Introduction

The development of an aquaculture farm has been proposed near Guthalungra, about 158 km south of Townsville. The farm would require the construction of one discharge and two intake pipes 1000 mm diameter extending out for a distance of 500 and 300 m from the adjacent coastline, respectively. This coastline is situated north of the Elliot River, which is thought to be the main source of sand for the beaches to the north. This report will assess the potential impacts of the proposed pipeline on the natural processes of sand transfer in the area and the stability of the coastline.

The report will address the following Terms of Reference provided by Sinclair, Knight Merz:

- *Describe the natural historical changes that have taken place along the coastline from Cape Upstart to Mt Curlewis.*

- *Describe the potential impact of the pipeline on natural sand movements in Abbot Bay, including patterns of longshore drift along the coastline.*

Background

Cape Upstart is a sub-circular granitic outcrop joined to the mainland by a tombolo that consists of a double barrier complex, directly adjacent to the mouth of the Elliot River. The Elliot River, which is 40 km long and drains a catchment area of 290 km^2, has contributed large volumes of sand to the tombolo in the past (Hopley, 1970). The creation of the tombolo changed the hydrodynamic conditions in both Abbot and Upstart Bay. Hopley's (1970) historical account describes how sand deposition from the Elliot River created the tombolo that linked Upstart Island to the mainland during the Pleistocene. Continued deposition has led to the progradation of the shoreline to its current position. This narrow sand ridge or tombolo is the only feature connecting Cape Upstart to the mainland that is not subject to tidal inundation.

Methods

In order to describe historical coastal change and establish patterns of sediment movement in the Guthalungra region, a variety of methods were employed. The analysis of aerial photography represents an efficient and economical method of detecting historical coastal change over long sections of coast (Jimenez et al., 1997). Sedimentological analysis, i.e. determining the grainsize and sorting characteristics of the surficial sediments can provide clues on the source and maturity of sediment, from which transport pathways and processes may be inferred in conjunction with hydrodynamic modelling such as wave refraction.

Aerial photo analysis:

The coastline between Cape Upstart and Mt Curlewis was mapped from three sets of vertical aerial photos from 1942, 1974 and 1998. The coastline was taken at highest astronomical tide (HAT). The resultant map is a useful visual representation of coastal change. However accurate measurements of shoreline advance or retreat, could not be taken directly from this map which incorporates inaccuracies due to radial distortion in the aerial photos. The position of coastline was accurately measured directly from the aerial photos. Five lines were drawn roughly parallel to the coastline between features that have remained constant and were visible throughout the aerial photo record. Transects were then taken at right angles to these lines approximately every 250 m, 4.25 km north and 3.5 km south of the proposed location of pipeline (Figure 1). The distance to the various positions of the coastline, as identified from each aerial survey, was measured along these transects and compared using the exact scale of each photograph, as determined from the distance between identifiable points.

Surficial sediment sampling

Over one hundred sediment samples were collected from dune, beach, intertidal and offshore areas along the coastline between Cape Upstart and Mount Curlewis. Onshore samples were collected by hand, while a dredge was deployed from a boat for the bottom samples. The samples were analysed using standard dry sieving techniques (Lindholm, 1987) and the particle size statistical software package Gradistat (Blott and Pye, 2001).

Wave Refraction

Wave refraction maps were constructed for Abbot Bay using a template derived from a graph illustrating the relationship between water depth, wave period and wave length (King, 1972). Three maps were drawn, for south easterly, easterly and north easterly winds using 5 second wave interval[+] and 20 wave crest spacing. The closest Bureau of Meteorology wind recording station is at the Bowen post office from 1969-1987 and from 1987 onwards at the Bowen airport. South easterly and easterly winds are dominant for most of the year (May – Nov) while north easterly winds are common during summer (Dec - Apr) and can be associated with cyclones.

Results

Description of coastal change

Figure 2 shows the changes in the position of the coastline from Cape Upstart to Mt Curlewis from 1942 - 1998. At this scale the coastline appears relatively stable, although still dynamic, with rapid rates of both progradation and erosion occurring in different areas. Major changes from 1942 - 1974 include the main tidal channel breaching the coastline to discharge directly out to sea. The barrier spit has advanced both seawards and across the river mouth between 1942 - 1974.

A flood event in February 1991 caused the tidal channel to breach the spit again, completely detaching it from the coast. This breach lead to the erosion of an estimated 36,360 m^{3}[*] of sand from the end of the spit between 1974-1998, as well as the addition of an estimated 38,736 m^{3}[*] of sand to the front of the spit since 1974. It is likely that another breach will occur along the spit in the future, perhaps in response

[+] 5 second wave interval is common in nearshore bays of north Queensland due to the proximity of the Great Barrier Reef.

[*] Volumes of sand were calculated by assuming a standard height value of 1m.

to a flood event. The left bank of the river mouth has eroded an average of 60 m since 1942. Approximately 11,300 m^{3*} of sand has been added to the coastline directly adjacent to the river mouth from 1974–1998, which equates to an advance of up to 84 m. A small recurved spit extending from this coastline appears in the 1974 photo and has continued to grow across the mouth until 1998. If both spits continue this pattern the current mouth of the Elliot River may be blocked off completely from the sea, and a new mouth may be formed elsewhere along the coast.

Direct measurements of shoreline position around the proposed location of the pipeline indicate a complex pattern of erosion and progradation over the 56 years between 1942 - 1998. The direct measurements of coastal change along each transect from 1942 - 1974 and 1974 - 1998 are illustrated in Figure 3.

The coastline directly adjacent to the proposed location of the pipeline (1500 m either side) is very dynamic and has prograded an average of 32 m or at a rate of 1 m/ yr between 1942 - 1974. This rapid advance was followed by a retreat along this whole 3 km stretch of coast in more recent years (1974 - 1998). Substantial erosion occurred along the proposed location of pipeline and along the 750 m section of coast north of the proposed location of the pipeline with an average retreat of 21.9 m from 1974 - 1998 or a rate of 0.9 m/ yr. However the coastline 1500 m to the south of the proposed location of the pipeline has been relatively stable from 1974 - 1998, for example there has been less than 4 m of erosion and 3.6 m of progradation, 250 m south of the proposed location of the pipeline. In contrast to the other sections of coast, the area 2000 m north of the proposed location of the pipeline suffered erosion of 24 m from 1942 - 1974 and has since recovered, prograding 26.4 m during the subsequent 24 years to 1998.

The rest of the coast to the north of proposed location of the pipeline 2750 - 4250 m has steadily prograded from 1942-1998, advancing an average of 50 m from 1942 - 1998 or at a rate of 0.9 m/ yr adding to the substantial Holocene barrier system which has accumulated over the last 5000 years. The most substantial rates of shoreline advance occur from 3000-3500 m south of the proposed location of the pipeline, which is directly adjacent to the mouth of the Elliot River. This section of the coast prograded an average of 59 m from 1974-1998, an annual rate of 2.4 m between 1974-1998.

Description of surface sediments

The distribution of sediment size and sorting within the study area are illustrated in Figures 4 & 5. Overall there is a seaward fining of sediment from very coarse (grainsize of 1 - 2 mm) to fine sand (grainsize of 0.125 - 0.25 mm) with patches of silty fine sand further offshore. The patches of silty sand reflect the presence of seagrass (Figure 6). The very coarse – coarse sediments are concentrated in the river channel, however there is a small area of very coarse sediment about 500 m offshore just north of the proposed location of the pipeline. Onshore sediment deposits become finer towards Cape Upstart, with very coarse-coarse sand deposits on the barrier spit and the spit directly adjacent to the river mouth fining to medium to fine sand towards the Cape. There is a patch of coarse sediment deposited on the shore about 4.25 km north of the proposed pipeline. Despite a trend of a northward fining in the nearshore sediments (< 500 m off the coast) further off the coast, coarse sediment is consistently found, fining just south of Cape Upstart. Well sorted sediments are found in the river mouth, while moderately well to poorly sorted sediments are found in both the nearshore and further off the coast up to the Cape (Figure 5). The area around the proposed pipeline is dominated by moderately well to moderately sorted sediments.

Discussion

The entire coastline between Cape Upstart and Mt Curlewis is dynamic, exhibiting rapid rates of coastal change since 1942. This is not surprising for a stretch of coastline that is being directly fed by a fluvial source during major floods or break out events. The coastline around the proposed location of the pipeline is particularly dynamic, with substantial amounts of progradation and erosion over this 56 year period.

The dynamism of this section of coast is probably a result of wave refraction around Camp Island (Figures 7-9). The concentration of wave energy on this section of coast may explain the anomalous presence of coarse and very coarse sediment deposited in the nearshore area of this section of coast. It seems likely that there may be a 30 year cycle of accretion and erosion. If this is occurring then we would see erosion continuing at the same pace 0.9 m/ yr for the next few years and then perhaps a recovery of about 1.5 m/yr over the next few decades. This cyclic pattern is probably related to changes in the dominant wave pattern, in response to changes in the dominant wind direction. For example in the Torres Strait Rasmussen & Hopley (1997) have shown a significant change in wind patterns in the late 1970's. Greater predominance of southerly winds over the last 20 years has changed patterns of sand transfer leading to greater erosion along the southern beach of Warraber Island (Rasmussen and Hopley, 1997). A 20 - 30 year wind cycle has also been reported in the southern Great Barrier Reef by Flood (1986) where south south easterly winds dominated in the early 1960's and changed to east south easterly winds in the late 1970's which has reversed patterns of sand transfer around Heron Island. Therefore the patterns of sand movement in Abbot Bay, including longshore drift, may well reflect changes in wind patterns.

Analysis of wind data for Bowen 1969 - 1998, reveals significant changes in the wind regime beginning in the late 1970's. There is a significant (R^2 = 0.8713) decrease in the frequency of winds from all directions between 1-10 km/ hr from 1969 – 1998 (Figure 10). Similarly there is a significant (R^2 = 0 .4949) increase in the frequency of winds over 30 km/hr during that same period (Figure 11). While the winds have increased in velocity from 1969 – 1998, the frequency of winds from each direction has remained fairly constant, with dominant south easterlies (occurring 38% of the time) (Figure 12) and easterlies (occurring 22% of the time) (Figure 13). However, there have been significant increases in the velocity of these dominant south easterly and easterly winds since 1969 with R^2 values of 0.9053 and 0.457 respectively (Figures 14 & 15). Also while the frequency of strong north easterlies over 21 km/ hr has remained the constant (Figure 16), the frequency of north easterly winds of all speeds has decreased significantly (R^2 = 0.7999) from 1969-1998 (Figure 17).

Wave refraction around Camp Island will direct wave energy at the mainland coastline, with the area of concentration sensitively varying according to wind direction i.e. moving south when winds are more northerly and moving north when winds are more southerly. This adds to the dynamic nature of this section of coast and is superimposed on the more general south to north movement of sediments along the beach. Figures 7, 8 & 9 show the different patterns of wave refraction that are formed by the three most common wind directions - south easterly, easterly and north easterly. During south easterly winds wave energy is concentrated along the coastline, which may bring sediment on to the shore. Easterly winds produce a sparse concentration of wave energy on the shore, however wave energy is still concentrated at the location of the proposed pipeline. North easterly winds tend to produce much more concentrated wave energy along the coastline and the wave refraction pattern suggests that this may produce the transfer of sand towards the Elliot River mouth. This may result in erosion along the coastline and accretion near the river mouth. If the trend shown in the 1969-1978 wind data is representative of the previous 25 years, we can surmise that the wind regime was weaker from 1942 – 1978, this may account for the widespread coastal progradation between 1942-1974. Subsequent erosion around the proposed location of the pipeline and continued progradation at the northern and southern ends of the coast from 1974 - 1998 may reflect the strengthening of winds during this period.

Possible Effects of the Pipeline on Sand Movement

The sensitivity of this area of beach to changes in wind and wave patterns, means that the effects of any structure which blocks the longshore movement of sediment will vary at different seasons and from year to year. The net movement of sand is from south to north, however as it can be reversed given strong north easterly components, the impact on the beach to the north may only become apparent after several years. If the pipelines are surface structures, they will act as groynes, with a build up of sand on either side of the structures dependant on weather conditions. Some sand will be diverted into the offshore zone but will then be lost from the beach system altogether if it remains in the effective wave action zone.

The most effective solution to the problem may be to bury the pipeline below the beach level and below the sea bed as far out as the limit of the effective sand moving wave base, to about 3 m below L.A.T. The pipelines would then have minimal effect on sand movement and shoreline stability. An alternative solution of raising the pipelines above the beach and seabed is not recommended, as achieving stability of supporting pillars may require foundations many meters below surface bed and even then, depending on their design, may still cause some degree of obstruction to sand movements.

Conclusion

The coastline from Cape Upstart to Mount Curlewis is dynamic, with substantial change in the position of the shoreline over the 56 year period from 1942 – 1998. Consequently there are major volumes of sand being transferred around Abbot Bay. Thus, the introduction of any feature, such as a pipeline on the sea bed extending out 500 m from the shore is likely to interrupt the natural movements of sand around the bay, unless it is buried along the section between the beach and the lower limit of the normal wave action zone at 3 m below L.A.T.

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