Designing the Shape of the Gold Coast Reef: Field Investigations

J. A. Hutt[1], K. P. Black[1], A. Jackson[2] and J. McGrath[3]

[1]Centre of Excellence in Coastal Oceanography and Marine Geology.
National Institute of Water and Atmospheric Research and
The Department of Earth Sciences at The University of Waikato,
P.O. Box 11-115, Hamilton, New Zealand.
[2] International Coastal Management
P.O. Box 7196, Gold Coast, Australia
[3] Gold Coast City Council, Gold Coast, Australia
[1]Phone: 64 7 856 7026 Fax: 64 7 856 0151 Email: j.hutt@niwa.cri.nz

SUMMARY A programme of measurements was undertaken to support numerical studies to design a submerged reef at Narrowneck Beach on the Gold Coast, Queensland, Australia. An instrumented sea-sled was developed to record bedforms, suspended sediment load, currents, waves and the bathymetry profile as it was hauled through and beyond the surf zone at Narrowneck. The sled was deployed on seven occasions over the period from November 7, 1997 to January 28, 1998. Offshore wave data were recorded continuously at Narrowneck using an S4 InterOcean current meter. The bathymetry profile varied from exponential ("storm" shape) to having one or two well-defined bars. The position of the dominant offshore bar was found to be a linear function of the prevailing wave height; the larger the wave height, the further the bar was located offshore. Sediment suspension in the nearshore zone was measured using Optical Backscatterence Sensors (OBS). High concentrations of suspended sediment were generally related to wave groups rather than the passage of individual waves. Longshore currents ranged between 0 and 80 $cm.s^{-1}$ and were measured oriented both to the north and south. The main difficulties encountered in the field operation were re-mobilising the sled after it had been left in a fixed position, particularly beyond the offshore bar, and public safety.

1 INTRODUCTION

Beach widening to provide an increased storm buffer and additional open public space is planned for the northern Gold Coast in southern Queensland, Australia It is proposed that over 1 million m^3 of nourishment material will be taken from the Broadwater and placed on the beaches between Narrowneck and Northcliffe. The renourishment is to be stabilised at the northern end of the beach at Narrowneck by a sub-tidal reef which will provide a barrier to sediment losses, while also improving the surfing climate (1, 2). The submerged reef is to be constructed to provide a coastal control point to maintain the widened beach profile.

Narrowneck Beach is highly active and bathymetry surveys show the banks migrating cross-shore in response to storms and swell. The longshore sediment transport is estimated to be 500,000 m^3yr^{-1}, but this has never been directly measured, only inferred from amounts presently being by-passed across a nearby estuary entrance at the Broadwater (3, 4) and other related studies (5, 6, 7, 8). In addition, aerial photographs and bathymetry surveys depict a complex structure of migrating banks and channels responding to the continual variability in daily wave and wind conditions. The wave climate driving these changes at short and long time scales has not been measured at Narrowneck, only offshore. Refraction, frictional attenuation and shoaling of the waves as they approach the shore are strongly influenced by the complex topography in the region, particularly for waves approaching from the south. Thus, field measurements and calibrated numerical modelling were needed to develop an accurate wave climate for the inshore site that then leads to predictions of longshore and cross-shore sediment fluxes.

The likely effects of natural banks and the characteristics of the regional wave climate needed to be accounted for in the reef design to optimise the surfing quality and the positive benefits on coastal stability. Moreover, reef burial or scouring by natural bank movements could lead to structure failure or cause negative impacts on downstream reefs. Thus, the efficacy of the reef for enhancement of beach stability couldn't be confidently determined if local longshore and cross-shore wave, current and sediment dynamics were not known.

To address these matters, a programme of measurements was undertaken at Narrowneck Beach, Kirra Point and Burleigh Heads in conjunction with numerical model simulations of wave refraction, wave-induced circulation and sediment transport (9, 10, 11). The part of the field program described in this paper, provided information about currents, waves and sediment movement at Narrowneck Beach, plus data for numerical model establishment and validation. Several different techniques were applied including the development of a purpose-built instrumented sea-sled which recorded bedforms, suspended sediment load, currents and waves as it was hauled through and beyond the surf zone along a transect at Narrowneck Beach. The sledding procedure provided access to the surf zone in waves up to 2.7 m height and was highly successful for collection of surf zone data, although some operational difficulties were experienced as discussed below.

2 DESCRIPTION OF THE FIELD PROGRAM

An instrumented sled was constructed of aluminium with a design that resembles a catamaran with a 9 m^2 (3 m by 3 m) deck and an 8 m-tall mast (Fig. 1). Seven sled runs were carried out from November 7, 1997 until January 28, 1998. The timing was such that results were obtained from a broad range of wave and wind conditions.

Figure 1 Sled being towed up the beach face at Narrowneck

During each survey, a nylon line was taken from the beach by jet ski out to a vessel waiting beyond the breakpoint. The sled was then towed offshore by the vessel into approximately 7 m of water, or approximately 600 m offshore of the crest of the dunes at Narrowneck, where it was left for a minimum period of 20 minutes to measure offshore wave conditions. It was then towed back toward shore in stages using a vehicle on the beach. During the tow-in phase, the sled was left for a minimum of 20 minutes at ‘stops’ along the profile. The number of stops and their positions varied between sled runs but were chosen so that records were always made at the breakpoint and on the dominant bar crest and trough. While being towed, position fixes were taken approximately every 10 m using a tracking Geodimeter sighting onto a cluster of prisms mounted on the top of the mast to provide horizontal position and elevation of the sled. The resulting data provided a continuous profile which could be obtained in almost any conditions, as waves, currents and tide had almost no effect on the sled operation.

In addition to the surveying equipment, a number of wave, current and sediment transport instruments were fixed to the sled to operate simultaneously as the beach surveys were being undertaken. The instruments were; an *InterOcean* S4 current meter, wave pressure sensor, three optical backscatterence sensors (OBS), a bedform wheel and sediment traps.

The main data acquisition logger was placed in a purpose-built housing on the sled. The system was constructed at the Centre of Excellence in Coastal Oceanography and Marine Geology for the sledding experiments. For each sled run, data were logged continuously at a sampling frequency of 2 Hz. With this sampling regime, which rapidly generated large amounts of data, approximately 3.5 hrs of continuous measurements could be made. If more than one run was carried out on a particular day, as it was on Runs 2(a,b), 4(a,b) and 6(a,b), the data were down-loaded between runs with a portable computer on the beach while the data logger was still attached to the sled. This process took approximately 10 minutes. In all cases data had to be down-loaded the same day before the battery voltage became too low. On one occasion (Run 6), data were lost due to the battery pack being accidentally disconnected.

As much as possible, the sensors were mounted in an exposed part of the frame to reduce the effects of turbulence generated around the sled. The S4 was placed at 0.63 m above the bed on the front of the sled. The “bedform wheel” was attached to the side of the sled prior to each run. The most sensitive instruments, the OBS, were placed at 0.18-0.90 m above the bed on a vertical pole. This pole was mounted on the offshore corner at 45^o to the sled so that the OBS projected both forwards and longshore. The skis of the sled were designed to support the frame while mobile, but narrow enough so that they travelled some 5 cm below general bed level. This meant that the skis were usually covered by sand when the frame was stationary leaving only the 6 upright supporting poles exposed near the sea bed. While interference could not be totally eliminated, sea bed observations by divers found no apparent additional sediment suspension near the instruments due to the presence of the sled.

Sediment traps were attached to the sled frame for Runs 4, 5, 6 and 7. The traps were made of PVC piping closed at one end. Traps were attached to the sled vertically with the open end facing upwards. The traps were 400 mm in length and had a diameter of 40 mm, thus giving an aspect ratio of 10:1, as suggested for turbulent environments (12). The aspect ratio is important for the retention of particles in the trap.

An *InterOcean* S4 current meter, fitted with a high-resolution pressure sensor, was separately deployed in 8 m depth at the offshore extremity of the sled transect. The S4 continuously collected time series of waves and currents over the full period of the field operation.

3 RESULTS

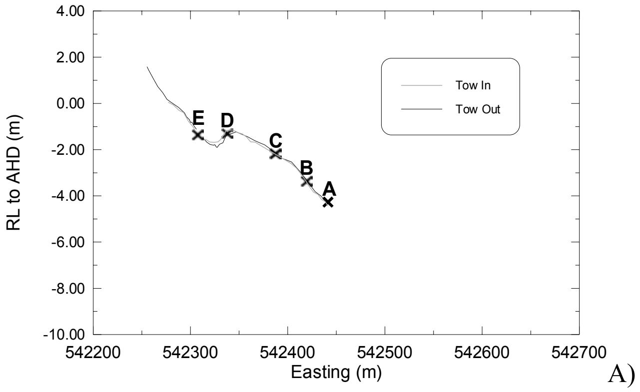
3.1 Narrowneck Wave Climate

The time series data showed that the significant wave height ranged from 0.45 to 2.7 m but was less than 1 m approximately 75% of the time. Significant wave period ranged from approximately 3 to 12 s. Smaller periods tended to accompany the smaller waves. Wave direction ranged from 210° to 300° (going toward) which corresponds to a NNE to an ESE direction (coming from). The mean wave direction was 265°.

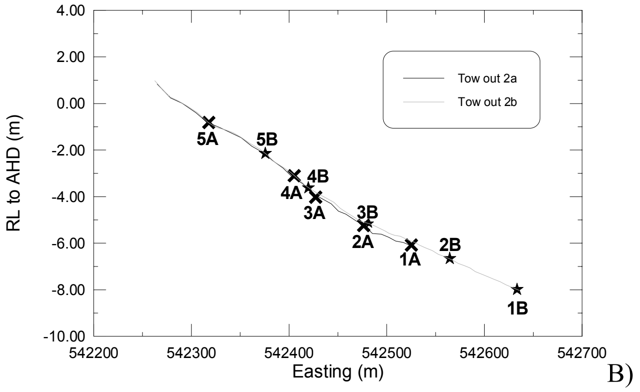
3.2 Sled Profiles

Surveyed beach transects measured during all seven sled runs are presented in Figure 2. The transects show a steep beach face, and either: (1) a nearly horizontal beach platform or channel merging with an offshore bar; or (2) a well developed channel and bar system. The profiles are nearly linear further offshore with a gradient of approximately 1:50. There is usually only one longshore bar, but its cross-shore position varies considerably. The profile measured on January 15 1998 (Run 5) shows multiple bars with crests 139 and 200 m offshore of the datum. In Run 2, no longshore bar or trough is present and the beach face has a near linear gradient of approximately 1:40.

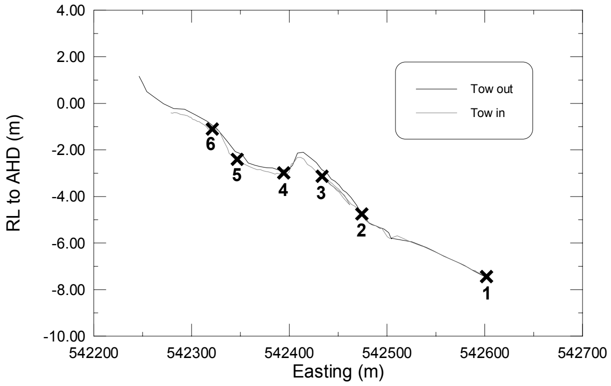
Depths to the bar crest were 1.24-2.34 m. The ratio of trough depth to crest depth of the primary bar ranges between 1.34 (Run 7) and 1.74 (Run 6). The height of the bar was taken as the difference between the trough and the bar crest and ranged from 0.46 m (Run 7) to 0.92 m (Run 4 and 6).



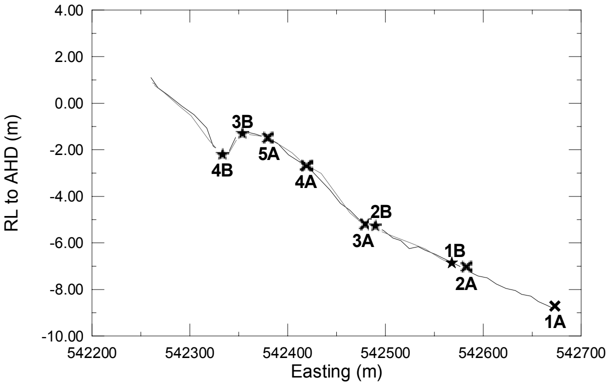
Run 1 (07/11/97)



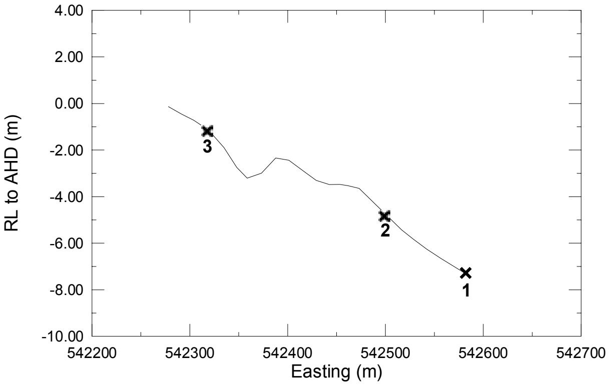
Run 2 (18/11/97)



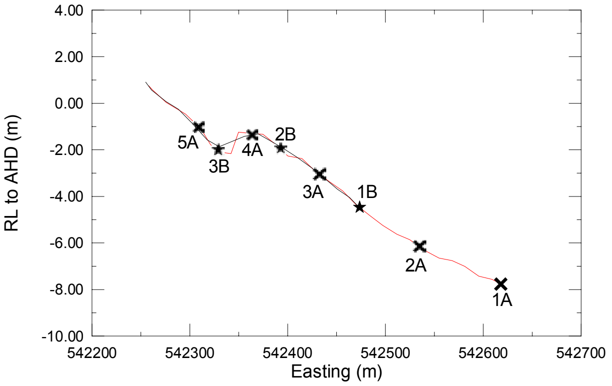
c) Run 3 (18/12/97)



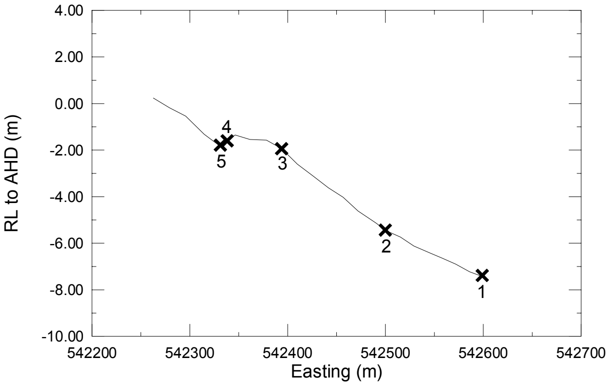
D) Run 4 (07/01/98)



E) Run 5 (15/01/98)



f) Run 6 (20/01/98)



g) Run 7 (28/01/98)

Figure 2 Beach profiles surveyed during each sled run operation. The location of 'stops' that the sled made are also shown "A" and "B" distinguish cases when two runs were done on the same day.

A relationship was found between the significant wave height measured from the sled and the position of the longshore bar relative to the zero origin (Fig. 3). Run 2 is not plotted as no offshore bar exists in the profile. Two points have been plotted for Run 3, as it represented a special case. During the 24 hours prior to Run 3, the average significant wave height was < 1 m (point 3b). However, on December 12 1997, the significant wave height peak at 2.7 m. The profile measured may be relict from this larger wave event and therefore wave height associated with this earlier event has also been plotted (point 3a). For runs 1, 6 and 7 the significant wave height varied by only 0.2 m, with the depth to the crest of the bar varying by only 0.11 m and its distance offshore by 8.1 m.

A linear fit to the data (excluding point 3b) gave a high r-squared value of 0.93 (Fig. 3). This relationship indicates that the position of the offshore bar is directly responding to incident wave height.

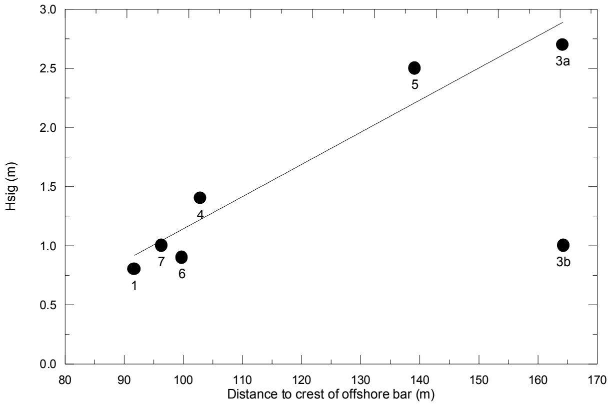


Figure 3 Cross shore distance to the bar and significant wave height. Line of best fit has r^2=0.93.

3.3 Currents at Narrowneck

The current measured from the sled was separated into the two components, U (onshore/offshore) and V (longshore). The mean current U is positive towards the beach. The mean current V is positive southward. The onshore/offshore and longshore currents measured at each stop of each sled run are presented in Figures 4a,b,c.

Longshore currents range between 0 and 80 cm.s^{-1} and were measured running both to the north and the south. The strongest current was recorded during sled run 5 at 80 cm.s^{-1} to the south. The largest wave heights were also recorded during Run 5 (up to 2.7 m) with an average wave direction recorded in 8 m depth of 249° or from the north-east quadrant.

On most occasions, both the longshore and onshore/offshore current was close to zero when the sled was at its most seaward position. As the sled was towed landward, the currents generally increased to a maximum, before decreasing as the sled came even closer to shore, within 20 m of the swash zone. On some occasions (Runs 3, 4 and 7), the offshore current was stronger than the longshore current and it is suspected that the sled transect was running through a rip cell. Run 3 and 6a show the longshore current moving to the south near the break point and to the north inside the break point.

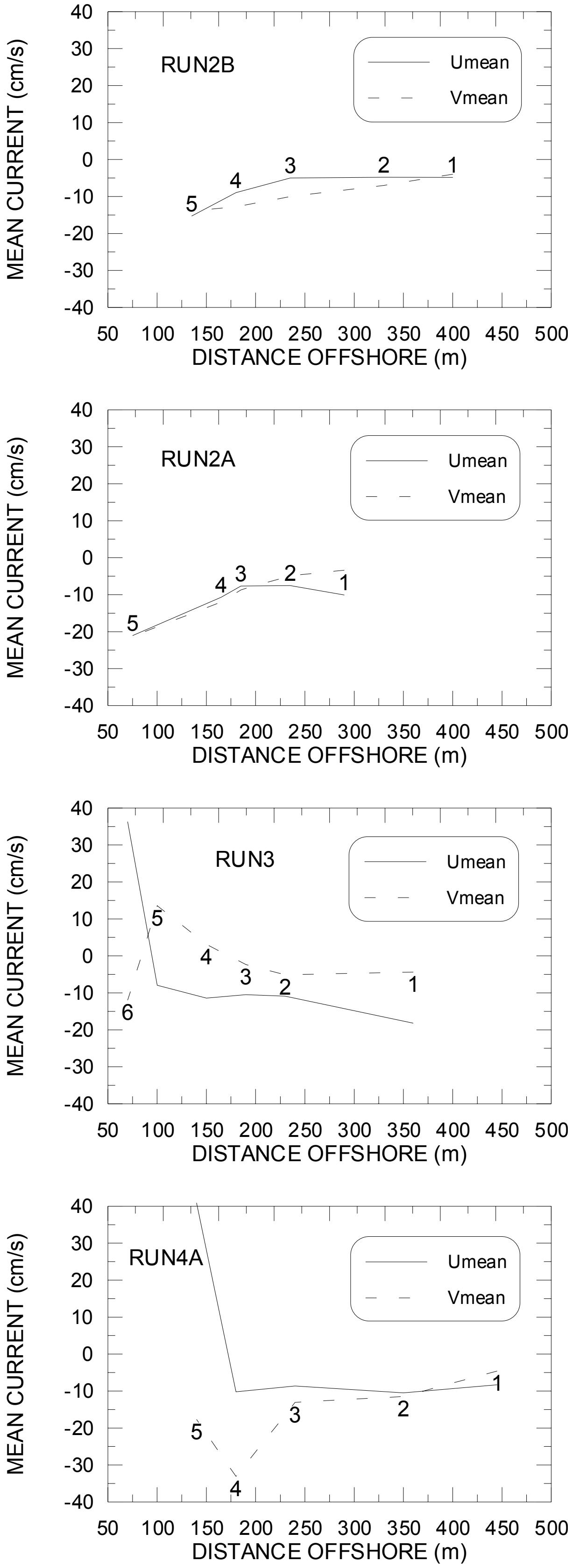


Figure 4a Currents Umean (+ve onshore) and Vmean (+ve south) for each sled stop of Runs 2A, 2B, 3, 4A.

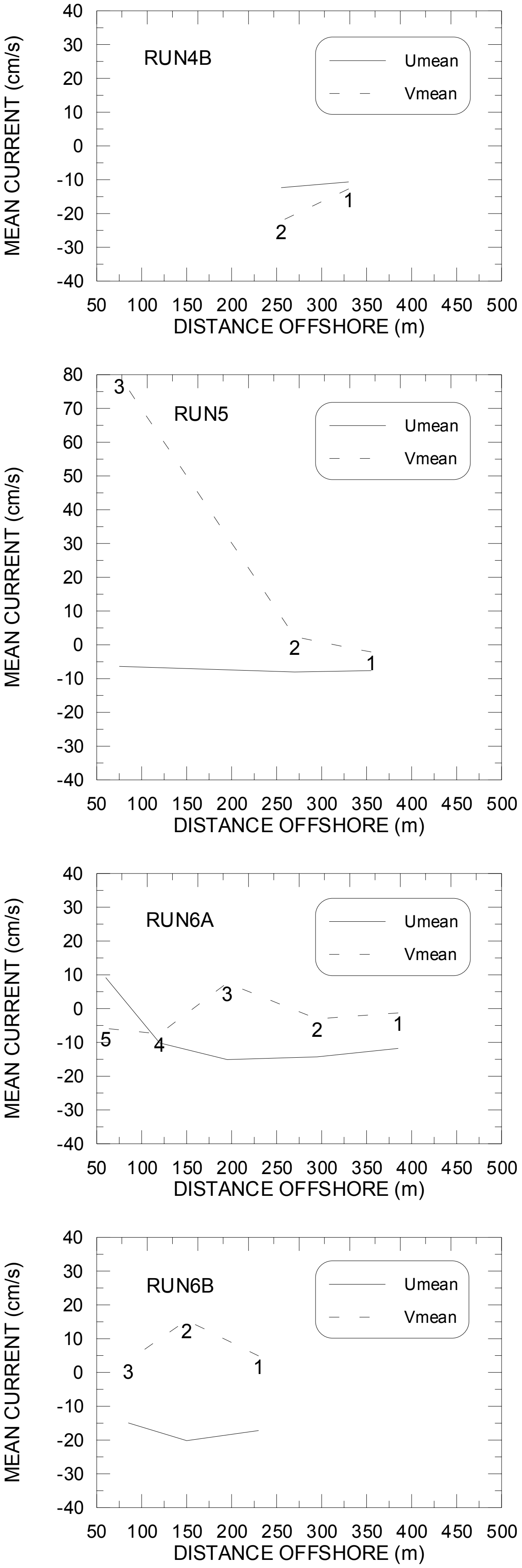


Figure 4b Currents Umean (+ve onshore) and Vmean (+ve south) for each sled stop on Runs 4B, 5, 6A and 6B.

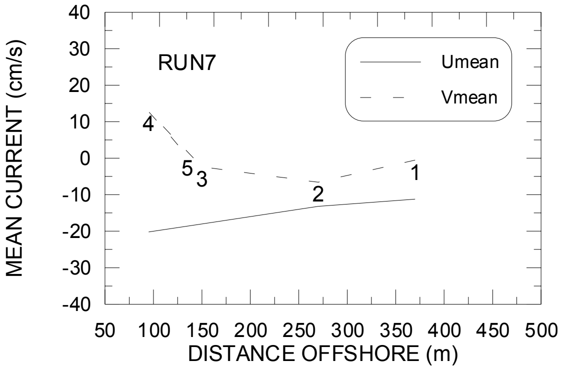


Figure 4c Currents Umean (+ve onshore) and Vmean (+ve south) for each sled stop on run 7.

3.4 Sediment Concentrations at Narrowneck

Suspended sediment concentrations (SSC) were calculated using the OBS data measured during each 'stop' of each sled run (Fig. 5). Suspended sediment concentrations around the surf zone are related to wave properties, and the position relative to the breakpoint. High concentrations of suspended sediment were generally related to wave groups rather than the passage of individual large waves (Fig. 5).

For most of Run 7 Stop 1 sediment concentrations were less than 3 kg/m^3, but higher concentrations (of the order of 15 kg/m^3) occurred for up to 30 seconds. These results are consistent with previous investigators who found nearshore sediment concentrations of the order of 10 kg/m^3 when the peak wave period was 12 s (13). Sediment concentrations three times lower than those presented here were measured in the North Sea (14) where sediment characteristics were similar to those found on the Gold Coast. However the significant wave period was somewhat lower (4 s) than recorded during Run 7 (8 s) and could account for the difference. In addition the unknown characteristics of the bedforms may also be playing a role.

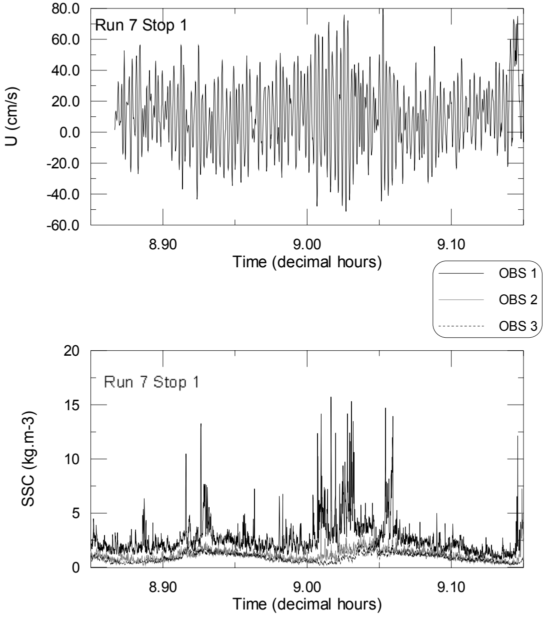


Figure 5 Sea level recorded with the Dobie pressure sensor and SSC recorded with the OBS instruments 1,2 and 3 at elevations 0.18, 0.43 and 0.88 m respectively of stop 1 of Run 7.

4 PROBLEMS ENCOUNTERED IN THE SLED OPERATION

The main problem encountered during the sled operation was re-mobilising the sled after stops when sediment built up on the skis of the sled, and the cable was buried along its full length across the surf zone. This was particularly troublesome when the sled was lodged on the seaward side of the offshore bar. Initially, a steel cable with a breaking strain of 1500 kg was used to tow the sled landward. However, this cable broke on several occasions and was found to be creating a dangerous situation when the cable re-coiled up the beach. As an alternative, a 14 mm silver rope (which also had a breaking strain of 1500 kg) was attached to the sled and, although a large amount of stretch occurred, the rope didn't break. The stretch on the rope allowed the sled to slowly dislodge from the sand, unlike the abrupt pull on the sled by the steel cable. However, since the rope floated it caused a large amount of drag and better operation may be achieved with a non-floating rope, as the sled migrated longshore during run 4.

Narrowneck beach is very popular amongst walkers, joggers, swimmers and surfers. The sled operation essentially cut-off a section of the beach to the public and a fence was assembled for each sled run to alert beach users to the operation and to force a single path that could then be easily controlled. On some occasions, the longshore current was strong and surfers were continuously drifting into the path of the sled creating a potentially dangerous situation.

5 CONCLUSION

A programme of measurements was undertaken to support numerical studies to design a submerged reef at Narrowneck Beach on the Gold Coast, Queensland. An instrumented sea-sled was successfully used on seven occasions to record bedforms, suspended sediment load, currents, waves and the bathymetry profile as it was hauled through and beyond the surf zone at Narrowneck. The sled was constructed of aluminium with a design that resembles a catamaran with an 8m tall mast. A cluster of prisms was mounted on the top of the mast for surveying of horizontal position and elevation. The main difficulties encountered in the field operation were re-mobilising the sled after it had been left in a fixed position, particularly beyond the offshore bar, and public safety.

6 REFERENCES

1. Jackson, L.A.; and McGrath, J. E. (1995) Proposed headland for Surfers Paradise. Proc. 12th Australasian Coastal and Ocean Engineering Conference, Institution of Engineers, Melbourne.
2. International Coastal Management (ICM) (1997) Recommendations for Northern Gold Coast Beach Protection Strategy. Prepared for Gold Coast City Council by International Coastal Management, Gold Coast, Australia. 15 p.
3. Polglase, R. H., (1987): The Nerang River entrance sand bypassing system. 8th Australian Conference on Coastal and Ocean Engineering, 222-226
4. Munday, D.P. (1995) Coastal responses to the Nerang River inlet stabilisation, Gold Coast, Australia. Unpublished BSc (Hons) thesis. Queensland University of Technology.
5. Chapman, D.E.M. (1981) Coastal erosion and sediment budget, with special reference to the Gold Coast Australia. Coastal Engineering. 4: 207-227
6. Delft (1992) Gold Coast, Queensland Australia - southern Gold Coast littoral sand supply. Final Report, Volume I and II, Delft Hydraulics, 559 p.
7. Patterson, C.C.; Patterson, D.C. (1983) Gold Coast longshore transport. Proceedings 6th Australasian Conference on Coastal and Ocean Engineering, Institution of Engineers, Australia. p. 251-256.
8. Tomlinson, R.B. (1991) Processes of sediment transport and ebb delta development at a jettied inlet. In Kraus, N.C., Gingerich, K.J. and Kreibel, D.L. (eds.) Coastal Sediment '91 (ASCE) New York. P. 1404-1419.
9. Hutt, J., Black, K., Jackson, A., and McGrath, J., (1998) Narrowneck Reef. Report 1: Surf Zone Experiments. Report prepared by the Centre of Excellence in Coastal Oceanography and Marine Geology, NIWA and the University of Waikato, NZ, for the Gold Coast City Council.
10. Black, K., Hutt, J., and Mead, S. (1998) Narrowneck Reef. Report 2: Surfing Aspects. Report prepared by the Centre of Excellence in Coastal Oceanography and Marine Geology, NIWA and the University of Waikato, NZ, for the Gold Coast City Council.
11. Black, K. (1998) Narrowneck Reef. Report 3: Sediment dynamics. Report prepared by the Centre of Excellence in Coastal Oceanography and Marine Geology, NIWA and the University of Waikato, NZ, for the Gold Coast City Council.
12. Flint, S. B., (1998): Sediment trapping in the nearshore coastal environment, unpublished MSc. Thesis, Earth Sciences Department, The University of Waikato.
13. Black, K. P., Gorman, R. M., and Symonds, G. (1995): Sediment transport near the break point associated with cross-shore gradients in vertical eddy diffusivity, Coastal Engineering (26) 153-175.
14. Kos'yan, R. D., (1997): Net suspended sediment transport in the surf zone, Second Indian National Conference on Harbour and Ocean Engineering, Thiruvananthapuram, December 7-10, 1997.

7 AKNOWLEDGEMENTS

As with any field operation of this scale a number of people are required to make things happen. We'd like to thank the Gold Coast City Council survey team and beach crew including; Frank Goetsch, Shane Sterry, Andy Keally, Doug Williamson, Chris Matsis, Terry Murphy, Clive Sealy, Bernie McDonald, Alan McCrea, Paul Adcock. Also the Gold Coast City Council Lifeguard Service.