CASE STUDY

Coastal Geomorphology and coastal change in Dundrum Bay: management implications

ABSTRACT:
This report sets out to describe the coastal morphology of Dundrum Bay and to assess historical changes in the shoreline and nearshore in the context of future management options for the area. The report is intended to summarise existing geomorphological knowledge and to explore the implications for management. It does not claim to be a comprehensive assessment, but rather sets management dilemmas against the current state of knowledge. A number of options are outlined and suggestions for further research necessary for a variety of management strategies are set out in the text.

LOCATION:
Dundrum Bay, County Down – Northern Ireland

KEYWORDS: *Beach morphology and evolution, Beach protection, Beach Management in Practice*

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EXECUTIVE SUMMARY

Dundrum Bay comprises an approximately 20 km-long embayment between St John's Point and Newcastle Harbour. A further subdivision in the shoreline is produced by Craigalea Rocks that separate the Tyrella beach-dune system from that of Newcaslte-Murlough-Ballykinler. This report deals with the latter section of coast only.
Analysis of changes in the morphology of the bay since the earliest reliable map evidence (1835) have been conducted using the mapped position of the shoreline. This analysis shows an overall pattern of sediment accretion (i.e. seaward advance) at both high water mark (where *c* 470,000m² has been gained) and low water mark (where *c* 443,000m² has been gained. This is most pronounced at the northern end of the bay, along the dune front at Ballykinler and on the southern margin of the inlet channel where a new spit has developed between 1863 and 1984.
Up to the beginning of the nineteenth century the only two man-made structure present in the area were the two piers of the harbour, located in the interior of the present harbour, and the lines of stones which comprise a medieval fishing system on the intertidal area of the south corner of the bay.
The overall pattern of shoreline behaviour at Newcastle is of sediment transport to the north. The wave modelling predictions of a northward transport are matched by physical evidence of sand accumulation at the south edge of the tidal outlet and at Ballykinler. They are not, however, matched by definite map evidence of a depleting sand source, as the potential erosion in shoreline position that may have occurred at Newcastle is masked by the shore defence works.
It appears that four management strategies are possible for managing the beach resources at Newcastle. These involve either living with the change that currently takes place; actively promoting beach use at Murlough where there is an abundance of sand, actively promoting sand accumulation at Newcastle or creating an artificial beach zone.

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1. Introduction

Current perceptions of a loss of beach sand at Newcastle and of progressive erosion along the shoreline have given rise to concerns about the physical nature and sustainability of the beach system at Newcastle-Murlough.
This report sets out to describe the coastal morphology of Dundrum Bay and to assess historical changes in the shoreline and nearshore in the context of future management options for the area. The report is intended to summarise existing geomorphological knowledge and to explore the implications for management. It does not claim to be a comprehensive assessment, but rather sets management dilemmas against the current state of knowledge. A number of options are outlined and suggestions for further research necessary for a variety of management strategies are set out in the text.

2. Geomorphology

Dundrum Bay comprises an approximately 20 km-long embayment between St John's Point and Newcastle Harbour. A further subdivision in the shoreline is produced by Craigalea Rocks that separate the Tyrella beach-dune system from that of Newcaslte-Murlough-Ballykinler. This report deals with the latter section of coast only.
The Newcastle-Murlough-Ballykinler embayment comprises a back-barrier estuary (Dundrum Inner Bay) which is separated from the the open sea be effective barriers that comprise a system of sand dunes fronted by a wide intertidal beach. The highest section of the beach between Newcastle and Murlough is backed by a semi-continuous gravel ridge. The intertidal beach displays a distinctive ridge and runnel morphology with up to 6 ridges aligned parallel or sub-parallel to the shore. These bars increase in spacing but decrease in amplitude seaward. On average, the beach ranges from 400 m to 900 m wide at low tide. The outlet channel of Dundrum Inner Bay is fronted by and ebb-tidal delta, a large sand body which intercepts and stores sand intermittently and modifies wave patterns as they approach the shore.
Offshore, the bay is gently sloping and consists mainly of sand substrate with occasional bedrock outcrops and areas of gravel.

3. Historical Changes

Analysis of changes in the morphology of the bay since the earliest reliable map evidence (1835) have been conducted using the mapped position of the shoreline. This analysis shows an overall pattern of sediment accretion (i.e. seaward advance) at both high water mark (where *c* 470,000m^2 has been gained) and low water mark (where *c* 443,000m^2 has been gained. This is most pronounced at the northern end of the bay, along the dune front at Ballykinler and on the southern margin of the inlet channel where a new spit has developed between 1863 and 1984. Elsewhere along the shoreline, the high water mark appears to have remained essentially stable over the historical period.
At Newcastle the apparent stability in MWM position is an artefact produced by the progressive engineering at the upper beach limit. Apparent shoreline accretion around the Shimna river mouth too is the result of engineering associated with the construction of the Newcastle Centre in the early 1980's. The low water mark position in this area shows a more erratic behaviour, and fluctuates across a distance of 100-200m. Where a river enters the intertidal area, it creates a channel. This channel may be ephemeral (as in the case of the Glen's river mouth), or may vary in position on the incohesive sandy sediments and the low gradient slope of the surface (a characteristic of the Shimna river mouth). Only after 1863 did water begin to flow over the intertidal area from the Shimna River, probably as a result of engineering and promenade constructions. Along Murlough Beach, although

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the high water line shows little movement between 1835 and 1984, with an envelope of mobility of around 20m, it appears to show a slight trend toward progressive shoreline accretion. The low water mark, on the other hand, shows great mobility (around 150m), with periods of accretion and erosion. This might be expected on a ridge and runnel beach where the selection of a low water position by a surveyor may vary from one ridge to another, depending on tidal state. An area of erosion is evident toward the outlet channel of Dundrum inner bay and this presently marked by a high scarp.

The inlet and ebb tidal delta areas have experienced the greatest mobility in the bay during the time period studied. Changes in high water mark depict the development of a small spit on the south margin of the inlet channel. The feature formed between 1863 and 1904 and has grown steadily since then. On the opposite north margin of the channel, the high water line is stable in the upper parts of the channel, with a small zone of erosion which was stabilised with rock armour by the army in the 1980's. This has since experienced accretion and is now covered with sand.

Ballykinler beach has long been isolated from uncontrolled human interference by virtue of its military use. Only a few pathways cross the dunes linking the army base with the beach. Trends in HWM in this area exhibit progressive accretion that is most evident in the period 1930-1984. Variations in LWM do not show a clear pattern, which may be due to the difficulty in surveying on a ridge and runnel beach.

Offshore, comparison of bathymetric charts of 1861 and 1968 reveals a marked accumulation of sand in the nearshore zone. It is that both bathymetries show a gentle slope from shallower to deeper waters.

Volumetric comparisons of the two maps show the area of the bay be c.184×10^6 m², and in this area, a total gain of *c*◦.43×10^6 m³ of sediment occurred between 1861 and 1968. Spatially across the bay, sediment accumulation was significantly more widespread than erosion, with a positive volume change of *c*.20×10^6 m³.

The spatial distribution of the changes in the volume of Dundrum Bay between 1861 and 1968 reveals patterns of accretion over much of the sea floor, especially along the deep water boundary. From Newcastle to Craighalea rocks this accretion is more pronounced around the central bay areas, approximately between Newcastle Golf Club and the Murlough side of the ebb-delta, from the – 10m isobath. There are other more localised areas of accretion. One is on the Ballykinler side of the ebb-delta, and in the Newcastle harbour area a patch of sand has accumulated during the last century. Sea floor erosion is characteristic of the area seaward of the intertidal zone and the area south of Ballykinler, around the – 15m isobath. In a number of areas throughout the bay the change in volume was minimal, and at the Newcastle area, apart from the patch at the harbour previously described, little net change is evident.

In addition to producing changes in the sea floor bathymetry, these changes in the submarine topography of Dundrum Bay may have had an impact on wave patterns, since wave energy at the shoreline is directly affected by the sea-bed over which the waves propagate. Variations of seabed topography cause wave crests to change direction and/or speed. This affects the patterns of wave energy decay and ultimately, sediment transport and related erosion and depositional patterns. The presence or absence of shoals or changes in the morphology of these may translate into changes of wave energy at the shoreline. It may thus be inferred that the morphology of the intertidal beach is directly related to variations in offshore sea-bed topography.

4. Wave Modelling and Sediment Transport

a. Overall pattern

Waves are the most important driving force in coastal dynamics in Dundrum Bay. Newcastle is situated in a fetch limited wave environment, which implies that locally generated waves are, along with tides, the main driving force in beach erosion and accretion. Dundrum Bay is dominated by low energy sea-waves due to the limited fetch (distance over with the wind blows) across the Irish Sea. Waves approaching the bay from a south-easterly direction are dominant fro both mean wave conditions and also during storms. Beaches are exposed to this predominant wave direction. That the wide beach and shallow inshore slope means that wave energy is dissipated over a wide area, but gradients in wave energy over this area cause distinctive patterns of erosion and deposition of

sand. The variations in wave induced stress (parameter related to wave energy) are directly linked to the initiation of sediment transport. Since direct measurement of wave energy and stress is difficult, analysis of wave propagation across the bay was conducted using computerised 2-dimensional wave simulation modelling. Two simulations were undertaken and compared over the entire bay. One was based on sea floor data from 1861 and the second was based on data from 1968 . The most distinctive variation between these is found in the location of wave energy dissipation points. A higher concentration of wave energy dissipation occurs on the ebb-tidal delta for the 1968 simulation. Also the surf zone appears to be wider at the NE end of the area of study in 1861. This implies that the ebb tidal delta may be enlarged during the period between bathymetrics, and also that wave energy gradients which increased from NE-SW in 1861 are reversed and increase from SW-NW at the present.
The distribution of wave-induced stress in the bay in 1861 show distinctive patterns. Most remarkable are two bands of energy concentrations that extend across the entire bay from deep water to the surf zone running in an oblique direction. In the 1968 simulation the gradients are of wave-induced stress increase more rapidly than in 1861 at the outer margins of the surf zone at Newcastle beach. This means that the results from 1968 indicate a potential flow of sediment from the SW to the NE, where gradients of stress rapidly decay. This flow has strengthened over the past century. Likewise, the wave-induced stress shows a more pronounced south-westerly trend over the 1861 bathymetry (the dispersal of energy occurs with more homogeneous gradients at the Newcastle area 1861. This is illustrated by the spacing of wave height contour lines).
In general terms, simulations of wave propagation over the 1861 bathymetry suggest that sediment would have accumulated in the south-west of the bay. This tendency may have itself influenced changes of seabed topography and therefore influenced wave approach and sediment transport, so that the contemporary analysis of wave-induced stress (1968) suggest a north-easterly sediment flux in the surf zone that may have been caused by the progressive change in sea-bed morphology.
This comparative analysis of the 1861 and 1968 conditions suggests that changes in sea bed morphology may have introduced considerable variations in the pattern of wave energy on a general scale. This is shown by more pronounced dissipation of energy on the ebb-tidal delta and predominance of potential sediment transport to the NE. This can be interpreted as the main factor in transporting sediment from the large deposits of the ebb-tidal delta to the beach at Ballykinler.

b. Coastal cells

Nearshore cells have been used in many studies to investigate long term coastal evolution as points of erosion, transport and deposition of sand can be mapped. Nearshore circulatory cells can be defined by variations in wave energy, and each cell comprises an initial point for sediment transport or erosion a point of maximum current velocity and transport and a point of net deposition . Wave modelling in Dundrum Bay can be useful to illustrate the spatial distribution of the littoral drift and allows circulatory cells to be identified at low and high tide.

At **low tide** the harbour area shows low wave intensity. A strong current flowing toward the harbour is inferred from decreasing forces (from a point south of the harbour) and this suggests the deposition of sediment on the lee (downdrift) side of the harbour. Weaker currents are then generated from this towards Newcastle.

From Newcastle to the inlet at Murlough, a series of nearshore cells can be identified, each with a S-N sediment transport direction. A generalised pattern of increasing wave force is clear along the entire zone with flows that intensify particularly near the ebb tidal delta. Several sub-cells can be interpreted along the surf zone, but a net longshore transport towards Murlough is clearly evident. The development of sub-cells however, tends to minimise the net drift and instead the points in the sub-cells are likely to be associated with localised depositional zones. This suggests that significant northerly transport of sediment will occur in the area.
At Ballykinler, the predominant direction of wave circulation (and potential sediment transport) is again towards the NE. A small sub-cell can be identified in the region around the ebb tidal delta with

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a SW transport direction. Currents gradually increase in force towards the NE boundary of the area of study.

During **high tide**, with water levels up to +3.0 metres OD and tidal range of 5 metres, wave shoaling occurs over an extensive surf zone that under this condition also includes the intertidal beach. Waves propagate and dissipate energy across this region and are capable of moving sediment on the high tide gravel beach whose slope is significantly greater than the sandy intertidal beach. Cells under these conditions were delineated along a band of maximum dissipation located upon intertidal beach face.

Very steep gradients of radiation stress can be seen near the harbour. Several cells with opposing transport directions can be delineated in this vicinity, These fluctuations suggest and intense circulation of sediments that would transport material from the south (exposed face of the harbour) towards the more sheltered northern side. The intensity of wave energy also suggests that only shadow effects occur (accumulation on the lee side of the harbour) but also southward currents may be generated (as depicted by the negative component of radiation stress) that could lead to siltation of the harbour entrance and depletion of sediments off Newcastle intertidal beach.

At Murlough, under storm high-tide conditions, the wave energy flows are toward the NE. Numerous sub-cells are indicated with strong currents and related depositional areas. The interpreted flow pattern shown as straight arrows indicate grouped sub-cells and the main high intensity inflection points . The highest peak in wave energy is shown at Murlough, which suggests that the concentration of sediment transport may drift between that point and the channel area. This relative decrease in the longshore intensity of radiation stress probably supplies sediment to the submerged ebb tidal delta.

A cell can be identified NE of the outlet channel area, where wave force levels approach zero values. The low intensities of longshore currents may indicate strong sediment transport across the shore, which would account for the accretion of Ballykinler beach.

In summary, the wave modelling analysis shows the potential distribution of sediment transport pathways in Dundrum Bay. Newcastle, under most conditions, is at the origin of a NE-directed longshore wave and sediment circulation cell, which implies that, in the absence of a regular sediment supply, these conditions may led to loss of beach sand. However, movement of sand onshore by the depletion of the offshore banks, could be supplying sand to the area. Shore defence works have historically been undertaken in Newcastle and may be indicative of sediment starvation and wave attach on the high water mark. Sea walls were placed to protect promenades and recreational installations from the sea. Longshore defences (groynes) were similarly designed to stop longitudinal flow of sediments. These defence works, however, as well as protecting the high water mark, produced new patterns of wave/sediment interaction. These are outlined below.

5. History of Shore Defence Work

Up to the beginning of the nineteenth century the only two man-made structure present in the area were the two piers of the harbour, located in the interior of the present harbour, and the lines of stones which comprise a medieval fishing system on the intertidal area of the south corner of the bay. These walls acted as traps to retain fish as the tide fell. Following the expansion of the town in the 1850's, a revetment was installed on the foreshore throughout Newcastle for recreational purposes. This facilitated the construction of promenades, gardens and bathing areas. Harbour improvement work also took place from time to time. Eventually the Slieve Donard Hotel and the Royal County Down Golf links were completed at the beginning of the present Century complementing the recreational development. At this stage erosion began to pose a perceived threat to human activities and during the 1930s a revetment composed of timber groynes and a row of wooden railway sleepers was installed along the shoreface of Newcastle beach. A further 3000 sleepers were installed following a severe erosional episode in 1961, and more sleepers were installed in those areas considered particularly vulnerable along the base of the dune at the golf course. Eventually rock armour partially covering this area was emplaced during 1992 and 1993 (Pye, 1997). The extension of this rock armour to protect the dune along the full length of the golf links is under consideration following erosional episodes during the autumn and winter of 1995/96. The biggest engineering work

undertaken in Dundrum Bay, however, was a new promenade (1980's) that replaced and extended the existing promenade as far as the grounds of the Slieve Donard Hotel. Where the old promenade meets the new one the Newcastle Centre was erected, a semicircular construction made of granite blocks and concrete. This extends seaward of the promenade and is built partially on top of the upper beach. Associated with this work was the canalization and reclamation of the Shimna river mouth for recreational purposes and the creation of a new car park and picnic area at the northern end of the new promenade. Figure 8 illustrates the location of man-made structures in the sea front and intertidal area of Newcastle during the past 150 years.
The sea walls constructed in Newcastle were used as a solid support for improved promenades. The effects of such structures on nearshore processes is likely to be similar to those of structures designed purely for protection of oceanic beaches or foredunes. In coastal protection utilisation of a sea wall was encouraged by the fact that they reflect wave energy seaward (Silvester and Hsu 1991). Sea walls do indeed reflect wave energy back to deep water when waves approach normal to the shoreling, however, as they do so, the re-generated wave fields generates an off-shore directed circulation)Van de Graff and Bijker, 1988). If, on the other hand, the wave approach is oblique to the wall, then the wave field re-generates after the impact against the wall, and forms a caustic wave field through which the incoming waves propagate. A first consequence of the excess in energy density is that waves break, so that both reflected and incoming waves dissipate most of their energy. The location where this loss of energy occurs is associated with sediment deposition, which is generated at locations where no deposition formerly occurred. In contrast, the sea wall front, where reflected waves will exert most of the new flows in the seaward direction, will suffer severe erosion at the bed, inducing potential undermining of the structure and/or the removal of beach sediment.
An erosion sequence is immediately started at the boundaries of the wall induced by strong refraction and diffraction patterns on the new short-crested wave field. Many world-wide examples show that the usual response to the problem is the extension of the wall, in order to protect more. The lengthening of the wall will increase the reflecting face and therefore its erosive capacity (Silvester and Hsu, 1991). It has also been shown that following storms, beaches on which a sea wall is constructed to protect properties, disappear faster and recover later than natural beaches which use more material in the initial recovery but do so far more effectively (Dolan, 1983).
Groynes are structures inserted perpendicular to the beach to intercept material drifting alongshore (Carter, 1988). The ultimate objective of groynes is the reduction of the rate at which sediment moves along the coast in the prevailing direction of littoral drift. The theoretical effect of these shore-normal defences is to generate acute re-orientation and decay of wave energy that travels at an angle to the structure. When sand is rebuild on the intertidal beach, these structures no longer activate the same processes on incoming waves. However, if groynes are removed, longshore transport on the new beach profile may be exacerbated and rates of erosion may be largely enhanced. The removal of shore-normal structures may be directly related to beach deflation. Groynes may be designed to achieve the total interruption of the flux or only a partial retardation, thus stabilising areas where sediment is lost from beaches. Groynes can also be designed so that the shore normal (off-shore) effect of the waves is also considered (Bijker and de Graff, 1983; Carter 1988). The groynes at Newcastle were emplaced to trap and hold sand that drifted to the NE. Since they have decayed, they have been ineffectual in trapping sand and may have contributed to sand depletion at Newcastle.

6. Discussion

The overall pattern of shoreline behaviour at Newcastle is of sediment transport to the north. The wave modelling predictions of a northward transport are matched by physical evidence of sand accumulation at the south edge of the tidal outlet and at Ballykinler. They are not, however, matched by definite map evidence of a depleting sand source, as the potential erosion in shoreline position that may have occurred at Newcastle is masked by the shore defence works. There is a possibility that the apparent loss of sand from the beach surface at Newcastle is due to this northward drift, although evidence for sand loss from the beach does appear to be equivocal, particularly as postcards from the turn of the century reveal areas devoid of sand a6t that time . It cannot be said with certainty whether there is a sand depletion problem.

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The accumulation of sand in the offshore may have provided a source of sand that has sustained the northward sediment transport over the historical period and indeed the entire bay shows evidence of long term sediment accumulation, however, it is unlikely that the northward littoral transport and the delivery of sand to replace that which has been lose are in phase. Thus periods of erosion and accretion may characterise a single position on the shoreline from time to time.
The role of changing offshore bathymetry is important in interpreting the changes that have occurred. In the 1860s the area subject to northerly drift was smaller than that which is now affected. Thus there may have been an increase in the rate of northward transport over this period, and this would account for the development of the spit at Murlough and accumulation at Ballykinler.
At every temporal and spatial scale there is evidence of onshore movement of sediment in the bay, although the geomorphological study of the last 150 years illustrate that within this accretionary pattern, temporally and spatially localised erosion may occur. This has had an impact particularly in 6the integration of the human activities that coincided with a phase of change in the main distribution of coastal sediments. The impact of coastal protection work may also be viewed in the context of their limited capacity to improve coastal stability and the influences that they may have had in exacerbating sediment losses in some areas of the Dundrum Bay system.

7. Managing Implications

Newcastle is at the updrift end of a sediment cell and is therefore most likely to experience sand depletion from time to time. The amount of sand on the beach will depend on the ability of offshore processes to deliver sediment to the shore to replace that which has moved northward. Part of the apparent loss of beach sand may, however, also be put down to the fact that some of the recent shore defence works have extended onto what was formerly beach area and have thus diminished the area of sand exposed.
Much of the apparent erosion of the high water mark appears to take place during extreme storms which must coincide with high water and are, therefore, comparatively rare. The unprotected shoreline does not show evidence of sustained retreat. This implies that periods of erosion of the frontal dune system are followed by recovery periods. Thus alongshore extensions of the high water mark sea defences are probably unnecessary.
It appears that four management strategies are possible for managing the beach resources at Newcastle. These involve either living with the change that currently takes place; actively promoting beach use at Murlough where there is an abundance of sand, actively promoting sand accumulation at Newcastle or creating an artificial beach zone. Each is briefly outlined below.

Option 1. Living with current fluctuations in beach volume at Newcastle. This option simply enables continued use of the beach at Newcastle at what appear to be regarded as sub-optimal conditions for beach users. Adoption of this strategy could be accompanied by efforts to explain the fluctuating sand supply, which may alleviate beach users perceptions of a deteriorating resource.

Option 2. Promoting beach use at Murlough. This option requires management to promote Murlough as a beach facility by signposting and a publicity campaign and might even go as far as seeking a Blue Flag award with the necessary management approaches (life guards, water quality monitoring, etc). the intertidal beach in this area of Dundrum Bay is backed generally by a gravel storm ridge that acts as natural protection for the dune system, except when storm waves combined with high tides reaches the dune too. This natural mechanism protects the beach and make sand available for nourishment of the beach during the post storm phase. The existing beach exhibits a wide sandy intertidal area during low tide (av. 500m.) with ridge and runnel topography.
A potential disadvantage is the distance from the Newcastle town area. It may be necessary to improve facilities and infrastructure at Murlough to accommodate greater numbers of people. These should include public transport, road access and car park facilities. Another shortcoming of this solution may be related to the management of increased number of visitors to the Murlough Nature Reserve, which may represent a challenge to existing conversation programs.

Option 3. Promoting sand accumulation at Newcastle. Since Newcastle is at the supply end of a sediment transport pathway, it is likely to experience sand loss at times faster than it can be replaced from offshore. This could be countered by artificial sand placement at critical recreational sites on the natural beach (beach nourishment). The cost of this strategy would vary according to the volume and extent of sand being replaced and also to the rates of sand dispersal which are likely to be related to storm frequency and hence difficult to predict. A suitable sand source would have to be located either on-or offshore, although the latter usually proves more cost effective. Beach replenishment is usually a suitable method for areas where sustainable renourishment is available. This implies frequently recurrent beach fill and therefore design of the projected beach face is of crucial importance. In dissipative beaches like Newcastle, the design phase of the nourishment scheme may introduce a high degree of wave propagation modelling to forecast sediment transport scenarios under modal or storm waves after re-generation of the beach profile. Re-establishment of groynes to interrupt the NE drift could be contemplated if it can be establish that there is a potential sediment source. The visual impact of such features should be assumed but they do provide an amenity in themselves.

Option 4. Creation of an artificial beach. This would involve the construction of a retaining wall behind which sand could be placed for recreational use. Such an option would provide a permanent sand recreational area irrespective of the tide and could be strategically sited adjacent to the main areas of beach use. Its location and size would determine the cost and environmental impact of such a scheme.

These and any other options could be the subject of a more detailed feasibility study before a definitive answer is chosen.

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