waves, calculation of the driving forces due to radiation stress gradients, momentum balance for the cross-shore and longshore direction giving the wave set-up and the longshore current velocities. The model can be applied on complex coastal profiles with longshore bars. In the case of a longshore bar the broken waves can reform in the trough onshore of the bar. The waves can be treated as regular or irregular and the effect of directional spreading can be included in the description.

It is assumed in the model that the conditions are uniform along the straight coast.

Having computed the longshore current - by the hydrodynamic module - points are selected which are representative for the littoral drift. The sediment transport calculations carried out by the STP module, are made to reflect the local conditions with respect to the energy dissipation, the percentage of non-breaking waves and the rms of the wave heights, cf Deigaard et al (1988).

The total sediment transport is dominated by transport contribution from areas where wave breaking occurs. The point selection procedure therefore gives preference to points in this area. In case of a bar-profile, the sediment calculation points will thus be located on the bars where the waves are breaking.

This gives the distribution of sediment transport across the profile, which is integrated to obtain the total longshore sediment transport rate.

By considering the variation on the hydrodynamic climate (eg the yearly wind, wave, tide, storm surge and profile conditions), it is possible to determine the net/gross littoral climate at a specific location (sediment budget).

Important effects such as the linking of the profile to the wave climate, the wave climate to the storm surge and the variation in sediment properties across the profile are included.

B1.4 Cross-shore Profile Evolution Model - LITPROF

LITPROF described the cross-shore profile changes based on a time series of wave events. The model is based on a one-line theory in which it is assumed that longshore gradients does not exist, i.e. the depth contours always are parallel to the coastline. Thus the coastal morphology is solely described by the cross-shore profile bathymetry.

Through success calls to STP, the associated program PRFTABL calculates and tabulates transport rates for a given wave period and grain diameter as functions of the water depth, wave height and bed level gradient. For breaking waves the additional parameters are wave height gradient, roller reduction factor and roller reduction gradient.

LITPROF being a time-domain model includes the effects of changing morphology on the wave climate and transport regime. This enables a detailed simulation of profile development towards a new equilibrium for a time-varying incident wave field.

The limitation of LITPROF is that the grain must be uniform across the profile as only one grain diameter is considered in the transport tables. No sorting mechanism is regarded in LITPROF.

The bed level change is described by the continuity equation for the sediment:

$$\frac{\delta z}{\delta t} = \frac{1}{1-n}\frac{\delta q_s}{\delta x}$$

where z is the bed level and n is the porosity of the bed material. The boundary condition is that the sediment transport, q_s is zero at the coastline.

The morphology model cannot be based directly on the sediment transport rates calculated from the local wave parameters, because it is not physically correct to expect an immediate local response of the sediment transport to varying hydrodynamic conditions (Roelvink and Stive (1988)). Today no theory exists that can describe the actual cross-shore variation of the sediment transport calculated from the local conditions has been applied. The transformation reflects that the circulation current does not adjust immediately to the driving forces, but develops gradually. The peak of sediment transport is therefore shifted shorewards relative to the maximum of the driving forces. The transformation, giving the sediment transport q_{s1}, used for the profile modelling, is expressed as a response function:

$$\delta\frac{q_{s1}}{\delta x} = \frac{q_s - q_{S1}}{L}$$

where the length scale L, is proportional to the local water depth, L = 5D.

LITPROF can be applied to the study of the evolution of a cross-section profile, influenced by a time varying wave field.

Some specific application for LITPROF area:

- Profile response to various conditions
- Fate of nourished material
- Null point location of structures

LITPROF is therefore an aid for the understanding of the mechanisms of the cross-shore sediment transport and a tool for the estimation of on-offshore transport rates.

B1.5 MIKE 21 HD Combined Tidal and Wave Current Models

The hydrodynamic model in MIKE 21 (MIKE 21 HD) is a general numerical modelling system for the simulation of water levels and flows in estuaries, bays and coastal areas. It simulates unsteady two-dimensional flows in one layer (vertically homogenous) fluids and has been applied in a large number of studies.

The following equations, the conservation of mass and momentum integrated over the vertical, describe the flow and water level variations:

$$\frac{\partial \zeta}{\partial t} + \frac{\partial p}{\partial x} + \frac{\partial q}{\partial y} = 0$$

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial x}\left(\frac{p^2}{h}\right) + \frac{\partial}{\partial y}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial x}$$

$$+ \frac{gp\sqrt{p^2+q^2}}{C^2 h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial x}\left(h\tau_{xx}\right) + \frac{\partial}{\partial y}\left(h\tau_{xy}\right)\right] - \Omega q$$

$$- fVV_x + \frac{h}{\rho_w}\frac{\partial}{\partial x}\left(p_a\right) = 0$$

$$\frac{\partial p}{\partial t} + \frac{\partial}{\partial y}\left(\frac{q^2}{h}\right) + \frac{\partial}{\partial x}\left(\frac{pq}{h}\right) + gh\frac{\partial \zeta}{\partial y}$$

$$+ \frac{gp\sqrt{p^2+q^2}}{C^2 h^2} - \frac{1}{\rho_w}\left[\frac{\partial}{\partial y}\left(h\tau_{yy}\right) + \frac{\partial}{\partial x}\left(h\tau_{xy}\right)\right] + \Omega p$$

$$- fVV_y + \frac{h}{\rho_w}\frac{\partial}{\partial y}\left(p_a\right) = 0$$

The following symbols are used in the equations:

h(x, y, t) -water depth (m)
ζ(x, y, t) -surface elevation (m)
p, q, (x, y, t) -flux densities in x- and y-directions ($m^3/s/m$) = (uh, vh); (u, v) = depth averaged velocities in x- and y-directions
C(x, y) -Chezy resistance ($m^{1/2}/s$)
g -acceleration due to gravity (m/s^2)
f(V)-wind friction factor
V, V_x, V_y(x, y, t)-wind speed and components in x- and y-direction (m/s)
Ω(x, y) -Coriolis parameter, latitude dependent (s^{-1})
P_a(x, y, t) -atmospheric pressure ($kg/m/s^2$)
ρ_w -density of water (kg/m^3)
x, y-space co-ordinates (m)
t -time (s)
τ_{xx}, τ_{xy}, τ_{yy} -components of effective shear stress

The currents may be tidal, wind-driven, wave-driven or a combination of the three. The effects of both breaking and non-breaking waves on the transport rates are also accounted for.

The littoral currents at each node of a rectangular grid covering the area of interest is determined using the bathymetry, the water depth, and the current and wave characteristics as input data. Erosion and deposition rates in the model area are estimated from the current field and the nature of the bed and suspended sediment load.

The data concerning wave current conditions are provided by other modules of the MIKE 21 system and must be prepared prior to the simulations of the littoral currents. The water depth and the current field are calculated with the hydrodynamic module MIKE 21 HD, while the wave fields are determined by the parabolic mild-slope wave model, MIKE 21 PMS.

B2.0 MODELLING OF THE SEDIMENT TRANSPORT REGIME

B2.1 Longshore Sediment Drift

The longshore sediment drift calculations were carried out using the LITDRIFT model which computes the sediment transport due to wave, tide and wind driven currents. The LITDRIFT model calculates the drift across a section on the assumption that two dimensional effects are not significant in altering the longshore transport at that point. At Magheraroarty this restricts the use of this model to the coastline to the west of Magheraroarty beach.

Bathymetry

The bathymetry for the modelling was based on the survey of autumn 1996 by Kirk McClure Morton as part of this study together with Admiralty Source Data.

Sediment Grading

The sediment grading used in the analysis was based on samples taken from the beach by Kirk McClure Morton. Details of the grading curves are given in Figures 27 to 31.

For the modelling of the longshore transport a range of Dn_{50} sizes grading spreading factors were used which varied across the profile to match the material measured in this field.

Annual Drift Quantities

The potential net annual drift quantities were computed for the sections along the coastline around Magheraroarty Pier and to the west of this structure. The annual 3 hourly wave climate for Site 1 (Figure A5) was used in the simulation which took account of the tidal levels change including the neap/spring cycle.

This analysis was primarily used to assess the blocking by the Magheraroarty Pier of the shingle supply from the west.

B2.2 Cross Shore Sediment Transport

The cross shore sediment drift computations were undertaken using the LITPROF model which simulates the cross-shore profile changes due to storm wave events.

Profiles

The initial profiles for the modelling were based on the beach and hydrographic survey of autumn 1996 together with data from the British Admiralty chart source survey data. The profile was modelled from the 10 m depth contour to the dune line at the back of the beach. A grid spacing of 3 m along the profile was used to ensure accurate simulations.

Sediment Grading

The sediment grading used in the analysis of the profile changes was based on site measurement of the beach.

A D_{n50} size of 0.22 mm with spreading factor of 1.5 was used for the modelling of the movement in the sand beach.

Wave and Tidal Conditions

The 1 in 50 year event was used to examine the effect of storms on the Magheraroarty beach and the Dooey Peninsula dunes.

72 hours of storm were simulated with spring tide and storm surge. The water levels varied with the tide between 4.9 m and 1.3 m.

The significant wave height (at the 10 m contact) varied between 7.9 m to 5.6 m appropriate to the tidal level. The wave period was 16 seconds.

B2.3 2 Dimensional Transport Modelling

The MIKE 21 modelling system was used to investigate the littoral currents around Magheraroarty beach, Inishboffin Island and the entrance to Ballyness Bay.

Radiation stress were computed using MIKE 21 PMS model with 979,000 nodes on a 7.5 m x 7.5 m grid. The 7.5 m spacing was used for the grid to ensure accuracy in the

breaking wave zone. The MIKE 21 HD model was used to simulate littoral currents from the combined action of wave and tidal current which drive the sediment transport around the beaches, islands, piers, etc.

As the most significant transport occurs during periods of high wave activity, typical gale conditions were simulated to derive the sediment transport regime.

Wave directions at the entrance to Inishboffin Bay of 285°, 300°, 320° and 015° were used to examine the sensitivity of the transport regime to wave direction. The effects of tidal levels were included by examining the transport regime at high water, mid-tide and low water conditions.

The transport regime was illustrated by means of littoral current vector plots of the 7.5 m grid model. Only 1 in 5 vectors were plotted to maintain clarity in the diagrams.

The 2-D transport models were run for the existing conditions and with the various piers and causeway in position. Thus the effect of the proposed structures on the sediment transport regime was assessed by comparing the vector plots for the models with the structure in place against those for the existing conditions.

APPENDIX C

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C1 INTRODUCTION

C1.1 An ecological appraisal was undertaken of Ballyness Bay, Co. Donegal. The conservation value of the Bay and potential erosional impact of the sea on local ecology are assessed in this report. This scoping exercise may be regarded as a first step towards a satisfactory outcome for the dune system.

C1.2 Ballyness Bay is situated on the north-west Donegal coast adjacent to the towns of Gortahork and Falcarragh. The underlying geology is predominantly pelites with some smaller areas of limestone and quartzite. This is largely covered by windblown sand and peat.

C1.3 The Bay is essentially shallow with extensive areas of sandyflats exposed at low tide. It is almost completely cut off from the open sea by two large sand-dune covered spits. The Dooey peninsular sand dunes have grown to a considerable height near the tip of the spit. However the highest dune appears to be collapsing. This dune is considered to be unique in Ireland (and possibly in NW Europe) as a totally bare dune in dynamic equilibrium.[1]

C1.4 The Dooey and Drumnatinny spits and Ballyness Bay are included within the proposed NHA and the proposed cSAC due to their habitat and botanical interest. Sandflats, shallow bays, fixed sand dunes and Machairs are all EU annexed habitats. The dunes and sandflats at Dooey Point are considered to be of national importance while the waterfowl interest is considered to be of regional importance. The presence of Corncrake in the proposed NHA greatly increases the ecological importance of the site.[2]

C2.0 METHODOLOGY

C2.1 An expert-eye appraisal of flora and fauna was undertaken on 4 October 1996. Additional information was obtained from literature and personal communication with statutory and non-statutory consultees.

C3.0 ECOLOGICAL APPRAISAL

Flora

C3.1 Extensive flora records for Ballyness Bay are not forthcoming, however, an initial appraisal of the existing environs suggests that the Dooey Peninsula is lacking flora diversity. Pyramidal *(Anacamptis pyramidalis)* is the only orchid recorded for this region. Greater Butterfly Orchid *(Platanthera chlorantha)* and Early Marsh Orchid *(Dactylorhiza incarnata)* occur on the eastern edge of Drumnatinny. Northern Marsh Orchid *(Dactylorhiza purpurella)* has been recorded to the west of Ballyness Pier. A large dune system in west Donegal (such as Ballyness Bay) would be anticipated to support 8 to 10 species of orchid.[1]

C3.2 Behind the dunes at Drumnatinny are areas of wet and sandy grassland of the Machair variety. Species occurring in the Machair include Red Fescue *(Festuca rubra)*, Thrift *(Armeria maritima)*, Primrose *(Primula vulgaris)* and Thyme *(Thymus praecox* subsp. *arcticus)*.[2]

C3.3 Areas of saltmarsh, grassland and heath add further diversity to the site.

Fauna

Invertebrates

C3.4 Accessible invertebrate records have not yet been produced for Ballyness Bay. Unconfirmed butterfly sightings include Grayling *(Hipparchia semele* subsp. *hibernica)*, Common Blue *(Polyommatus icarus* subsp. *mariscolore)* and Dark Green Fritillary *(Argynnis aglaja)*.[1]

Birds

C3.5 Ballyness Bay is of importance for wintering waterfowl with regionally important numbers of birds. The most important loafing area is the backstrand of Dooey especially along the middle and eastern stretch near the dune islands. Dominant species include Ringed Plover *(Charadrius hiaticula)*, Brent Goose *(Branta bernicla)*, Red Breasted Merganser *(Mergus serrator)*, Sanderling *(Calidris alba)* and Wigeon *(Anas penelope)*.[1/2] Ringed Plover may be described as a 'near-threatened' species in Ireland.[3]

C3.6 The Bay is the only Golden Plover *(Pluvialis apricaria)* site of consequence in NW Donegal, with a maximum of 600 birds being recorded in October 1992.[1] This species is described as vulnerable in Ireland i.e. likely to become endangered in the near future if causal factors continue operating.[3]

C3.7 A small flock of Long-tailed Duck *(Clangula hyemalis)* has been sighted in the outer bay (the Port Marsh). This is quite important in the Irish context.[1]

C3.8 Choughs *(Pyrrhocorax pyrrhocorax)* have been sighted feeding near Binavea strand.[2] This is a rare species in Ireland and is in decline in the west.[3]

C3.9 A recent survey (1993-1994) of nationally endangered Corncrake *(Crex crex)* recorded two areas within the site in which calling male Corncrakes were heard. Four individuals were heard near Magheraroarty village and a further four males were heard near Ballyness town.[2] This species has shown a rapid decline in recent years and is endangered in Ireland. It is the only extant Irish bird listed as 'Rare' on a worldwide scale.[3] Corncrake is an Annex 1 species in the EU Birds Directive.[4]

C3.10 A full list of bird species recorded at Ballyness Bay is presented in Appendix 2.

Mammals

C3.11 Otter *(Lutra lutra)* has been sighted on Dooey Peninsula and Fox *(Vulpes vulpes)* on the eastern edge of Drumnatinny. Rabbits *(Oryctolagus cuniculus)* are abundant throughout Ballyness Bay. An unconfirmed sighting of Irish Hare *(Lepus timidus)* has also been reported.[1]

C3.12 A small population of Common Seals *(Phoca vitulina)* use the Bay with haul out sites located on the central sand barrier and western side of the outflow. A breeding colony of Grey Seals *(Halichoerus grypus)* occur at Inishbofin.[5]

C3.13 Otter, Irish Hare, Common Seal and Grey Seal are annexed species under the Habitats Directive.[6]

C4.0 REFERENCES

1 Sheppard, R., personal communication.

2 National Parks and Wildlife Service. *Ballyness Bay Site Synopsis (Site Code: 001090).*

3 Whilde, A. 1993. *Irish Red Data Book 2: Vertebrates.* HMSO.

4 EEC, 1979. *Council Directive 79/409/EEC on the conservation of wild birds.*

5 Duggan, D., personal communication.

6 EEC, 1992. *Council Directive 92/43/EEC on the conservation of natural habitats and of wild flora and fauna.*

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SPECIES LIST 1 – BIRDS

Species List 1. Birds recorded at Ballyness Bay

Error! Bookmark not defined.Common Name	Scientific Name	Breeding	Wintering	Feeding	RDB Category
Twite	*Acanthis flavirostris*		X		I
Pintail	*Anas acuta*		X		R
Wigeon	*Anas penelope*		X		
Brent Goose	*Branta bernicla*		X		
Barnacle Goose	*Branta leucopsis*		X		II
Sanderling	*Calidris alba*		X		
Dunlin	*Calidris alpina*		X		V
Ringed Plover	*Charadrius hiaticula*		X		
Long-tailed Duck	*Clangula hyemalis*		X		
Corncrake	*Crex crex*	X			E
Peregrine Falcon	*Falco peregrinus*		X	X	II
Red Breasted Merganser	*Mergus serrator*		X		
Golden Plover	*Pluvialis apricaria*		X		V
Chough	*Pyrrhocorax pyrrhocorax*	X	X	X	II
Greenshank	*Tringa nebularia*		X		R

Key to RDP* categories

E	Endangered
V	Vulnerable
R	Rare
I	Indeterminate
II	Internationally Important

*Red Data Book