Keppel Bay beaches – monitoring and restoration

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Introduction

Beaches are dynamic systems that are naturally subject to major physical changes. The shape of any beach is defined by many factors including wave action, wind and storm damage. The urbanisation of beach habitat and surrounds creates a significant problem for civil engineers and how they can best manage the natural tendency for the beach to change. Beach protection methods, or more correctly, beach restoration processes, have widely been used in attempts to stabilise beaches and protect developed areas against erosion and storm damage.

This group of research projects looked at a range of beach restoration processes and factors that impact on efforts to stabilise the Capricorn Coast beaches of Keppel Sands and Yeppoon Main Beach. This paper summarises six reports, dealing with the following topics:

Ocean waves in Keppel Bay

Coastal engineers regularly require an estimation of wave conditions in coastal regions up to the waterline and at the front of coastal structures. Knowledge of wave characteristics and directions are dominant factors influencing the shaping of a shoreline. The Capricorn Coast beaches are subjected to wave action from the northerly to the south-easterly direction. The direction of waves is one of the important parameters in the analysis of sediment transport and methods of beach restoration processes.

In 1996 the Environmental Protection Authority (EPA) installed a directional Datawell Waverider buoy about 25 km off the Capricorn Coast, east of Emu Park. This buoy is called the 'Emu Park' buoy. The buoy measures water pressure and wave direction and these data are transmitted to the receiver station at Emu Park where they are analysed with the instrument Datawell computer program to produce wave heights, periods and direction.

The prediction of ocean waves can be done using empirical prediction models of wave parameters in shallow waters. The goal of the first report was verification of methods of wave prediction for Keppel Bay using data recorded by the Emu Park buoy.

Keppel Sands Beach

Keppel Sands area has been settled since the 1890s. At that time it was a gently sloping beach between two headlands, affording some of the safest ocean bathing in Queensland, and fringed with casuarinas and other subtropical shade giving foliage. Today, most of the sand, trees and foliage, particularly on the southern reaches of the beach, have been lost.

The last coastal defence work was the extension of the groyne in December 2001 by around 100 metres. The work was carried out by the Livingstone Shire Council (LSC). Central Queensland University (CQU), Faculty of Engineering and Physical Systems was commissioned to conduct surveying, monitoring and analysis (theoretical and numerical modelling) to evaluate the Keppel Sands beach restoration process following the groyne extension.

Yeppoon Main Beach

Yeppoon has long been the recreation site for Rockhampton and other central Queensland towns. Yeppoon Main Beach has seen many changes due to its increased use for recreation. The last one was connected with the upgrading of an existing rock wall, which began reconstruction in December 2000 and was complete in January 2003. This was the first step in the long-term program of a beautification of the existing esplanade. In the meantime, the problem of beach restoration arose as the rubble mound seawall itself, without additional measures, has a rather detrimental influence on beach conditions.

Again, CQU were commissioned to carry out surveying, monitoring and analysis (theoretical and numerical modelling) to find an acceptable option for the Yeppoon Main Beach restoration process after the upgraded rock wall was completed.

This report involved the summary analyses of the monitoring of beach changes since the rubble mound seawall upgrading and compares them with the available historical surveying data carried out in 1988–1993. Some prediction of the beach behaviour in the near future and suggested options for further beach restoration complete the report.

Methods

These studies have used a combination of numerical modelling and actual recorded data to verify predictions of wave characteristics and sand accretion along beaches according to the crenulate shaped bay theory. Common to most studies were the GENESIS numerical model, and data obtained from the Emu Park Waverider buoy.

Ocean waves in Keppel Bay

Empirical models for predicting wave parameters in shallow waters were compared to four years of recorded data. The recorded data was supplied by the Datawell Waverider buoy situated about 25 km east of Emu Park. Additional weather data were obtained from BOM weather stations at Cape Capricorn and Rundle Island. The models being tested were SPM revised by Hardle and Stive (1989) and Krylov's method (1996), as well as Vincent and Hughes formula (1985).

Four years of recorded data were analysed. Approximately 430 wave conditions covering the range of significant wave data from 0.5 m to 3.5 m; and peak period from 3 sec to 13 sec, with duration of over 9 hours in each case were selected for detailed analysis. Not far from the wave-recording buoy is a weather station located on Rundle Island where wind conditions have been recorded automatically every 3 hours.

With regard to the dominant wave direction approaching Yeppoon Main Beach, wave data from a directional Datawell Waverider buoy were analysed for the period August 1996 to November 2001 to evaluate the dominant direction and percentage of time when seas and swell occur. For one month, another instrument was deployed approximately 600 m offshore of Yeppoon Main Beach for the same type of analysis. This recorded data between 1st September 2001 and 6th October 2001.

Keppel Sands Beach

This study focussed on the verification of numerical modelling of the long-term shoreline evolution at Keppel Sands beach using the one-line model GENESIS. In particular, the question was asked, whether the model could reliably predict if lengthening of the groyne could positively affect shore accretion at the considered site considering its complicated bathymetry at nearby Cawarral Creek. Initially GENESIS was used to predict the effects of the groyne extension and whether sand deposition along the beach would support predictions from the crenulate shaped bay theory.

Crenulate shaped bay theory predicts the extended groyne would act as a natural headland and sand would accrete along the beach between the groyne and the natural headland at the southern end of the beach.

The computations carried out within the case study were based on the bathymetric data of a vast area stretching 12 km alongshore and approximately 15 km offshore and used the GENESIS one-line numerical model. Data were obtained from the Waverider buoy situated off Emu Park. Further analysis of the offshore wave climate has been analysed using the WSAV module of the NEMOS package on the basis of the wave buoy data.

Throughout this study, the GENESIS model has been used to predict and then verify the effects of the groyne extension and the adherence to the predictions of the crenulate shaped bay theory. Beach profiles were monitored to record actual rates of sand accretion and erosion.

Yeppoon Main Beach

The Yeppoon Main Beach study analysed beach changes based on historical data and regular surveying of beach profiles for a 2 year period, and by adapting the numerical model GENESIS to the local conditions. Eight beach profiles were monitored for changes to the beach. Having calculated changes in cross sectional areas and the distances between each profile, the total volume of sediment accumulated/eroded in the upper part of the beach was calculated.

A trial passive beach drainage site was established at the southern end of the beach in 1996 as a final year student project. This was monitored for only a few months and then abandoned.

A list of possible methods for beach protection and restoration were proposed from the study outcomes.

Results

Ocean waves in Keppel Bay

Analysis showed that the models significantly overestimated the predicted wave heights and periods compared to recorded data. The Vincent and Hughes formula for significant wave height in the depth-control wave train, when modified by the author by including dispersion of waves, represents recorded data very accurately.

In addition, waves with long periods (>9 sec), considered as swell waves, were analysed to evaluate predominant swell direction. The proper knowledge of dominant swell waves' direction is important in consideration of coastline realignment as a sustainable 'soft' method of beach stabilisation.

Analyses of the data recorded in front of Yeppoon Main Beach showed that the dominant wave azimuth direction changed from 83 degrees off shore to 78 degrees nearshore and the swell azimuth from 68 degrees to 75 degrees. Swell occurs for 33 percent of time offshore and increases to 70 percent of time nearshore.

Keppel Sands Beach

The initial results of GENESIS analysis, based on several simplifications and assumptions, provided satisfactory verification with data from the field survey. The model GENESIS was finally successfully applied to the modelling of shoreline evolution in the proximity of man-made structures at Keppel Sands Beach, and early results indicated that it would be useful for the analysis of coastal processes at other shores along the Capricorn Coast.

The second study included additional monitoring of the

beach in 2003 and allowed the verified model, GENESIS to make predictions of the shoreline movement. The measurements and verified model showed that the accumulation of sand in front of the rock wall would be limited. This was not due to the along-shore sediment transport but rather to the cross-shore transport of sediment, which dominates the Keppel Sands Beach.

The results from the verified GENESIS model were more satisfactory than those initially taken when compared to beach behaviour in the previous year. Simulations of the future shoreline changes showed that the process is not continuously progressive. It is dynamically changeable depending on the actual wave conditions and no sand accumulation was expected near the southern end of the rock wall.

The crenulate shaped bay theory, based on the action of swell waves when applied to the Keppel Bay Sands, shows on the other hand, that progressive sand accumulation along part of the rock wall is possible.

Final monitoring of the beach behaviour in the third study, during the two years after the groyne extension, showed that the beach had been in the process of reshaping the shoreline following the GENESIS prediction. Monitoring, however, also shows that any significant cumulation of sand in front of the existing rubble-mound seawall in the southern end of the beach cannot be expected.

Yeppoon Main Beach

The GENESIS analysis showed the periodical fluctuation of the shoreline without clear trends in erosion or accretion of the beach. Wave data for the last six years were analysed and dominant wave directions in the nearshore zone were found to be mainly between east and east-south-east.

The adopted GENESIS model, considering only long-shore sediment transport, showed a northward trend in sediment transport. With the limited supply, and the existing seawall along the beach, no changes to the beach were observed for several simulated options including groynes. The beach nourishment was the only option where beach improvement was observed.

With dominant cross-shore sediment transport, a crenulate shaped bay and beach would be expected. The analysis carried out about positions of the headland suggests that any type of headland (groyne or peninsula) at the northern end of the beach would have a positive effect on the beach stabilisation and restoration.

As an alternative to the headland, it is suggested that another option be implemented on a section of the beach where an experimental passive beach drainage system would be installed and monitored.

Conclusions

As a key outcome, this set of reports demonstrate that a numerical model needs a coastal expert to evaluate and interpret the results. To successfully manage beach restoration, the model results must be supported by 'engineering intuition', together with knowledge of the analysed coast segment and underlying physical processes.

Ocean waves in Keppel Bay

The findings regarding dominant and persistent direction of waves in this report indicates that the southern part of Yeppoon Main Beach is oriented normal to the approaching dominant wave direction. This means that sand can be accumulated in this section of the beach (with some additional so far unstudied influence of Ross Creek mouth) and has a tendency to move the beach erosion northward. Therefore any beach restoration would require additional methods, among which a headland control method should receive particular consideration. Finally, numerical modelling was recommended.

Keppel Sands Beach

The extension of the groyne in December 2001 influenced existing dynamics of the Keppel Sands Beach. The surveys of the beach profiles carried out for the last 2 years have shown the positive effect of the groyne on sand accumulation along the beach. It is particularly visible in the northern part of the beach and along 300 m of the rubble mound seawall where accumulation of sand is above mean high water spring (MHWS). The shoreline has been forming the crenulate shaped bay clearly visible at mean sea level (MSL). If subsequent summers do not bring severe stormy conditions, the restoration of the beach may progress very well. Otherwise stormy waves may erode accumulated sand and natural beach restoration will start again with swell waves during calmer weather after the summer period. With such a scenario it is not expected that beach condition will improve past its current state.

Application of the numerical model GENESIS suggests that no significant or permanent accumulation of sand in front of the rubble mound seawall could be expected. The complex nearshore bathymetry significantly influenced the final numerical results.

The options suggested for possible further management of the Keppel Sands Beach were in their recommended order:

1. do nothing but keep monitoring;
2. proceed with limited beach nourishment; and
3. introduce passive gravitational beach drainage system on a selected section of the beach with fully documented measurements and monitoring of how the system works.

Yeppoon Main Beach

The available surveying of beach profiles between 1976 and the most recent in 2003 show stable beach conditions without significant erosion or accretion. The fluctuations of the shoreline are periodic. The central and northern parts of the beach are most exposed to wave action.

Nine different options for beach restoration were simulated using the GENESIS model. They may generally be described as a basic 'do nothing' option, options with one or two groynes, an option with some type of peninsula created on the northern site of the beach, or finally, options with beach nourishment. The model considered only long-shore transport and with the dominant wave direction close to the normal to the beach, the simulation results were not very promising except the option to nourish the beach.

With application to the Yeppoon Main Beach, the order of recommended options for continued management are:

1. do nothing, but keep monitoring;
2. beach dewatering considered as an experiment with full monitoring and analysis;
3. construction of the headland with monitoring of beach behaviour; and
4. beach nourishment and groyne construction with monitoring of beach behaviour.

Further reading

Piorewicz, J. (2001). *Prediction of ocean waves in shallow water. Keppel Bay, Queensland, Recorded data analysis.* Research Report No. CE26. Central Queensland University, Faculty of Engineering and Physical Systems, Rockhampton

Piorewicz, J. (2002). *Analysis of dominant wave direction approaching the Capricorn Coast. Yeppoon Main Beach study.* Research Report No. CE27. Central Queensland University, Faculty of Engineering and Physical Systems, Rockhampton

Piorewicz, J. (2002). *Analysis of coastal processes along Keppel Sands beach after extension of the groyne.* Research Report No. CE28. Central Queensland University, Faculty of Engineering and Physical Systems, Rockhampton

Piorewicz, J. (2003). *Keppel Sands beach: Analysis of beach changes 2000–2003. Monitoring versus numerical simulation.* Research Report No. CE29. Central Queensland University, Faculty of Engineering and Physical Systems, Rockhampton

Piorewicz, J. (2003). *Keppel Sands beach restoration. Final report.* Research Report No. CE30. Central Queensland University, Faculty of Engineering and Physical Systems, Rockhampton

Piorewicz, J. (2004). *Yeppoon Main Beach restoration.* Research Report No. CE31. Central Queensland University, Faculty of Engineering and Physical Systems, Rockhampton