Shoreline Erosion Management Planning

Using numerical models to help guide coastal management decisions

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ABSTRACT

Queensland's coastline is dominated by beaches varying from wave dominated reflective to tide dominated dissipative beaches. The physical coastal processes acting on these beaches including winds, tides, waves and currents interact to define the sediment transport patterns that can lead to beach erosion or accretion. In many locations, development has been allowed to occur within the erosion prone area. Understanding these erosion or accretion patterns is essential to effective beach management.

Shoreline Erosion Management Plans (SEMP) are the preferred the Queensland Government's preferred method for local governments to deal with erosion issues. Adequate planning done before extreme erosion events occur can help to avoid inappropriate protection happening in an ad hoc, reactive manner.

This paper describes a method to develop a SEMP based on detailed numerical modelling to investigate options for managing shoreline erosion. The benefits and limitations of this approach are discussed using Stockton Beach as a case study. Such investigations include the modelling of short, medium and long term processes. Three stages are proposed that include 1) describing and quantifying the coastal processes and hazards, 2) assessing the feasibility, effectiveness and acceptance of management options, and 3) recommending the most locally appropriate solution.

INTRODUCTION

Queensland's coastal resources are extensive and have significant natural, cultural, economic and social significance. Our coast the most diverse representation of wetlands in Australia, the most significant population of loggerhead turtles in Australia occurs in Moreton Bay and three of Queensland's five World Heritage Areas. Eighty five percent of the Queensland population lives within the coastal zone and a general trend of increasing development within the coastal zone is apparent (EPA, 2001).

Given the importance of these habitats, the pressures placed upon them and the associated coastal management considerations, it is often easy to overlook the fact that the 9500 km of Queensland coastline is dominated by beaches that are exposed to natural processes of erosion and accretion. The physical coastal processes acting on these beaches including winds, tides, waves and currents interact to define the sediment transport patterns that can lead to beach erosion or accretion.

In many locations, development has been allowed to occur within the erosion prone area. Understanding these erosion or accretion patterns is essential to effective beach management. Detailed numerical modelling is an effective running various scenarios to gain a thorough understanding of the sediment transport processes for a particular stretch of coastline.

The Queensland Government has endorsed the development of a Shoreline Erosion Management Plan (SEMP) as the preferred method for local governments to address shoreline erosion issues at the local level. A SEMP is a non-statutory document that sets out an agreed framework and management strategy for responding to current and future erosion problems. The development of a SEMP is based around understanding the underlying causes of shoreline erosion and the likely future progression of that erosion (EPA 2006, Sultmann & Edmondson 2007).

Other Australian states have similar procedures for understanding and addressing erosion problems. The case study of Stockton Beach provided in this paper is based on the New South Wales method of Coastline Management Plans (NSW Govt, 1990). There are many similarities between the NSW and QLD approaches and Stockton Beach provides an illustrative example methodology that equally applies to many locations on the Queensland coast.

STOCKTON BEACH CASE STUDY

The details of this case study are taken from a project commissioned by the Hunter Coast and Estuary Management Committee. The value (and focus) of this case study is more in the description of the methodology than the results. More information regarding the results is available in Savioli et al (2007).

Background

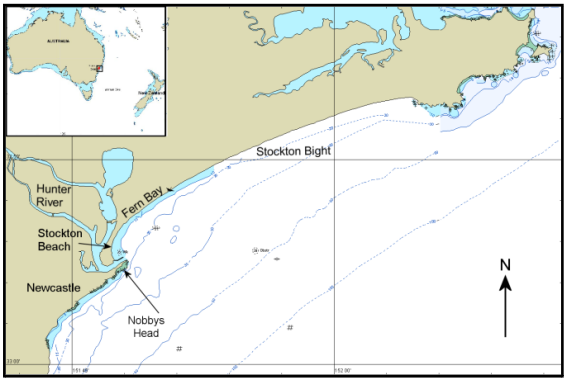


Figure 1 - Overview of Study Area

Stockton Beach is a sandy beach which extends from the northern side of the mouth of the Hunter River northwards to the boundary of the Newcastle local government area (Figure 1). For many years the area has been prone to erosion. Previous studies analysed the beach erosion at Newcastle based on historical recorded data. There was, however, no clear understanding of the coastal processes at Stockton Beach therefore a detailed coastal process study was recommended (Umwelt & SMEC, 2002).

The study was divided into three distinct phases, which reflect the steps for formulating a coastline management plan that are identified and outlined in the NSW Coastline Management Manual (NSW Govt, 1990).

While the recent study is not a complete Coastline Management Study in the NSW sense, since it is only focussed on beach erosion, it provides a very good example of a comprehensive SEMP in the Queensland context. It address the key concerns of a SEMP through defining the sediment transport processes, defining erosion hazards, community consultation, investigating beach protection options and costs, and then recommending the preferred option.

The three phases of this study are summarised as follows:

Stage 1 - Process Study
- Data collection and analysis;
- 1D/2D Numerical modelling of waves, currents and the resulting sediment transport; and
- Prediction of ongoing beach response/trends, including identification of hazards.

Stage 2 – Management Study
- Identification and assessment of management options;
- Community consultation on management options; and
- Selection of preferred management option.

Stage 3 – Management Plan Revision
- Update the current Newcastle Coastline Management Plan.

Stage 1 – Process Study

The study area is in close proximity to the river entrance, and thus the complex interactions between coastal and estuarine processes need to be resolved. Therefore the approach adopted in the study involves a combination of one and two dimensional hydrodynamic and sediment transport modelling.

To estimate the littoral transport in the area not influenced by 2D effects, the littoral transport model LITDRIFT of the LITPACK suite was applied. LITDRIFT is a comprehensive deterministic numerical model that computes the longshore currents, the littoral drift and the sediment budget.

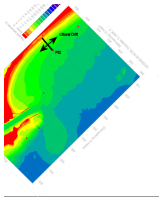
LITDRIFT consists of two major components:

- Hydrodynamic model;
- Sediment Transport Processes Model (STP).

The hydrodynamic model includes the description of the propagation and breaking of waves as well as a description of the driving forces due to the radiation stress variations. This model is applied on complex cross-shore coastal profiles that include features such as sand bars and variation of the sediment characteristics along the profile. Waves can be treated as regular or irregular and can be included as uni or multi-directional.

The hydrodynamic model provides input to the sediment transport components of LITDRIFT. In this way it is possible to compute the sediment transport conditions along the beach profile, including both the wave conditions and the wave driven currents. Other processes can also be included, such as additional currents, wind effects, etc.

The sediment transport module, STP, computes the sediment transport for combined wave and current action. In combined waves and currents the turbulent interaction in the near bed boundary layer is of importance for the bed shear stresses as well as for the turbulent processes.



The LITDRIFT model was applied for the period March 1992 – August 2004 at Point 2 (see Figure 2). The sediment transport calculations were undertaken for a coastline orientation of 138° (clockwise from the N to a line perpendicular to the beach). Wave conditions were transformed from the offshore Sydney Buoy (at 80m water depth at Long Reef) into the nearshore areas with a regional wave model (MIKE SW). This model was calibrated against local wave data, not shown here due to space limitations.

The littoral sediment budget for a coastal profile is the sum of the littoral transport contributions which are caused by all possible combinations of wave heights and directions.

Figure 2 - Location of littoral transport analysis where 2d effects are not significant (Pt 2)

The long-term average net littoral drift for these 12 years can be estimated as the total accumulated transport divided by the number of years, which indicates an average predicted net littoral drift.

The analysis of the sediment transport conditions carried out with LITPACK provides an overview of the sediment transport in the northern part of the study area. At this location the beach is quasi uniform since the beach contours vary gradually and are not affected by two dimensional flows. Under this type of conditions the longshore current and sediment transport are generated by the radiation stresses associated with the obliquely oriented waves.

However, in the vicinity of coastal structures, such as the breakwater at the Hunter River entrance, the current pattern can be significantly influenced. The application of a 2D model to analyse the sediment transport and subsequently the on-going processes is described below.

- A MIKE 21 PMS wave model was applied to simulate the nearshore wave field and the radiation stresses in the local model area using the selected wave events as boundary conditions. This model was applied here as it includes the wave processes that are most relevant in the Stockton area such as shoaling, refraction, wave breaking, diffraction, etc.;
- A MIKE 21 HD hydrodynamic model was applied to simulate the local flow pattern and taking into account the radiation stresses obtained from the local wave model, the tidal currents and the river discharges.
- The MIKE 21 ST sediment transport model was applied to simulate the sediment transport capacity in the local area caused by the Hunter River discharges and the wave driven currents;
- The results of the MIKE 21 ST model were weighted to determine the annual sediment transport field; and
- 2D sediment budgets were computed using average sediment transport rates.

Figure 3 shows the average yearly net transport based on the littoral transport statistics from the baseline study. The main directions of sediment transport are marked by red arrows, and indicate that the dominant waves from the SE-S generate a dominant northward transport.

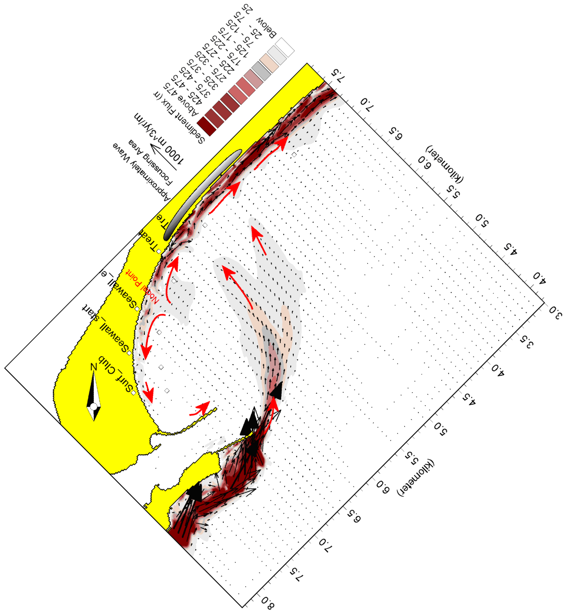


Figure 3 - Computed annual transport based on average conditions between 1992-2004

This detailed coastal process study has resulted in a clear description of the short, medium and long term beach erosion processes occurring at Stockton Beach.

One of the prerequisites for this type of approach is detailed measured data against which to calibrate the models. Without proper calibration the models cannot be relied upon to represent the naturally occurring conditions.

Stage 2 – Management Study

The real benefits of the numerical models was realised in Stage 2, the coastline management study. The 1 and 2D models were used to simulate a range of different beach protection options including do nothing, beach nourishment, seawalls, artificial headlands, multi-functional artificial reefs and offshore breakwaters. The list of potential options was prioritised, based on the following criteria:

- Protection;
- Social:
- Environmental; and
- Economic.

Issues covered in the category "Protection" include maintaining the plan shape of the beach, flood protection, beach profile protection and impacts on adjacent beach areas. If an option scored well in the criteria of beach plan protection, beach profile protection and flood protection it means that option will offer protection to the assets behind the beach and prevent damage to property and infrastructure as well asmaintaining a useable beach.

The criterion "Social" involved an analysis of the impacts on swimming/surfing, other recreational beach activities, cultural values and the visual amenity of the beach. Much of this assessment was

based on community consultation during the previous management study (Umwelt & ECMC, 2002) and public meetings held on December 14, 2005 and May 12, 2008.

The "Environment" category included consideration of water quality, marine habitat/biodiversity, terrestrial habitat/biodiversity and the preservation of coastal processes.

The "Economic" category included consideration of the capital and maintenance costs, impacts to existing infrastructure and impacts to the port operations.

Stage 3 – Management Plan
The results of the management study and the recommendation for the most sound beach protection option are still under review by the client. Upon acceptance of the Stage 2 report, the existing Newcastle Coastline Management Plan will be amended to include the recommendations for addressing coastal erosion on Stockton Beach.

This updated Newcastle Coastline Management plan will go on public display and be gazetted by the NSW government as the authorised plan covering the coastline within the Newcastle local government area.

DISCUSSION

Lack of understanding about the specific sediment transport processes and resulting beach erosion at Stockton Beach, lead to a detailed numerical modelling study to describe these processes. This situation is equally applicable to many locations along the Queensland coast.

Properly calibrated one dimensional modelling provides a cost effective and accurate way to undertake long term simulations of sediment transport processes. This method is applicable where waves approaching the beach, shoaling, refracting and finally breaking in a uniform manner. This generates well defined longshore currents that vary only due to the orientations of the beach or the incoming waves.

In areas of more complex bathymetry or including significant coastal structures, the more computationally demanding two dimensional modelling is required to accurately simulate the impacts of diffraction, refraction, shoaling and breaking.

Information on waves, currents, sediment characteristics and bathymetry is required to develop accurate, calibrated models. The quality of the results is highly dependent on the quality of the input data, and the assumptions made within the models.

A detailed hybrid 1D and 2D analysis of the sediment transport processes was undertaken in a complex coastal area at Stockton beach, along the mid-NSW coast. The results show that this approach provides a good description of the sediment transport conditions. The calibrated models support a detailed understanding of the physical coastal processes that drive sediment transport at Stockton Beach.

Detailed modelling allowed for an objective assessment of various beach protection strategies. It also provides the opportunity to model potential future scenarios to allow for contingency planning. When combined with community consultation and economic analysis the resulting recommendations have a high chance of successful implementation.

The three stage methodology used at Stockton Beach is consistent with the Queensland SEMP process (EPA, 2006). Explicitly breaking the SEMP process into these three logical steps clearly defines deliverables and outcomes and creates effective spaces and opportunities for community involvement.

TAKE HOME MESSAGES

1. Beach erosion is an issue that most coastal local governments need to address.

2. Effective and sustainable coastal management actions should be based on a sound understanding of the coastal processes occurring at specific beaches.

3. Numerical modelling is an effective way to gain a detailed understanding of the complex physical coastal processes leading to shoreline erosion. It also provides the opportunity to test various potential future erosion scenarios and prepare plans on how to deal with these.

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