

# The Practical Application of Four Commercially Available Numerical Beach Morphology Models on a High Energy Coastline

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**SUMMARY** As part of the detailed design and impact assessment for the Northern Gold Coast Beach Protection Strategy Master Plan, the commercially available models SBEACH and UNIBEST-TC were used to assess cross-shore beach profile response, while GENESIS and UNIBEST-LT were used in the assessment of longshore sediment transport and coastline re-alignment. The scope for model verification is excellent since the Gold Coast has abundant wave and beach profile data collected over more than 20 years. SBEACH and UNIBEST-TC were verified against data from six storm events between 1988 and 1997, with both models able to predict measured erosion volumes with some degree of success. The cross-shore models were then used to assess the impact of a range of design storms. Neither cross-shore model was able to reliably reproduce measured beach recovery during low wave conditions. Both GENESIS and UNIBEST-LT were used to simulate the widely accepted longshore transport rate of 500,000 m<sup>3</sup>/yr northward. GENESIS was used to model the impact of the proposed submerged reef on the shoreline alignment either side of it. UNIBEST-LT (with the Bijker sediment transport formula) was used to determine the cross-shore distribution of longshore transport. All models used in this study are being continually refined and improved by their developers.

## 1. INTRODUCTION

Many of the world's major hydraulic laboratories have developed numerical beach morphology models for the assessment of beach response to various wave conditions and coastal structures. While many smaller consultants and researchers have developed in-house (numerical) models for the assessment of beach morphological response, few of these models have been sufficiently developed to allow them to be distributed commercially (or otherwise) to the wider scientific and engineering community.

As part of the detailed design and impact assessment for the Northern Gold Coast Beach Protection Strategy Master Plan, (ICM, 1997) the commercially available models SBEACH and UNIBEST-TC were used to assess cross-shore beach profile response, while GENESIS and UNIBEST-LT were used in the assessment of longshore sediment transport and coastline re-alignment. The strategy involves construction of a submerged reef at Narrowneck and nourishment of the beach between Narrowneck and Northcliffe (Figure 1). Fortunately, abundant wave and profile data exists for the Gold Coast, allowing relatively comprehensive model calibration and verification for a high energy location.

## 2. CROSS-SHORE MODELS

### 2.1 Brief Description of Cross-Shore Models used

SBEACH (Storm-induced BEach CHange) was developed by the US Army Corps of Engineers, with technical information on the model provided in Larson and Kraus (1989) and Larson et al (1990). Version 2.0 was used in this study. UNIBEST-TC (UNIform BEach Sediment Transport-Transport Cross-shore) was developed by Delft Hydraulics in

The Netherlands. Version 1.00 was used in this study. Both models require representative sediment characteristics as input, and to fully utilise their capabilities, they require time series of wave conditions (height and period) and water level (including storm surge but excluding wave setup). Both models can be run with fixed values of wave height, wave period and water level, which can be useful in preliminary sensitivity runs, or for determining other parameters such as wave runup or wave setup at the shore.

### 2.2 Simulation of Historical Storm Events

From the Gold Coast historical data, a total of six storm events (between 1988 and 1997) were identified for which reliable waverider buoy data was captured and for which pre- and post-storm surveys of the beach in the vicinity of Narrowneck were undertaken proximate to the storm event. The two cross-shore models were run for these events and their relative performance and predictive capabilities assessed. Water levels for the simulations were taken from the Gold Coast Seaway tide gauge. Both models were able to predict measured erosion events with some degree of success.

An illustrative case is shown in Figure 2 for the storm events which peaked on 3 May 1996 and 17 May 1996 which were combined as a single event. The first event had a peak significant wave height ( $H_s$ ) of 7.1 m with  $H_s$  exceeding 2 m for approximately 8 days. The second event had a peak  $H_s$  of 4.0 m with  $H_s$  exceeding 2 m for approximately 5 days. It can be seen in Figure 2 that SBEACH better predicted erosion on the subaerial beach (between RL 3.5 and RL 0 m AHD) whereas UNIBEST-TC better predicted the offshore profile (between RL -4 and RL -10 m AHD). Both models approximated the limit of seaward profile change reasonably well.

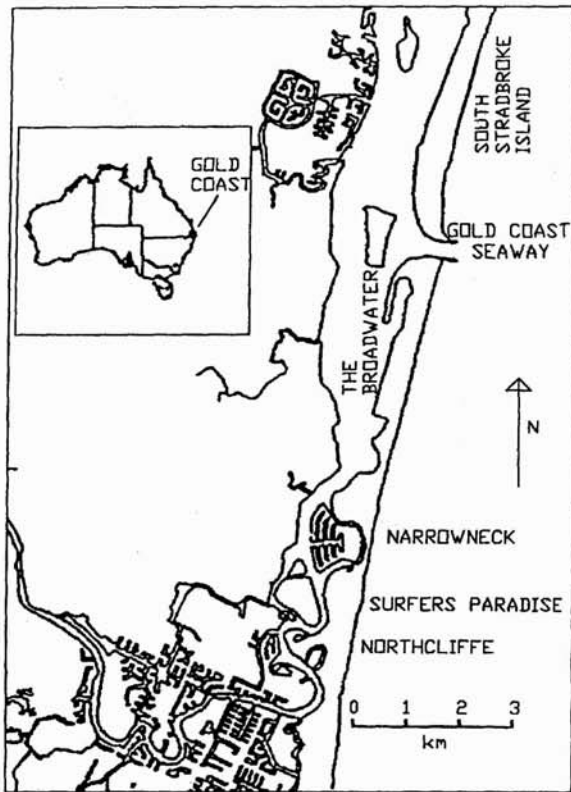


Figure 1: Locality Map

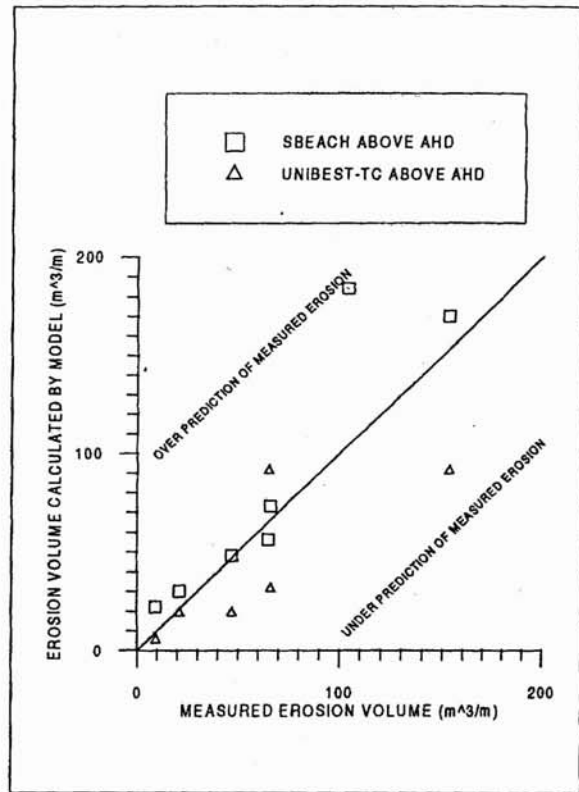


Figure 3: Predicted versus Measured Erosion Volumes

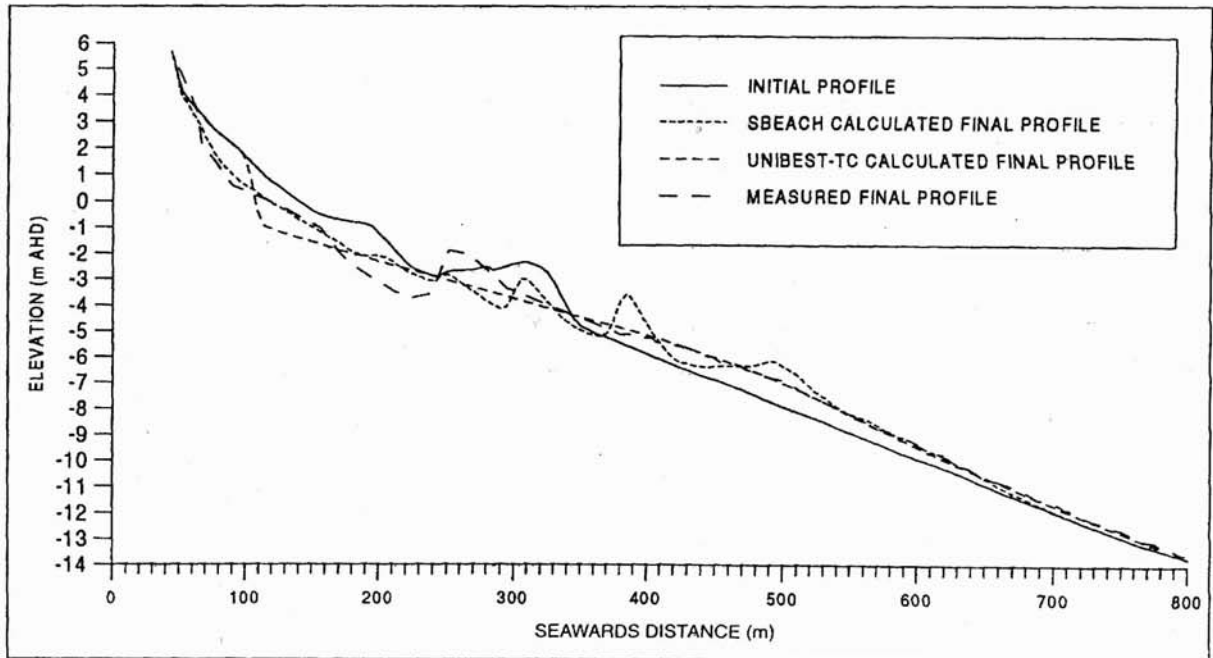


Figure 2: Model Verifications for Storm Events of May 1996

From a total of seven cases (the six previously cited plus the major storms of 1967 discussed in Section 2.3), eroded volumes predicted by the models versus surveyed eroded volumes (above AHD) are shown in Figure 3. It can be seen that in all but one case, SBEACH slightly over predicted erosion of the subaerial beach, whereas UNIBEST-TC under predicted erosion of the subaerial beach for most cases. The slight over prediction of SBEACH could be altered through reduction of the transport rate calibration parameter, however this then resulted in more cases of under prediction and was not pursued.

### 2.3 Simulation of Design Storm Events

Based on its better performance in predicting subaerial erosion (though not necessarily subaqueous change), SBEACH was run using the average profile at Surfers Paradise to predict erosion volumes for a range of single design storms having average recurrence intervals from 1 to 100 years. The design storms were developed from extrapolation of approximately 20 years of waverider buoy data.

Predicted subaerial erosion volumes for single storm events occurring on the average beach profile ranged from 22 m<sup>3</sup>/m (1 year ARI) up to ~70 m<sup>3</sup>/m for a single 100 year ARI storm. In light of larger recorded profile change from storms in 1967, further analysis was undertaken for the scenario of sequential multiple storm events.

In 1967 (prior to the installation of the waverider buoy), a series of storms struck the Gold Coast. McGrath (1968) catalogued a total of 21 storm events between January and June including seven tropical cyclones. Subaerial erosion volumes of ~150 m<sup>3</sup>/m were presented in Delft (1970) for surveys approximately 1 year apart.

Model runs were undertaken with SBEACH for the 1967 storms using estimates of wave heights and a total combined storm event duration of 78 days. For the Broadbeach profile presented in Delft (1970), subaerial erosion of 170 m<sup>3</sup>/m was predicted (versus 153 m<sup>3</sup>/m measured), again concurring with the trend of SBEACH to slightly over estimate subaerial volumes.

The average subaerial sand volume seawards of the seawall at Narrowneck (ETA67 profile) between 1974 and 1997 was ~80 m<sup>3</sup>/m, while at Surfers Paradise (ETA63 profile) between 1974 and 1997 it was ~200 m<sup>3</sup>/m. The Northern Gold Coast Beach Protection Strategy Master Plan proposes nourishment of the 2 km of beach from Narrowneck to Northcliffe of between 750 and 1000 m<sup>3</sup>/m. When distributed over the active profile (between RL 5.5 m and RL -16 m AHD) this is equivalent to a uniform profile progradation of between 30 and 50 m. The additional subaerial volume of such a progradation would be 165 to 275 m<sup>3</sup>/m, sufficient to withstand a single 100 year ARI design storm or a sequence of storms of similar severity to those of 1967.

### 2.4 Beach Accretion/Recovery

Both cross-shore models have the capability to predict beach recovery during low wave conditions. From the Gold Coast historical data, a total of nine recovery events were identified (between 1967 and 1996) and these were used to assess model performance. It was found however that neither model could reliably reproduce measured beach recovery. Both models were able to move sand landwards during low wave conditions, but not to the same extent or magnitude as the surveyed beach response. Aeolian (wind driven) transport may be responsible for much of the transport on the subaerial beach and this is not considered in either model.

Most cross-shore profile models for engineering use have been developed primarily to predict erosion during major storm events, and thus prediction of beach recovery has not as yet received the same development effort.

Economic studies of the Gold Coast have shown that beach recovery is critically important in the overall economic losses associated with an erosion event (ICM, 1997).

## 3. LONGSHORE MODELS

### 3.1 Brief Description of Longshore Models used

GENESIS (GENERALISED model for SIMulating Shoreline change) was developed by the US Army Corps of Engineers, with version 3 used in this study. Technical information on GENESIS is contained in Hanson and Kraus (1991) and Gravens et al (1991). UNIBEST-LT (UNIFORM BEACH Sediment Transport-Longshore Transport) was developed by Delft Hydraulics in The Netherlands, with version 3.1 used in this study. Both models are "one-line" models, that is, they assume a constant cross-shore beach profile.

### 3.2 Calibration with Adopted Longshore Transport Rate

Numerous previous studies have concluded that on straight, open coast beaches on the Gold Coast, the average annual net longshore transport rate is approximately 500,000 m<sup>3</sup>/yr northwards. Both longshore models require time series of wave conditions (height, period and direction) and representative sediment characteristics. For this study, 1 year of data from a recently installed directional waverider buoy was available. The wave height data (from the directional buoy) was compared with that obtained over more than 20 years from a non-directional waverider buoy and was found to be representative. Thus, a full 12 month time series of directional wave data was available for model input and calibration with the adopted longshore transport rate. Further sensitivity runs were undertaken for net longshore transport rates of 400,000 and 600,000 m<sup>3</sup>/yr.

### 3.3 Modelling the Impacts of Proposed Artificial Reef at Narrowneck

GENESIS was used to model the coastal evolution between Surfers Paradise and South Stradbroke Island with the incorporation of the proposed artificial reef at Narrowneck and the continuation of mechanical sand bypassing between The Spit and South Stradbroke Island. A range of wave transmission coefficients for the reef were modelled. The resulting change for the case of 70% wave transmission over the reef is shown in Figure 4. The beach in the lee of the reef is predicted to prograde at the shoreline salient by approximately 50 m after 10 years in the case presented. After several years of simulation, the model indicates that net northward longshore transport would be reduced by approximately 100,000 m<sup>3</sup>/yr initially, and by approximately 80,000 m<sup>3</sup>/yr after several years due to the presence of the reef.

A further GENESIS run was undertaken (Figure 5) incorporating the nourishment recommended in the Northern Gold Coast Beach Protection Strategy Master Plan, with the beach prograded by 30 m for a distance of 2 km south of Narrowneck. After 10 years of simulation, the extent of beach widening was found to extend a further 1 km south. Again it was found that the reef as modelled retards net northward longshore transport by approximately 100,000 m<sup>3</sup>/yr which reduces with time. Thus, this volume of nourishment sand would be needed to maintain the beaches immediately downdrift (north) of the reef in their original state. The sand could be backpassed from the Seaway.

### 3.4 Cross-Shore Distribution of Longshore Transport

GENESIS uses a modified version of the simple and widely used CERC equation (Hanson and Kraus, 1991). The CERC equation does not directly incorporate any cross-shore distribution of longshore transport, but rather calculates total longshore transport. UNIBEST-LT has provision for calculating longshore transport by five different methods with the Bijker method (Bijker, 1971) used in this study. Along with the CERC equation, it is the most widely used and it has been extensively developed and calibrated on the Gold Coast (Delft, 1970). From the UNIBEST-LT software, a cross-shore distribution of longshore transport using the Bijker method can be obtained.

Using a simplified version of the directional wave climate (due to the limitation of 100 separate wave conditions in UNIBEST-LT version 3.1), a cross-shore distribution of longshore transport was derived. The distribution for annual average conditions is shown in Figure 6. It can be seen that approximately 5% of transport is estimated to bypass the

seaward limit of the southern Gold Coast Seaway training wall. This is likely to represent a lower limit due to local 2-D surf zone circulation in the vicinity of the walls and the diurnal tidal exchange through the Seaway. During (rare) major storm events with significant wave heights in excess of 5 m, natural bypassing rates in excess of 50% are estimated at the southern Seaway training wall with waves breaking seawards of the wall.

Recently conducted field studies on the Gold Coast may provide some verification data for the cross-shore distribution of longshore transport estimated by UNIBEST-LT.

## 4. CONCLUSIONS

The Gold Coast provides an excellent site for application of beach morphology models due to the relative abundance of both profile and wave data.

For the area in the vicinity of Narrowneck, six storm events were identified (between 1988 and 1997) for which pre- and post-storm surveys had been undertaken, and for which reliable wave and water level data exist. In the simulation of these six storm events, SBEACH was found to better predict subaerial beach change, whereas UNIBEST-TC was found to better predict profile change further seaward. This led to SBEACH being used for prediction of subaerial erosion for a range of design storms, including single storms up to 100 year ARI and sequences of storms such as those of 1967.

Both cross-shore models were satisfactory in the prediction of erosion due to storm events, however, neither was able to simulate beach recovery during low wave conditions.

GENESIS and UNIBEST-LT (using Bijker formula) were used to simulate the widely accepted longshore transport rate for the northern Gold Coast of ~500,000 m<sup>3</sup>/yr northward. GENESIS was found to more readily incorporate offshore structures such as the proposed submerged reef at Narrowneck and was used to assess the reef's impact on the beaches either side. The success of this assessment will only be able to be verified in post construction monitoring. The superior ability of UNIBEST-LT software (and sediment transport formulae) in deriving cross-shore distributions of longshore transport was used in the assessment of likely bypassing rates of the southern training wall of the Gold Coast Seaway under both annual average and storm wave conditions.

All models used in this study are being continually refined and improved by their developers. Thus, their usefulness as design tools should continue to improve.

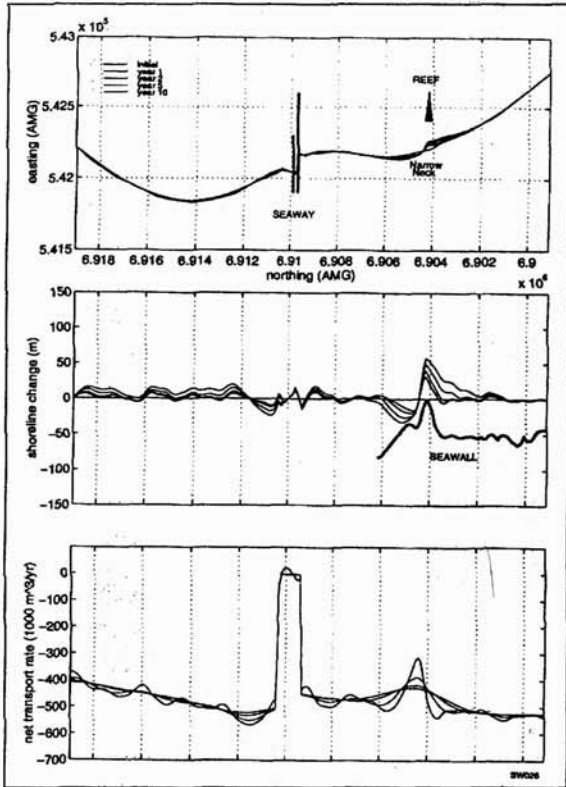


Figure 4: GENESIS Modelling (wave transmission 70%)

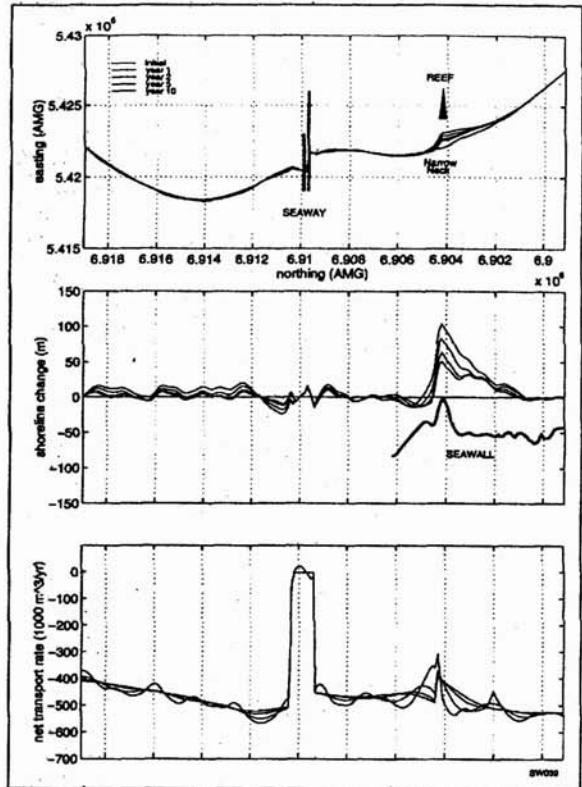


Figure 5: GENESIS Modelling with Nourishment Updrift

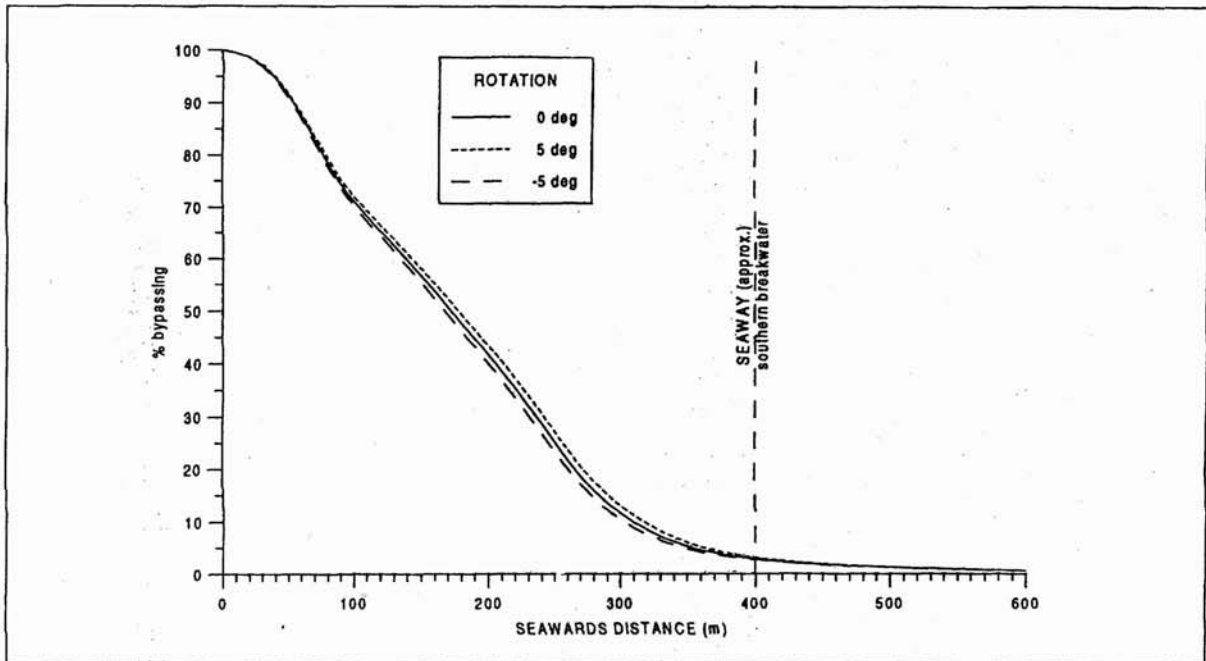


Figure 6: UNIBEST-LT (Bijker) Cross-shore Distribution of Longshore Transport

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