LAND & WATER CONSERVATION

QUEENSLAND GOVERNMENT
Department of Environment

Tweed River Entrance Sand Bypassing Project

Permanent Bypassing System

Technical Appendix IV: Monitoring of Turbidity and Suspended Solids Concentrations at the Gold Coast Seaway

Hyder Consulting

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FOR: New South Wales Department of Land and Water Conservation

and

Queensland Department of Environment

BY: WBM Oceanics Australia on behalf of
Hyder Consulting Pty Ltd, Patterson Britton Partners Pty Ltd and WBM Oceanics Australia
Joint Venture

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1 Introduction

The Tweed River Entrance Sand By-passing Project is a joint project undertaken by the State Governments of Queensland and New South Wales to establish and maintain a navigable entrance to the Tweed River and to enhance and maintain the amenity of the southern Gold Coast beaches.

The Project works will be carried out in two inter-related stages:

Stage 1 - Dredging of the Tweed River bar and replenishment of the beaches between North Kirra and Rainbow Bay.

Stage 2 - Construction and operation of a permanent sand by-passing system at the Tweed River entrance. As a part of the design studies for Stage 2 of the Project, the nature and characteristics of the sand discharge turbidity plume were measured at the Gold Coast Seaway sand by-passing operation (30 km north of the Tweed River) as a practical means of identifying the extent of the likely plumes for the Tweed system. This is possible because the characteristics of the sand to be pumped at the Tweed are essentially the same as those at the Seaway.

WBM Oceanics Australia was commissioned to monitor the plume turbidity and suspended solids concentrations at the Gold Coast Seaway associated with two discharge conditions which are to be considered for the Tweed system. The discharge conditions consist firstly of the discharge of sand onto the beach at high water mark and secondly of the discharge of sand into comparatively shallow water below the low water mark.

During each monitoring exercise at the Gold Coast Seaway measurements were also collated for a range of physical parameters affecting the plume behaviour (such as currents, wave and wind conditions) and aerial photographs were obtained of typical plume characteristics.

The results from the monitoring exercises are to be incorporated into a plume modelling study for further design work for the Tweed sand by-passing system.

1.1 Site Description

The Gold Coast Seaway sand by-passing system is situated at the Spit, Main Beach at the northern end of the Gold Coast. The Seaway separates the Spit and South Stradbroke Island and is the major navigable ocean entrance for vessels gaining access to the protected Southport, Broadwater and Nerang River waterways.

The Gold Coast Seaway sand by-passing system is owned by the Queensland Government and is operated and maintained by the Southport office of the Queensland Department of Transport. When originally developed in 1984, it was the first of its kind in Australia.

The system effectively maintains the dredged depth of the Seaway entrance by intercepting north bound sand and pumping it below the Seaway directly to the ocean beach of South Stradbroke Island. Sand is intercepted by a series of ten jet pumps situated along the length of a jetty situated some 150 m south of the Seaway entrance. The pumped sand is deposited by pipe at high water mark on the beach of South Stradbroke Island approximately 150 m north of the Seaway, allowing littoral transport to take care of the redistribution of sand along the beach. The system is shown in Figure 1.

Sand pumping is normally undertaken at night to minimise the electricity costs of pumping. Pumping can be undertaken under a range of weather conditions but is not normally undertaken during rough or extreme sea conditions as past experience has indicated that the jet pumps can quickly become clogged with beach debris and vegetation eroded during such periods.

The coastal sediments around the Seaway consist of fine grained clean white sand beaches with no silt but occasionally with small amounts of organic material usually derived from vegetation. As a consequence, the background turbidity of the ocean water surrounding the Gold Coast Seaway is typically low, being generally less than 10 NTU (Nephelometric Turbidity Units) and often lower than 5 NTU at high water. There are, however, localised turbidity influences such as the generally more turbid water ebbing from the Southport Broadwater or from the treated sewage discharges, located on both the northern and the southern Seaway training walls, and the influence of breaking ocean swell and wind waves, which can substantially increase the turbidity of the nearshore water adjoining the Seaway.

1.2 Discharge Conditions

Two sand discharge conditions which are to be considered for the Tweed sand by-passing system were monitored at the Gold Coast Seaway.

The discharge conditions were:

- the discharge of sand onto the beach at or about high water mark (which is the normal form of operation of the Gold Coast Seaway system), and
- the discharge of sand into the active sub-tidal zone (water depth of 2-3 m). This condition was simulated by the temporary removal of pipework at the Gold Coast Seaway sand by-passing jetty, allowing the pumped sand slurry from one of the jet pumps to cascade directly into deeper water below the jetty structure.

The first discharge condition was monitored from the beach adjoining the discharge pipe at South Stradbroke Island on Wednesday 21 and Thursday 22 August 1996.

The second discharge condition was monitored from the sand by-passing jetty and using an inflatable surf rescue boat working around the sand by-passing jetty on Tuesday, 17 September 1996.

Information on the relative scale of the monitored discharge conditions was provided by the Department of Transport.

The 450 mm discharge pipe at South Stradbroke Island typically carries a flow of between 1500 and 1700 m^3/hour of sand/water slurry. The tonnage of bulk sand delivered to the beach depends upon the buildup of sand at the jetty and the density of sand which can be pumped, but is typically of the order of 380-400 m^3/hour. Typically five or six jet pumps are operated at any one time to maintain this flowrate. A single jet pump therefore has a bulk sand pumping capacity of approximately 60-80 m^3/hour.

For the first of the discharge conditions monitored at South Stradbroke Island on 21 and 22 August 1996, the average slurry flowrate was 1645 m^3/hour, with a corresponding bulk sand transport capacity of approximately 400 m^3/hour. For the second discharge condition monitored at the sand by-passing jetty, a single jet pump (jet pump no. 3) was used to simulate the discharge of sand to sub-tidal water depths. Jet pump no. 3 is the third jet pump out from the shore. It was selected for use because of its location which corresponded with comparatively deep water of 2-3 m depth in a gutter along the beach and was somewhat protected from the direct swell by a sandbank situated further offshore. The estimated bulk sand transport capacity of jet pump no. 3 on 17 September 1996 was 65 m^3/hour (approximately one-sixth of that monitored at South Stradbroke Island).

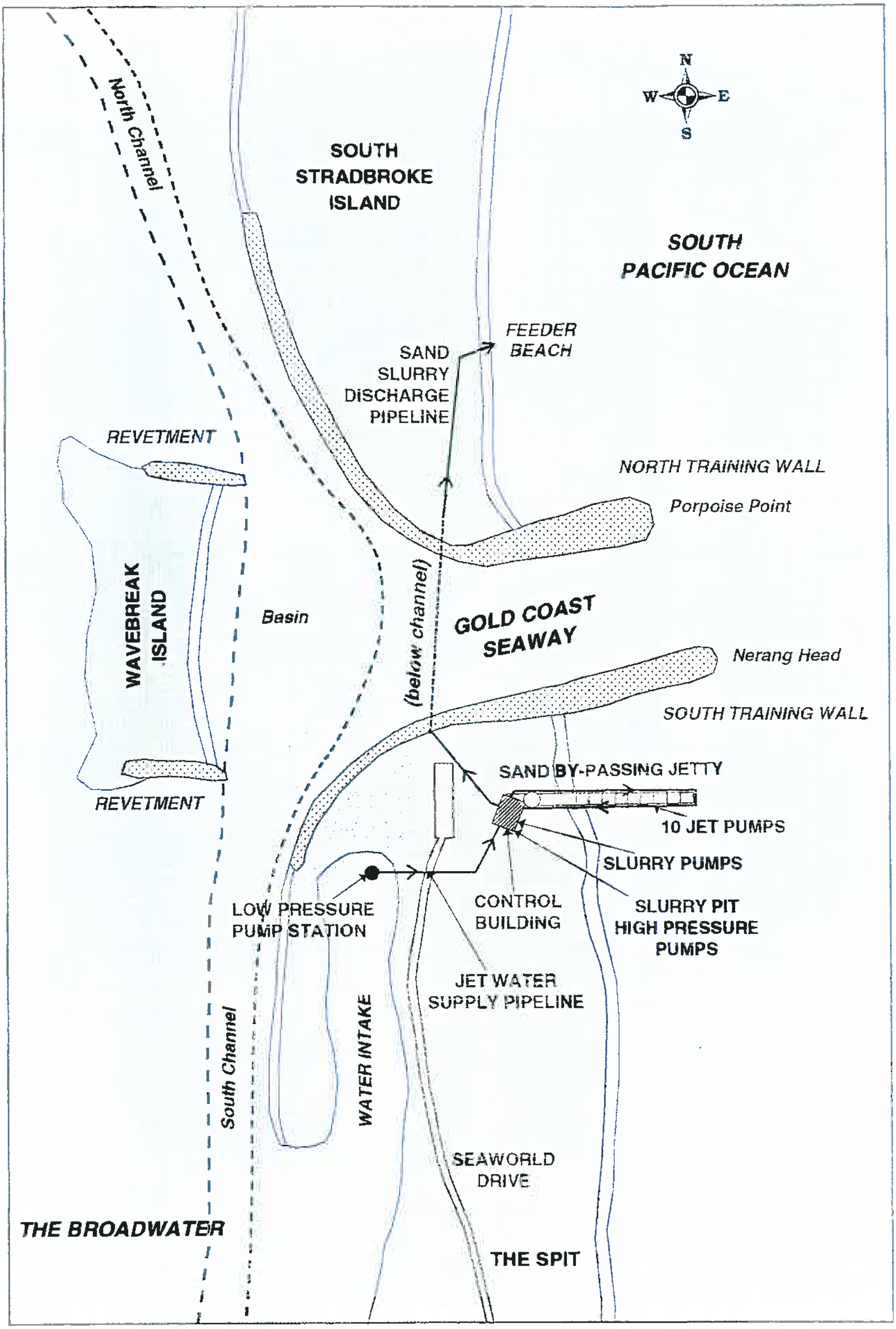


Figure 1
Schematic Diagram of the Gold Coast Seaway

1.3 Supplementary Data

For each discharge condition a range of measurements were collated for those parameters influencing the potential dispersion or movement of the turbid plumes (including wave height and period, current speed and direction and wind speed and direction).

Sources of this data were as follows:

- Wave height and period was measured by the Beach Protection Authority's Gold Coast waverider buoy positioned offshore from Main Beach. Hourly data was made available by the Beach Protection Authority. COPE (Coastal Observation Programme Engineering) type observations of the significant wave height and period were also made at each site.
- Current speed and direction was recorded by an InterOcean S4 recording current meter situated in the study area. Current speed and direction observations were also made by the release of Rhodamine dye satchels.
- Wind speed and direction was recorded by an automatic weather station situated at the Gold Coast Seaway which is operated by the Bureau of Meteorology. Half hourly data was provided by the Bureau of Meteorology.

Oblique aerial photography was also recorded for each discharge condition to define the physical extent of the plumes and to place the discharge plume into perspective with other regional turbidity influences, such as those generated by breaking waves.

2 Methodology

2.1 Turbidity Measurement

The measurement of turbidity for both discharge conditions was made using two YEO-KAL model 606 submersible data loggers. These instruments are capable of measuring a range of water quality parameters including water depth, water temperature, conductivity/salinity, pH, dissolved oxygen and turbidity. For this study the range of sensors programmed for measurement was limited to depth, temperature, conductivity/salinity and turbidity.

The instruments are calibrated and programmed using dedicated software installed on a personal computer. The instruments can be programmed for sensor sampling speeds ranging from once every two seconds to once per day with timed start or conditional start switch options. Data are normally stored internally. A communications adaptor and interface allow real-time viewing of recorded data or downloading of internally stored data files.

To measure the anticipated rapid fluctuations in turbidity within the surf zone, the instruments were programed for a sampling rate of 0.5Hz using a conductivity/salinity switch for their operation. This switch allowed the instruments to be automatically switched on for the measurement of turbidity (and the other parameters) only whilst they were immersed in sea water.

The turbidity sensors fitted to the instruments are nephelometric in principal, using a pulsed infra-red light beam and measure the 90□ scatter of light. The instruments are equipped with sensors calibrated in the range 0-200 NTU (Nephelometric Turbidity Units) with a maximum linear response of approximately 230 NTU.

At South Stradbroke Island, one of the two instruments was moored at a fixed position within the centreline of the plume using a taught line mooring from the seabed. The other was used as a roving instrument and was held in position within the centre of the plume by personnel at varying distances downstream of the discharge. Refer to Figure 2.

The turbidity sensor of the moored instrument was situated approximately 400 mm above the seabed and was approximately 0.8 m below the water surface, subject to wave and tidal action. The turbidity sensor of the roving instrument was held at a typical depth of 0.5 m below the water surface with the turbidity sensor facing away from the persons body projecting into the discharge plume. The centreline of the turbidity plume at each distance mark was estimated by eye and the instrument was positioned accordingly for 2-2.5 minute periods.

At the Gold Coast Seaway sand by-passing jetty, one of the two instruments was moored by weighting it and suspending it by rope from the jetty structure. The roving instrument was positioned using an outboard powered inflatable surf rescue boat. Figure 3 illustrates the location of instruments at the sand by-passing jetty. The roving instrument turbidity sensor was positioned at a depth of 0.5 m below the water surface with the sensor facing away from the boat. At each distance mark, the position of the plume centreline was estimated by eye and the roving instrument was immersed for a nominal 5 minute period.

2.2 Current Measurement

Combined water level and current velocities were recorded using an InterOcean S4 electromagnetic current meter suspended on a taught line mooring immediately adjacent to each turbidity measurement

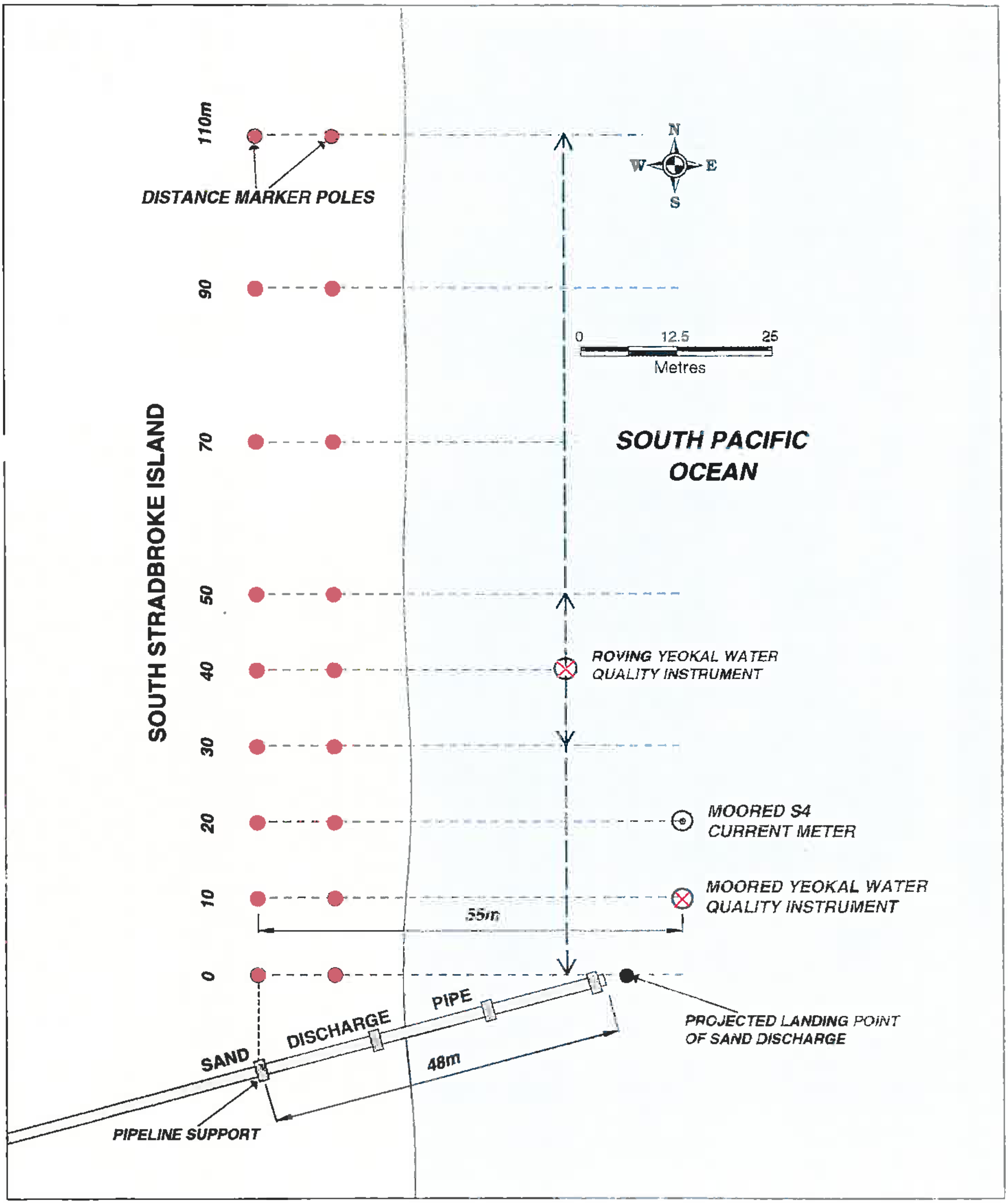


Figure 2
The Turbidity Measurement Site - South Stradbroke Island

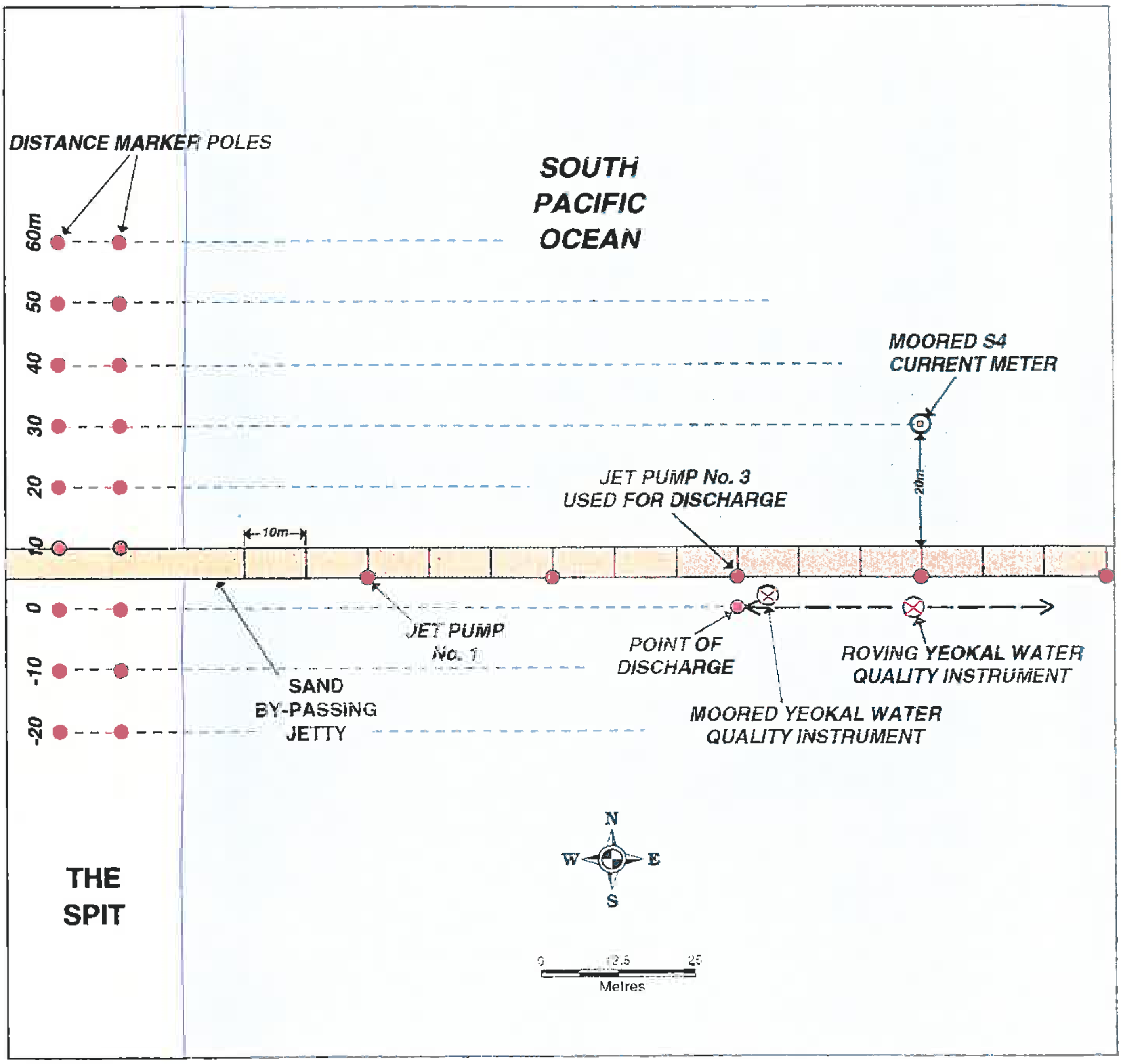


Figure 3
The Turbidity Measurement Site - Gold Coast Seaway Sand Bypassing Jetty

site. At each site, data were recorded as one minute averages (of 120 half second samples) every six minutes of the deployment term.

In order to avoid the spurious effects of large metallic structures on the electromagnetic current recordings it was necessary to moor the current meter a minimum distance of 10 m from the steel reinforced supporting piles of the sand by-passing pipeline at South Stradbroke Island and the sand by-passing jetty at the Spit (refer to Figures 2 and 3).

2.3 Measurement Conditions at South Stradbroke Island

Turbidity measurements were undertaken at South Stradbroke Island adjoining the sand by-passing discharge over two days (21 and 22 August 1996). These dates were selected following liaison with the Department of Transport so as to fit within the maintenance schedule for the plant and also allow measurements to take place on the flooding tide towards high water (rather than on an ebbing tide or at low water when other turbidity influences can occur).

The turbidity measurements conducted on 21 August 1996 were marred by the inconsistent operation of the roving YEOKAL submersible data logger. As a consequence, the roving turbidity measurements were repeated under similar conditions on the 22 August 1996.

On 21 August 1996, weather conditions were fine with light offshore winds in the morning. In the afternoon the wind changed direction to become a light north-easterly sea breeze. There was a northerly longshore current at the measurement site resulting from a moderate south-easterly swell. Depending upon prevailing swell conditions, breaking waves were occurring at distances up to 80 m seaward of the end of the sand discharge pipe. On the following day, the swell conditions had moderated slightly although there was still a defined northerly longshore current.

Records of the predicted tides, winds, wave and current measurements and observations for 21 and 22 August 1996 are summarised in Appendix A.

On 21 August 1996, background turbidity measurements (ie. those collected prior to operation of the sand by-passing plant) were collected soon after 10:00 am using both moored and roving instruments. A nominal recording interval of 2-2.5 minutes (with measurements at a sampling rate of 0.5Hz) was used for comparison of the background data between each instrument and subsequently for all roving measurements at South Stradbroke Island. Water samples were also collected for laboratory analysis of the suspended solids concentration at this time.

Roving turbidity plume measurements were begun at 11:30 am, approximately 20 minutes after the request to start the plant was given and were continued through until approximately 12:40 pm. The sand by-passing plant has an initial priming and clear water flushing time of approximately ten minutes prior to the delivery of sand to the beach at South Stradbroke Island. After this time, the density of the pumped sand slurry continues to increase to steady state for a further few minutes.

Between 11:10 am and 12:30 pm a series of water samples were collected for suspended solids analysis. Samples were collected from the centreline of the plume at distances of 1, 10, 20, 30, 40 and 50 m from the point of discharge.

Repeat sets of background and plume water samples were collected on the following day for suspended solids analysis. On 22 August 1996, background turbidities were measured and water samples were collected between 11:50 am and 12:05 pm. The pumping station was started at 12:20 pm and sand was observed at the discharge pipe at South Stradbroke Island at 12:30 pm. Two series of roving turbidity measurements and water samples were collected within the centreline of the plume beginning at 12:55 and were continued through until 2:35 pm.

On both days, the direction of plume travel was northwards along the beach, although rather than remaining parallel with the beach, the plume was swept closer to the shore as it progressed northward. This tended to make reliable quantification of the turbidity from the discharge plume quite difficult. This was because the further the distance from the discharge plume, the shallower the water became and the more influence there was from the turbidity associated with entrained sand particles resulting from breaking waves in the nearshore area.

2.4 Measurement Conditions at the Gold Coast Seaway Sand By-passing Jetty

Turbidity measurements were conducted about jet pump no. 3 of the sand by-passing jetty on the flooding tide on 17 September 1996.

The weather on this date was fine with light northerly winds in the early morning which increased in strength during the day. Sea swell conditions were small and from the east. Despite an increasing northerly wind, the measurement site was partially protected from the wind driven chop by the southern training wall of the Seaway.

The current conditions at the sand by-passing jetty were considerably different to those encountered at South Stradbroke Island. The current at the jetty on 17 September 1996 was an easterly rip current (ie. water moving offshore, parallel to the jetty) and as a consequence the distance markers set up on the beach were of little use in identifying the distance of travel of the plume. Fortunately, the support spans on the jetty are constructed at 10 m intervals and these were used as the distance markers for the measurement of turbidity. The lateral movement of the plume was able to be quantified by the distance marker poles on the beach.

The predicted tide, wind, wave and current measurements for 17 September 1996 are summarised in Appendix B.

Background turbidity measurements were begun at 8:30 am using the moored submersible data logger situated at a location 5 m distant from the predicted point of discharge and a depth of 1.5 m. (It was necessary to moor the instrument at this depth to prevent aeration and disturbance from breaking waves obscuring the turbidity sensor.) Comparative background measurements were also collected from the roving instrument at the same location for a five minute period between 8:55 and 9:00 am. Two background water samples were collected for suspended solids analysis prior to the start of the pumping station at 9:20 am.

Although the pumping station was initially started at 9:20 am, a blockage of jet pump no. 3, prevented plume discharge measurements until the blockage was cleared by Department of Transport personnel. At 9:45 am the jet pump blockage was cleared and sand began to discharge directly from the disconnected jet pump pipe and cascade to the water below.

Between 9:50 and 10:00 am a series of water samples were collected for suspended solids analysis. The water samples were collected along the centreline of the plume at distances of 1, 10, 20, 30, 40 and 50 m from the point of discharge at a depth of 0.5 m.

Between 10:05 and 10:50 am turbidity measurements were also collected at a depth of 0.5 m along the plume centreline at the above distances. At each distance the plume centreline was estimated by eye as being the point of maximum turbidity. There was a significant lateral variation in the track of the plume, which varied from one side of the jetty to the other during the course of measurements.

2.5 Plume Modelling

Following the field measurement of turbidity and collection and analysis of water samples for suspended solids concentrations at the Gold Coast Seaway, a gaussian plume dispersion model (SSPLUME) was calibrated to reproduce the measured suspended solids concentration for each of the discharge conditions described in Section 1.2.

3 Results

3.1 Results For Discharge At High Water Mark - South Stradbroke Island

The turbidity measurements collected by the moored instrument on 21 August 1996 are illustrated in Figure 4.

The results of the turbidity measurements collected by the roving instrument used on 21 August 1996 and 22 August 1996 and the analysis of suspended solids samples are summarised in Table 1.

Table 3.1 Turbidity and Suspended Solids Records from South Stradbroke Island (21 - 22/8/96)

Location	Turbidity (NTU)		Suspended Solids Concentration (mg/L)		
	Range	Average	Range	Average	Number of Samples
Background	5 - >230*	30	26-90	55	4
At discharge	>230	>230	-	40,000	1
1 m from discharge	>230	>230	1,300 - 3,200	2,070	3
10 m from discharge	10 ->230	230	500 - 1,900	940	3
20 m from discharge	8 ->230	150	300 - 820	520	3
30 m from discharge	5 ->230	130	77 - 1700	830	3
40 m from discharge	5 ->230	125	110 - 900	380	3
50 m from discharge	5 ->230	100	70 - 810	336	3
70 m from discharge	5 ->230	100	-	-	-

* Limit of linear calibration

A plot of the individual suspended solids profiles with distance away from the sand discharge is shown in Figure 5.

The photographic record of the turbidity plume generated by the discharge at South Stradbroke Island is illustrated in Plates 1-7. The visible limits of the plume generated on 21 August 1996 are shown in Figure 6.

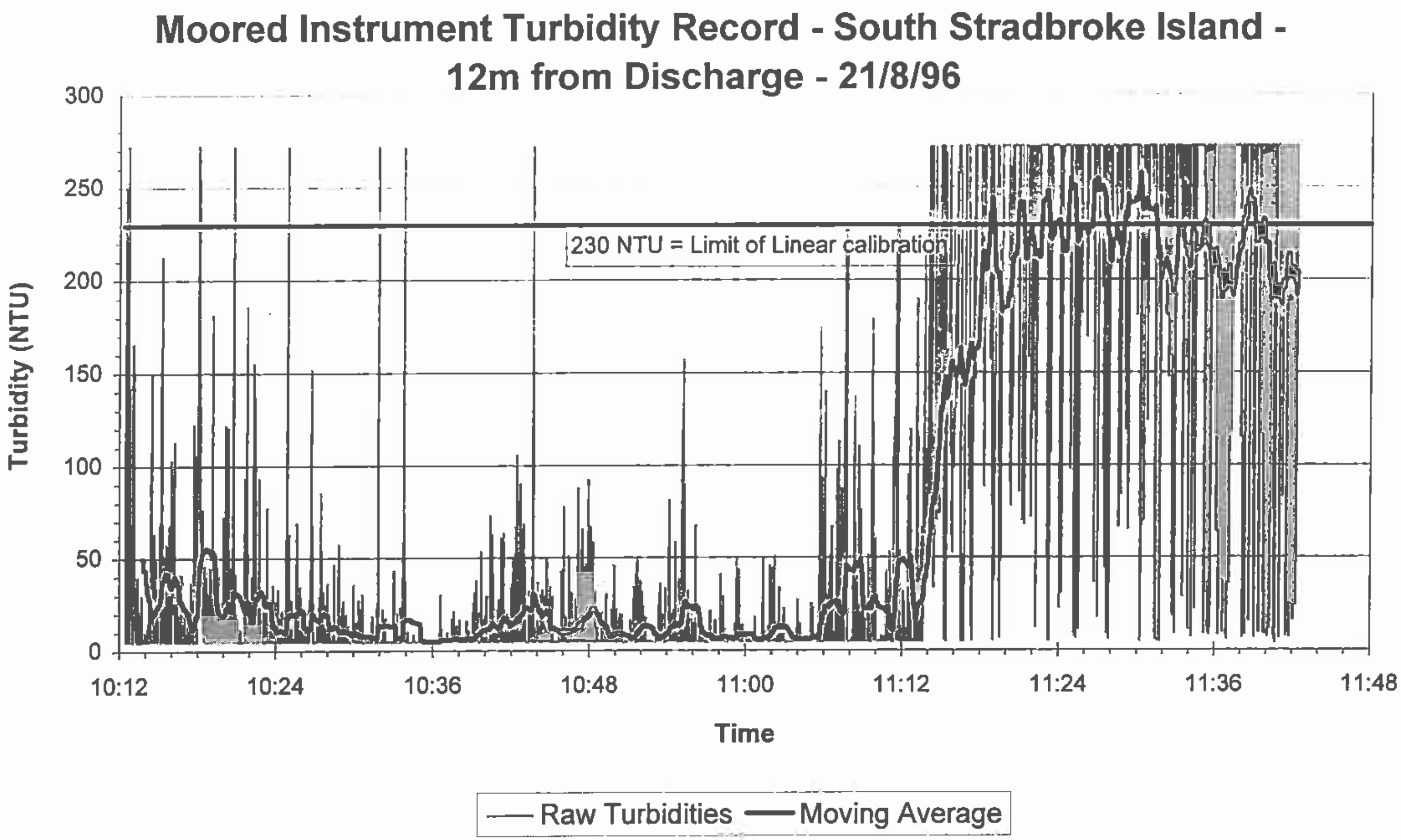


Figure 4
Moored Instrument Turbidity Record - South Stradbroke Island

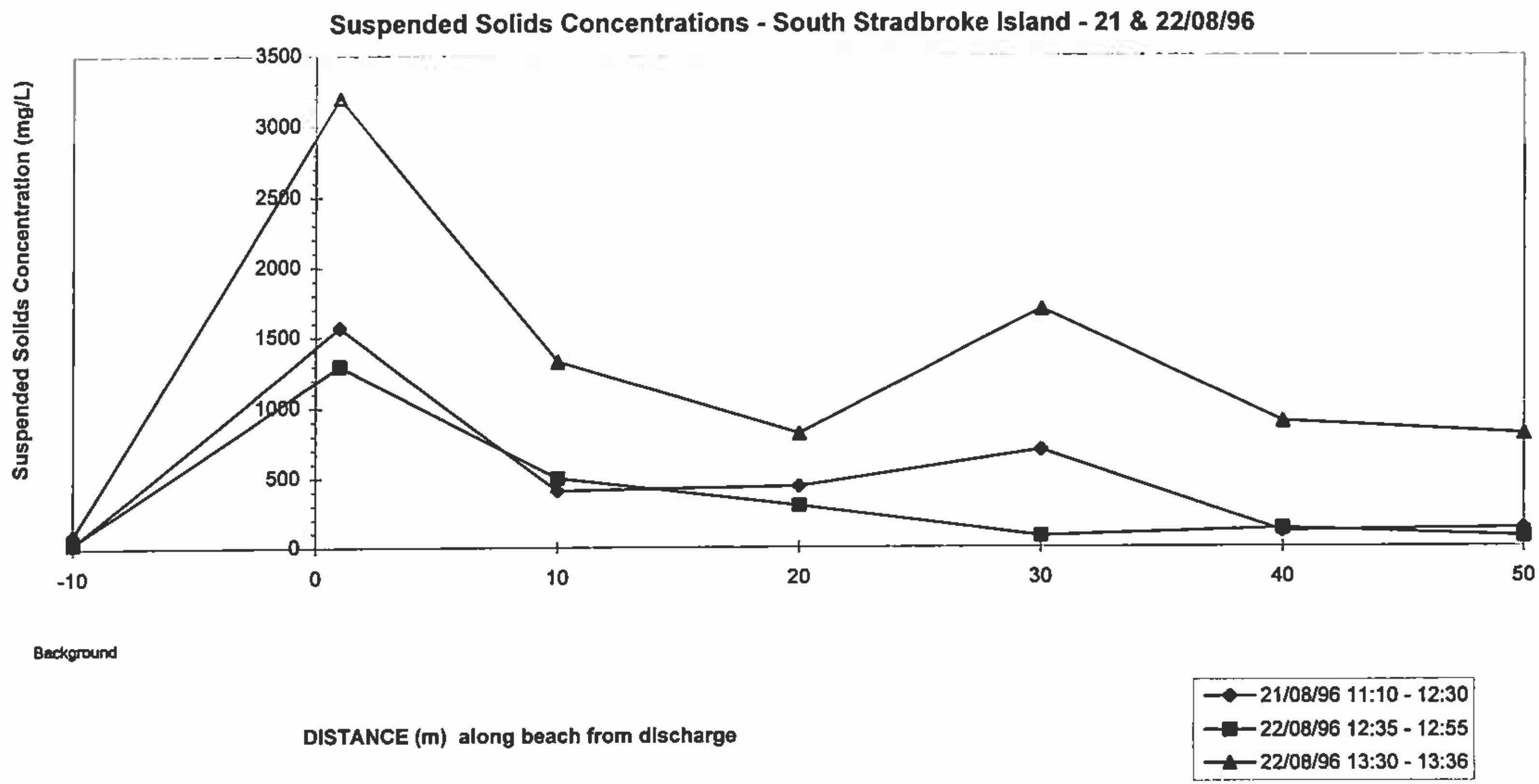


Figure 5
Suspended Soilds Concentrations - South Stradbroke Island

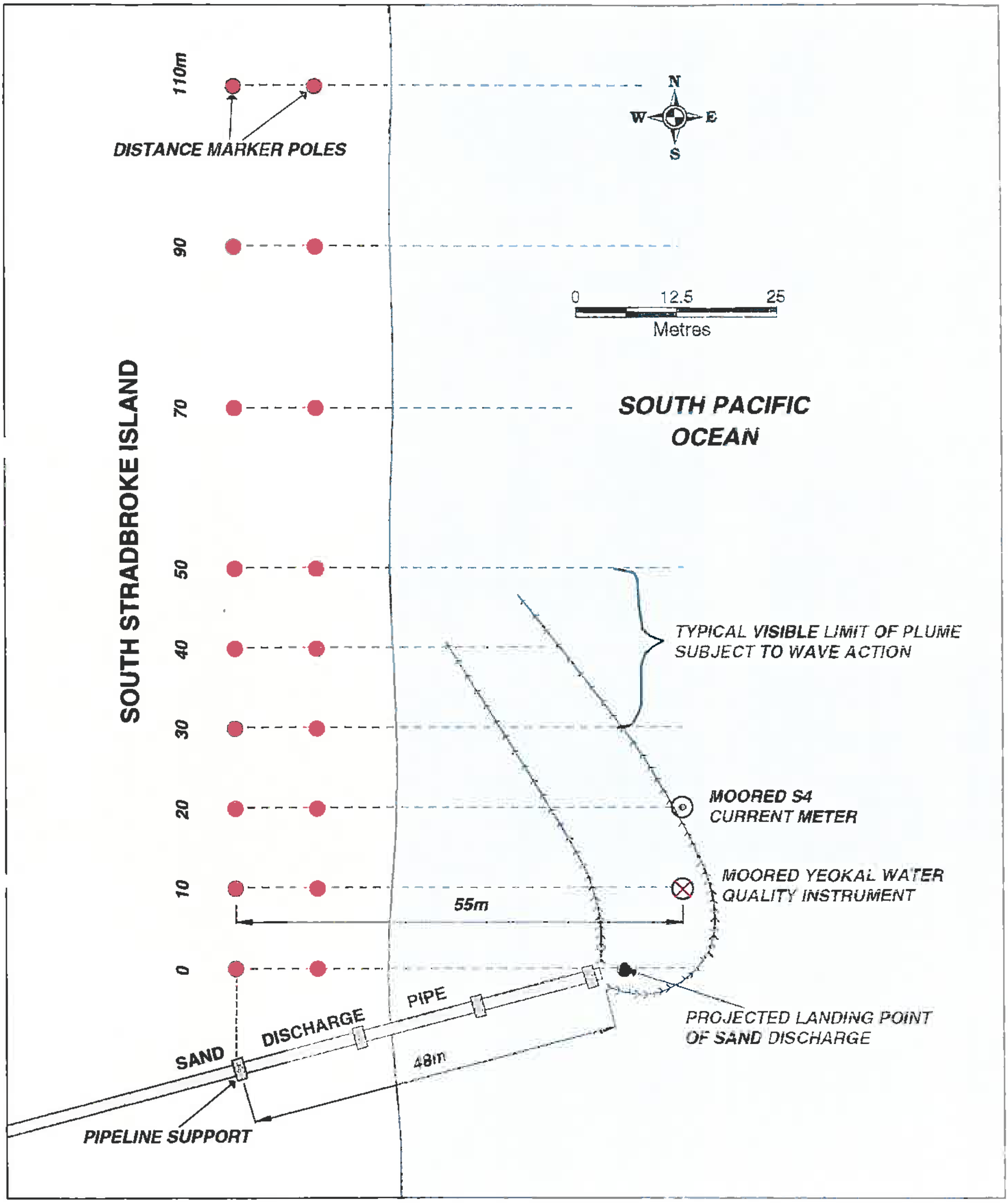


Figure 6
The Turbidity Plume - South Stradbroke Island

Plates 1 - 7 : Sand Discharge Turbidity Plumes. South Stradbroke Island, 21-22/8/96.

Plate 1 : Aerial view of the Gold Coast Seaway and the sand by-passing equipment consisting of the jetty and jet pumps at the Spit and discharge pipe (in operation) at South Stradbroke Island.

Plate 2 : The sand discharge at South Stradbroke Island showing the plume drifting northwards past the marker floats of the moored water quality instrument and current meter. One of the distance marker poles is shown in foreground.

Plate 3 : As above.

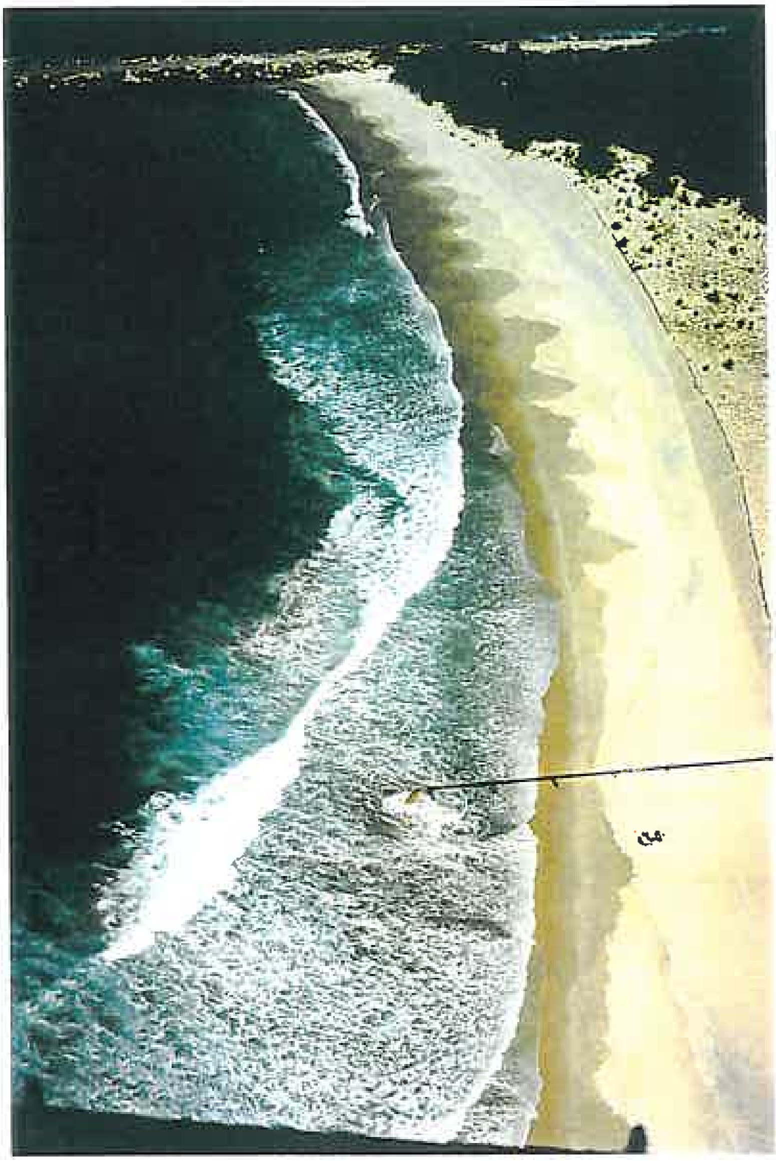


Plate 4 : Aerial view of the turbidity plume drifting north of the sand discharge. Note also the substantial turbidity generated by the breaking waves.

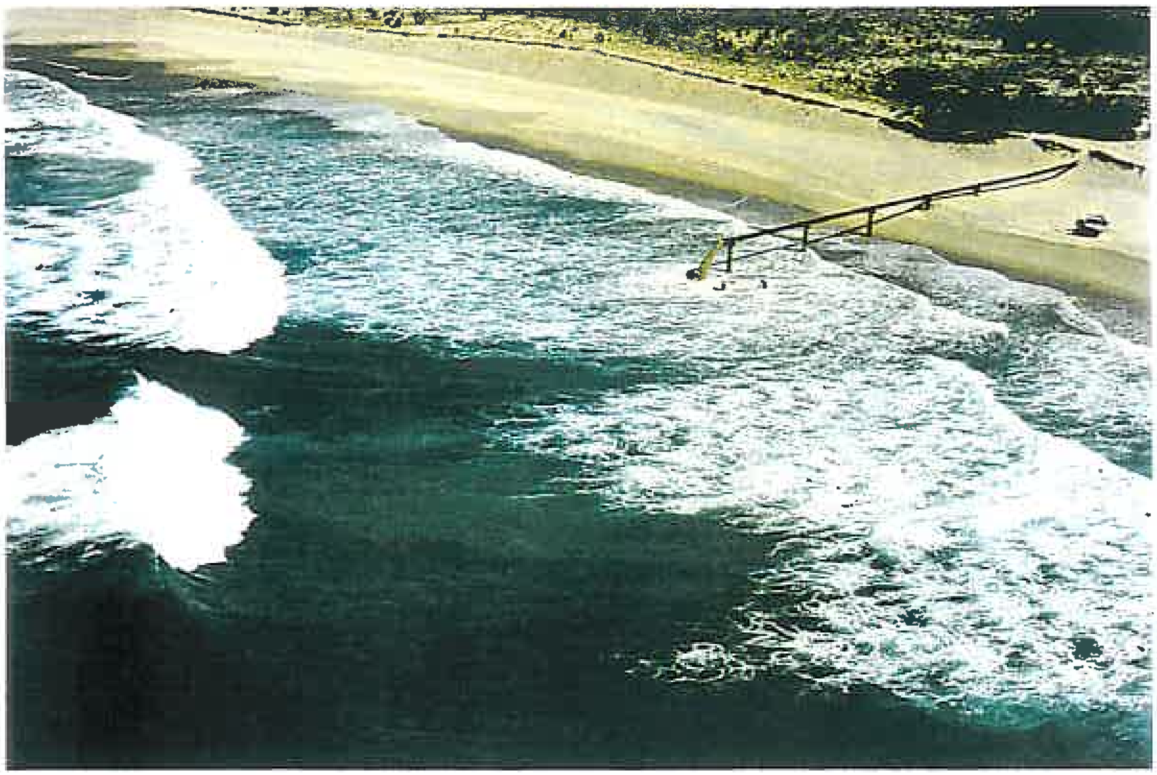


Plate 5 : Aerial view of the turbidity plume generated by the discharge, showing personnel positioning the roving water quality instrument at the discharge.

Plate 6 : As above.

Plate 7 : Corresponding turbidity conditions adjoining the sand by-passing jetty at the Spit on the 22nd August, 1996. Note the large amount of wave induced turbidity.

3.2 Results For Discharge To The Sub-tidal Zone - Sand By-passing Jetty

The turbidity measurements collected by the instrument moored from the sand by-passing jetty are illustrated in Figure 7.

The roving turbidity measurements and suspended solids concentrations for water samples collected from around the sand by-passing jetty are shown in Table 2.

Photographs of the turbidity plume generated at jet pump no. 3 are shown in Plates 8-12. The visible limits of the plume are illustrated in Figure 8.

Table 3.2 Turbidity and Suspended Solids records from the Gold Coast Seaway Sand By-passing Jetty (17/9/96)

Location	Turbidity (NTU) at 0.5 m depth		Suspended Solids (mg/L) at 0.5 m depth
	Range	Average	
Background	3-8	5	3.3, 19
1 m from discharge	40 - 230*	220	230
5 m from discharge	50 - 230	190	-
10 m from discharge	50 - 75	75	24
20 m from discharge	4 - 90	30	28
30 m from discharge	4 - 13	6	12
40 m from discharge	4 - 11	7	8.6
50 m from discharge	4 - 8	5	7.1

- Limit of linear calibration

3.3 Plume Modelling Results

The results of the gaussian plume model calibration runs for each of the discharge conditions are illustrated and described in Appendix C.

4 Discussion

4.1 Discharge At High Water Mark - South Stradbroke Island

The visual identification and the measurement of turbidity associated with the discharge of sand at high water mark from the Gold Coast Seaway sand by-passing station was only practical for a maximum distance of approximately 50 m from the discharge pipe on the measurement dates.

On each of these days, the effective turbidity created by the breaking of swell waves nearshore masked or exceeded the turbidity of the discharge beyond an approximate distance of 50 m, as is shown in the photographic record. The swell conditions encountered on the measurement dates were not extreme but typical of those occurring on the Gold Coast.

The confinement of the turbid plume within a distance of 50 m was assisted by the onshore sweep of the breaking waves which effectively brought the plume closer to shore, the further the distance from the point of discharge.

Closer to shore, any residual turbidity from the plume was overwhelmed by the turbidity generated by the breaking waves. This characteristic made the measurement of turbidity within the plume quite difficult to discern from that induced by the ambient wave climate. It is also the reason that the average turbidities measured at distances of 50 and 70 m were higher than the background turbidities, which were measured in deeper water adjoining the point of discharge.

The measurement of turbidity was effectively undertaken using the YEOKAL submersible data loggers set to record turbidity at a rapid rate (0.5Hz). This allowed the measurements to accurately reflect the quickly time varying nature of the background and within plume turbidity levels within the near-shore zone. However, the limitation of the turbidity sensors to an approximate maximum linear response of 230 NTU restricted the usefulness of the instruments in the immediate vicinity of the discharge.

The collection and analysis of water samples for suspended solids concentrations was found to be less informative since it was impossible to effectively account for rapid variation in turbidity (and thus the suspended solids concentration encountered) without the collection and analysis of many water samples.

The water turbidity in close proximity (12 m) to the discharge is illustrated in Figure 4, before and after the start-up and operation of the plant on 21 August 1996. Prior to start-up, the background water turbidities were quite variable but typically were in the range 4 - 50 NTU. After plant start-up, there is an approximate 10 minute lag before sand is pumped to the discharge beach at South Stradbroke Island. During this time the delivery pipe is primed with water and then gradually the density of the pumped sand/water slurry builds to a steady-state condition. This situation is clearly reflected in the measurements of turbidity in Figure 4 which steadily rise over the 10 minute period following start-up of the plant at 11:08 am, 21 August 1996. The first rises were in response to the pumping and priming of the pipeline with water only, which resulted in the localised bed disturbance of sand particles at the point of discharge. The subsequent steady rise in turbidity was due to the increasing density of the sand/water mixture being discharged. At steady-state, the average measured turbidities were consistently at the limit of linear calibration (approximately 230 NTU) for the turbidity sensor of the data logger.

There was, however, a significant variation within the range of turbidities recorded after steady-state operation of the discharge. During this time turbidities ranged from 100 NTU to well above the limit of linear calibration. After shut-down of the pumping station at 12.37pm the 21st August, 1996 the time for effective settlement and disappearance of the plume was estimated from the beach at approximately 2 minutes.

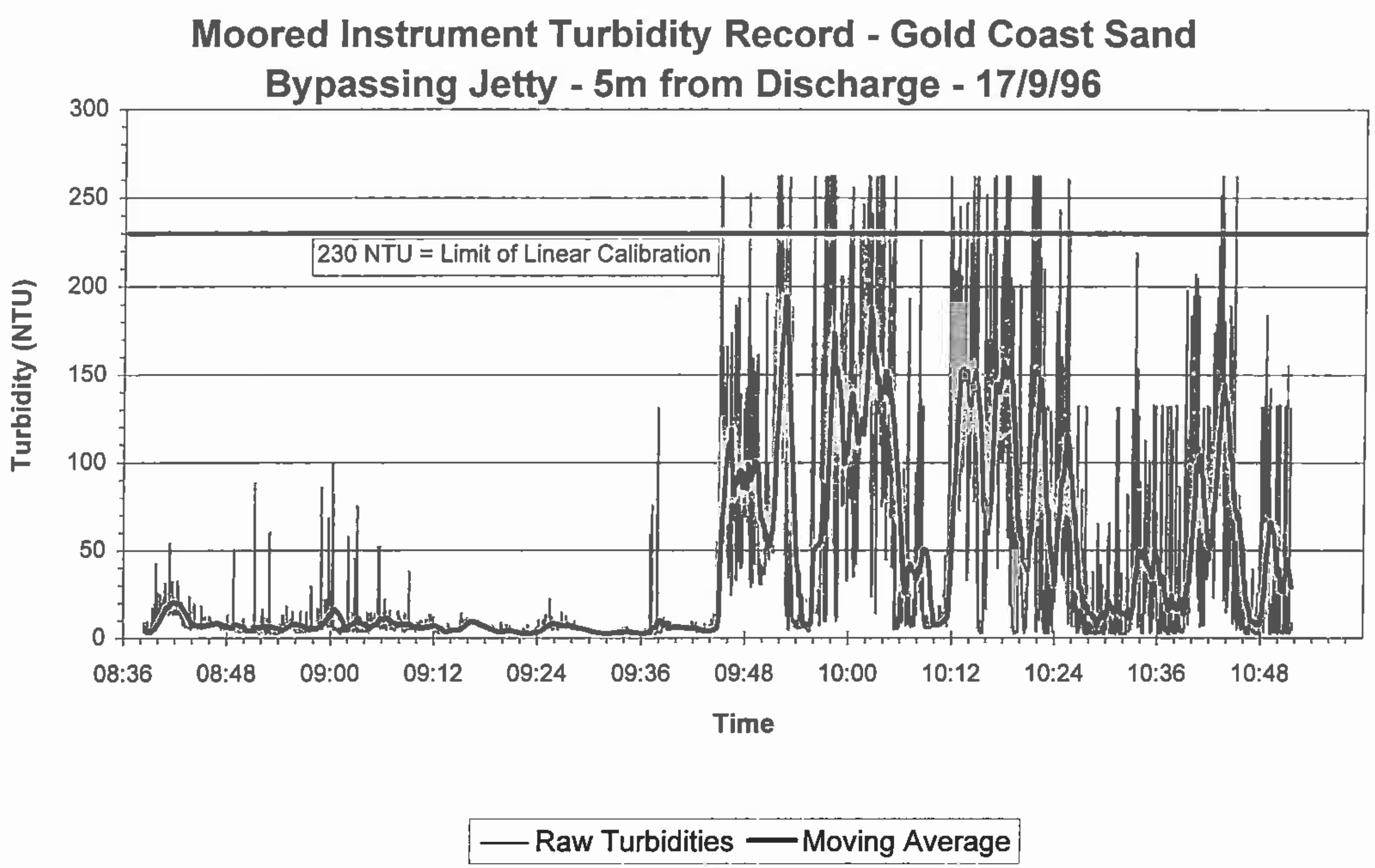


Figure 7
Moored Instrument Turbidity Record - Gold Coast Sand Bypassing Jetty

Plates 8-12 : **Sand discharge turbidity plume, Sand By-Passing Jetty, The Spit, 17th September, 1996.**

Plate 8 : Aerial view of the turbid plume from jet pump no. 3. The distance of travel of the plume is illustrated by the 10m separation between the supporting piles of the jetty.

Plate 9 : As above.

Plate 10 : As above. The closer view shows a part of the plume moving seaward below the northern side of the jetty.

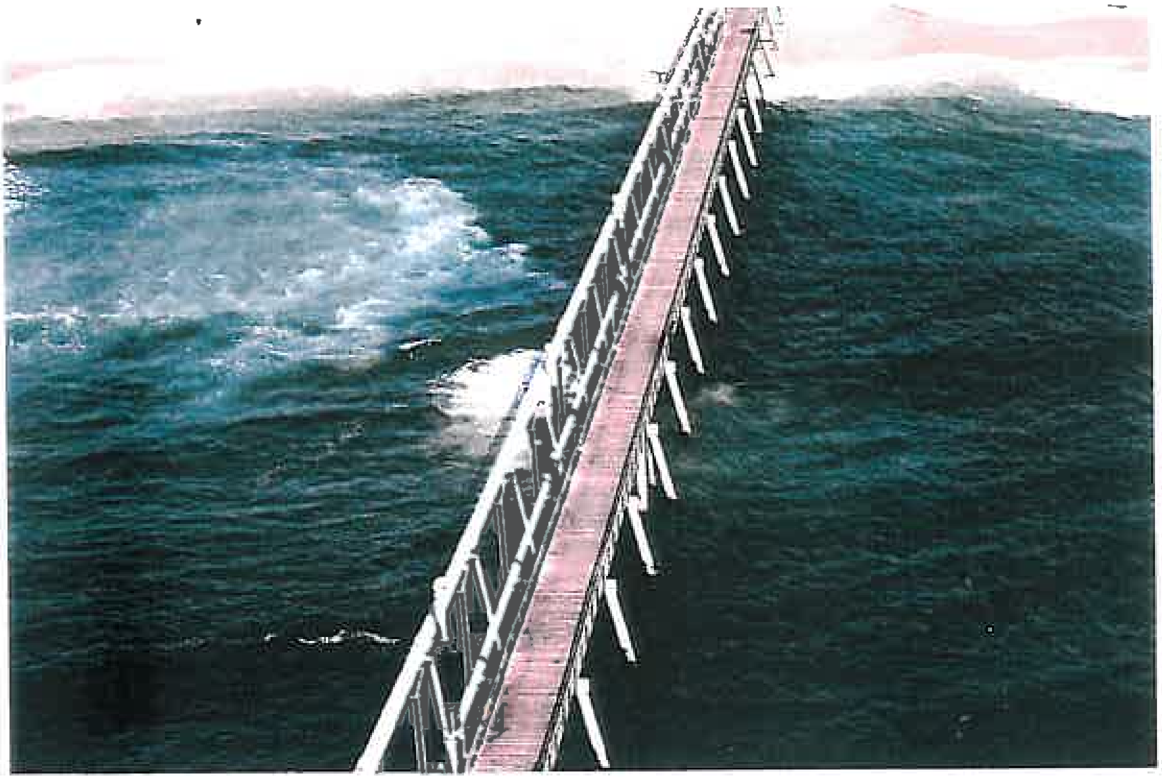


Plate 11 : As above.

Plate 12 : Aerial view of plume, also showing marker float position of moored current meter.

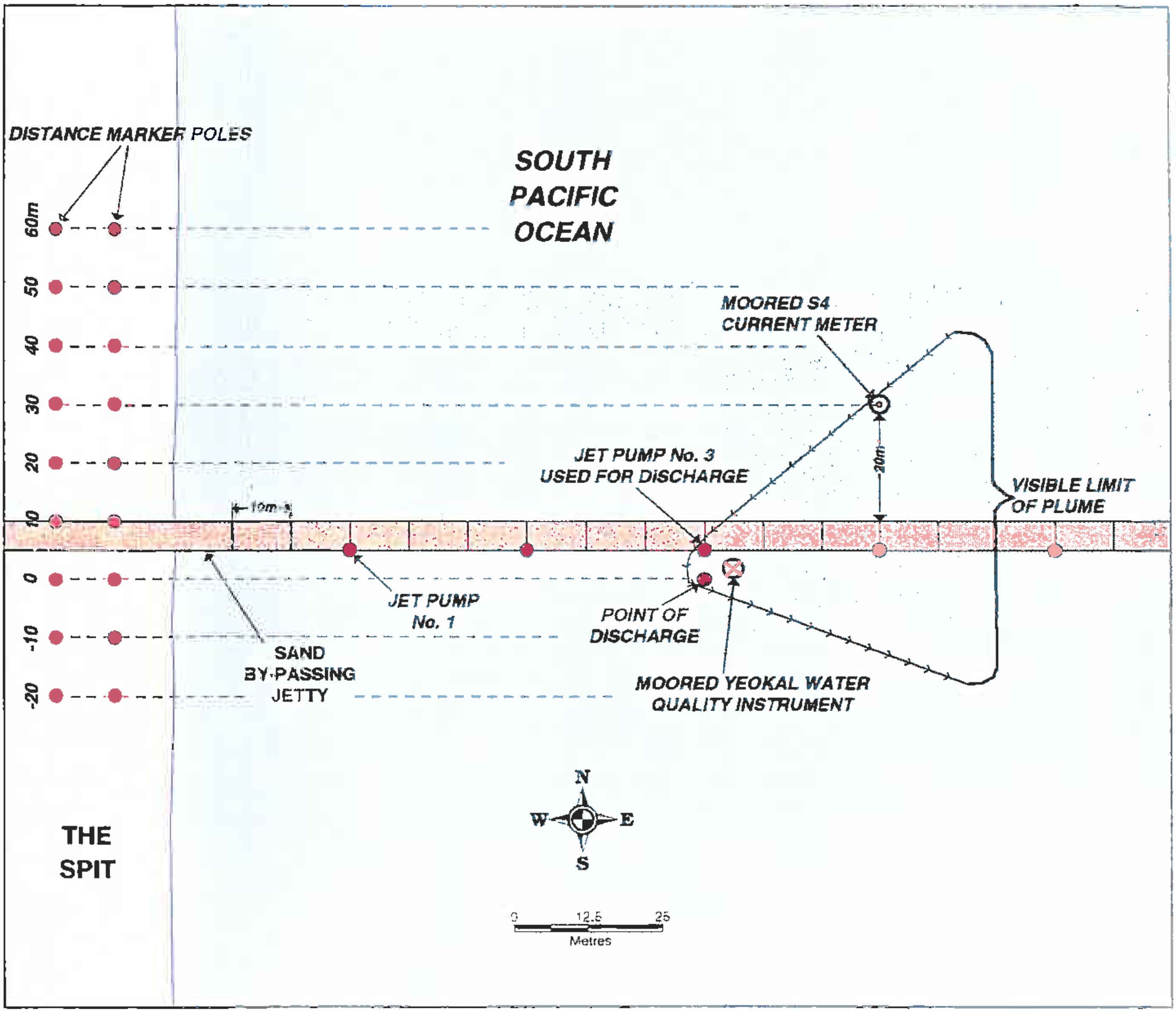


Figure 8
The Turbidity Plume - Gold Coast Seaway Sand Bypassing Jetty

The longitudinal profiles of suspended solids concentrations along the centreline of plume shown in Figure 5 are an instantaneous snapshot of the rapidly varying turbidity conditions. The large variations in the measured suspended solids concentrations are evidence of the constantly changing turbidity of the water both within the plume and generally within the surf zone. The nature of the suspended solids collected in all background and plume water samples consisted was beach sand.

As shown, there was a general trend of decreasing suspended solids concentrations with distance away from the discharge, though this trend was not always consistent. Additionally, the suspended solids concentrations seldom decreased to the range of background concentrations primarily for reasons discussed above, whereby measurements and samples within the centreline of the plume at increasing distances were conducted in shallower water and were therefore subject to more breaking wave action and turbulence.
Figure 6 illustrates the general pattern of the turbid plume and its progressive shoreward movement into shallower water where, due to the wave action, any evidence of turbidity due to the plume was overwhelmed by turbidity associated with entrained sand particles from breaking waves.

4.2 Discharge To The Sub-tidal Zone - Sand By-passing Jetty

The turbidity measurements and suspended solids analysis of water samples collected about jet pump no. 3 at the sand by-passing jetty indicate that the turbidity plume from sand slurry discharged into sub-tidal water depths was also contained within a distance of 50 m. At this distance from the discharge, the plume was no longer visible from the water surface and the range of turbidity and suspended solids measurements were within the lower range of background measurements made prior to the operation of the jet pump.

An approximate reduction of 85% of the turbidity and suspended solids concentrations resulting from the plume was effected within the first 20 m from the discharge.

At the conclusion of measurements at the jetty, jet pump no. 3 was switched off and the time for the effective settlement and disappearance of the plume was observed from the jetty. The turbid plume was no longer visible three minutes after the shutdown of the jet pump.

The turbidity record shown in Figure 7 represents the transition from background conditions, prior to operation of the jet pump at 9:45, 17 August 1996 to those occurring at the edge of the turbid plume generated by pumping.

The background turbidities were typically in the range of 4-20 NTU. Following operation of the jet pump, the turbidities showed a cyclical variation averaging between 50 and 200 NTU. Cyclical periods of high turbidity correspond with the situation of the turbidity sensor within the plume generated by the jet pump. Periods of low turbidity correspond with the brief movement of the turbid plume away from the moored instrument due to small changes in the current direction at the jet pump site.

These cyclical changes in the current direction resulted in a considerable lateral broadening of the turbidity plume as shown in plan in Figure 8. The turbidity within the bounds of the plume was not consistent but rather consisted of patches of turbidity. As a consequence, turbidity measurements at a given distance from the discharge had to focus on these patches of higher turbidity rather than on a defined plume centreline.

5 Summary

Background water turbidities in the nearshore and surf zone can be highly variable and are primarily dependant upon the wave climate. Waves produce quickly time varying turbidity conditions resulting from the entrainment and subsequent settlement of the sand particles in the water column.

The visible and measurable turbidity plumes generated by sand by-pass discharges at the Gold Coast Seaway at high water mark and to sub-tidal waters were confined to distances of 50 m on the measurement dates. This occurred despite sizeable differences in the discharge flowrate at either measurement location.

The nature of the sand sediments and respective discharge conditions at either location (high water mark and sub-tidal water) resulted in a residual turbidity lasting approximately two-three minutes after the cessation of pumping/discharge operations.

APPENDIX A: Supplementary Data For 21 - 22 August 1996

Table A1 Predicted Tides - Gold Coast Seaway - 21-22 August, 1996

Date	Time	Water Level (m)*
21/8/96	0005	1.16
	0619	0.18
	1304	1.21
	1909	0.41
22/8/96	0102	1.06
	0713	0.21
	1415	1.23
	2031	0.42

* Datum of Predicted Levels is Lowest Astronomical Tide

Table A2 Rhodamine Dye Current Observations at Discharge Locations - 21-22 August, 1996

Date	Time	Estimated Current	
		Speed (m/s)	Direction (quadrant)
21 August 1996	0950	0.40	North
	1158	0.30	North
22 August 1996	1148	0.20	North
	1240	0.10	South
	1256	0.20	North

APPENDIX B: Supplementary Data For 17 September 1996

Table B1 Predicted Tides - Gold Coast Seaway - 17 September, 1996

Date	Time	Water Level (m)*
17/9/96	0422	0.07
	1054	1.34
	1702	0.21
	2300	1.17

* Datum of Predicted Levels is Lowest Astronomical Tide

Table B2 Rhodamine Dye Current Observations at Discharge Location - 17 September, 1996

Time	Estimated Current	
	Speed (m/s)	Direction (quadrant)
0822	0.35	East

APPENDIX C: Plume Modelling Results

A gaussian plume dispersion model (SSPLUME) was calibrated to reproduce the measured suspended solids concentrations at a depth of 0.5m occurring along the plume centreline for each of the discharge conditions described previously, viz

- surface discharge into shallow water at or near high water mark at South Stradbroke Island, and
- surface discharge into the surf zone (water depth of 3m) below the Gold Coast Seaway sand by-passing jetty (90m from shore).

The plume modelling results were then available for application to the prediction of plume behaviour for the Tweed sand by-passing system.

The model results are compared with the measured suspended solids concentrations (in g/L) at a water depth of 0.5m in Figures C.1 and C.2 for each of the discharge conditions. The observed discharge parameters are summarised in Table C.1.

Table C.1 Discharge Parameters

Observed Parameters	Discharge Condition						
	High Water Mark - South Stradbroke Island						Sub-Tidal Water - Sand By-passing Jetty
Depth of Water at Discharge	1m						3.5m
Mean Current Velocity	0.3m/s						0.35m/s
Mean Wave Height	1.75m						1.1m
Discharge Rate	200kg/s						30kg/s
Discharge Location	Water Surface						Water Surface
Particle Size Range (mm)	1.18	0.60	0.425	0.30	0.15	0.10	Same
Particle Size Occurrence (%)	0.5	1.5	10	62	25	1.0	Same

The model results for both discharge conditions indicate reasonable agreement with the measured suspended solids concentrations at distances beyond 10m from the discharge. It was difficult to accurately represent the sharp decline in the measured suspended solids concentration in the near field, that is within a distance of 10m. This was believed to be as a result of the physical geometry of the seabed which developed soon after the initiation of sand pumping at the discharge site as well as the secondary effects of seabed resuspension due to turbulence.

However, the modelling results beyond the near-field are considered to be of most importance for the prediction of plume behaviour for the Tweed sand by-passing system.

Figure C.1 Measured and Modelled Suspended Solids Concentrations at 0.5m Depth for the Discharge at High Water Mark - South Stradbroke Island

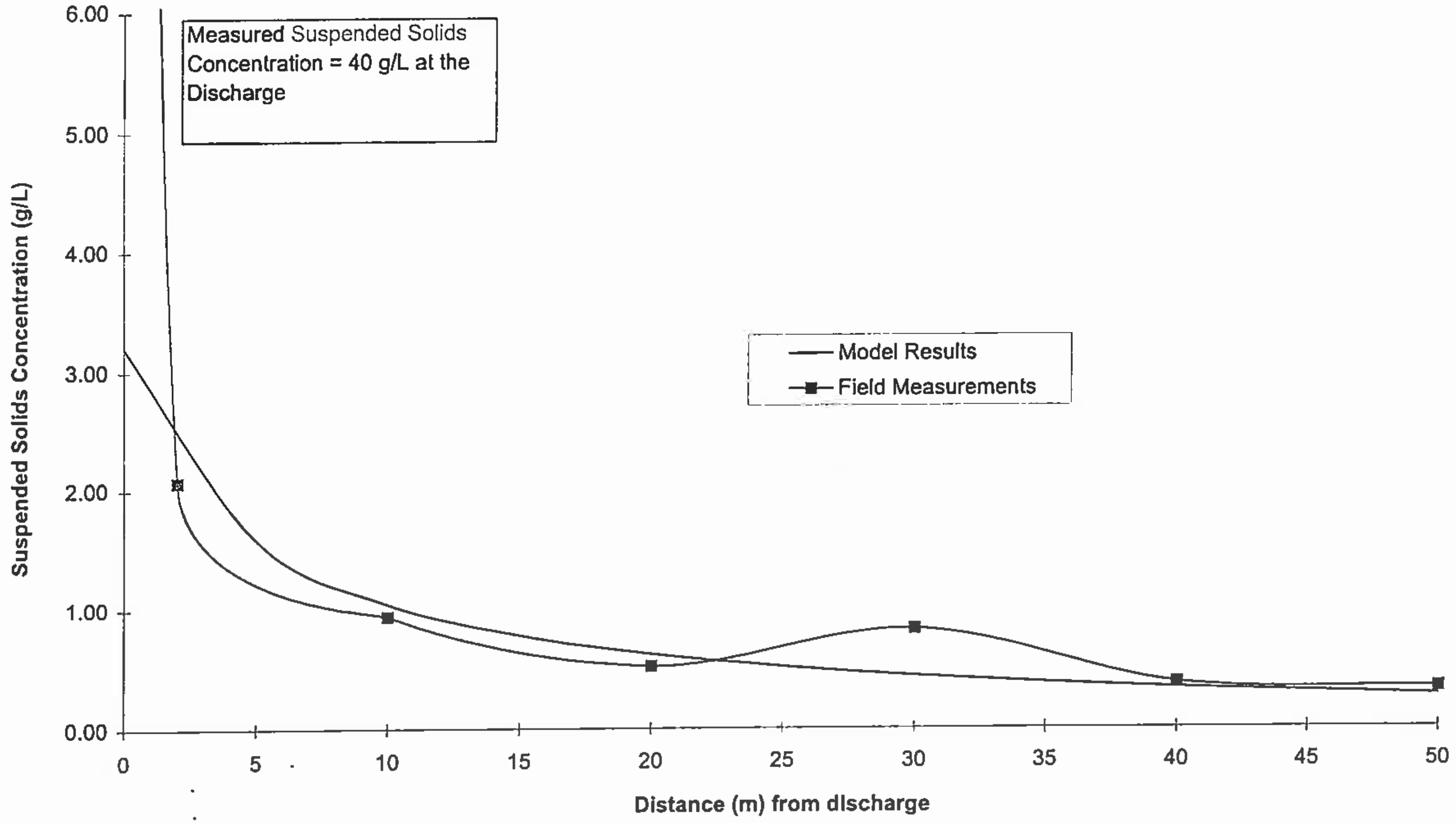
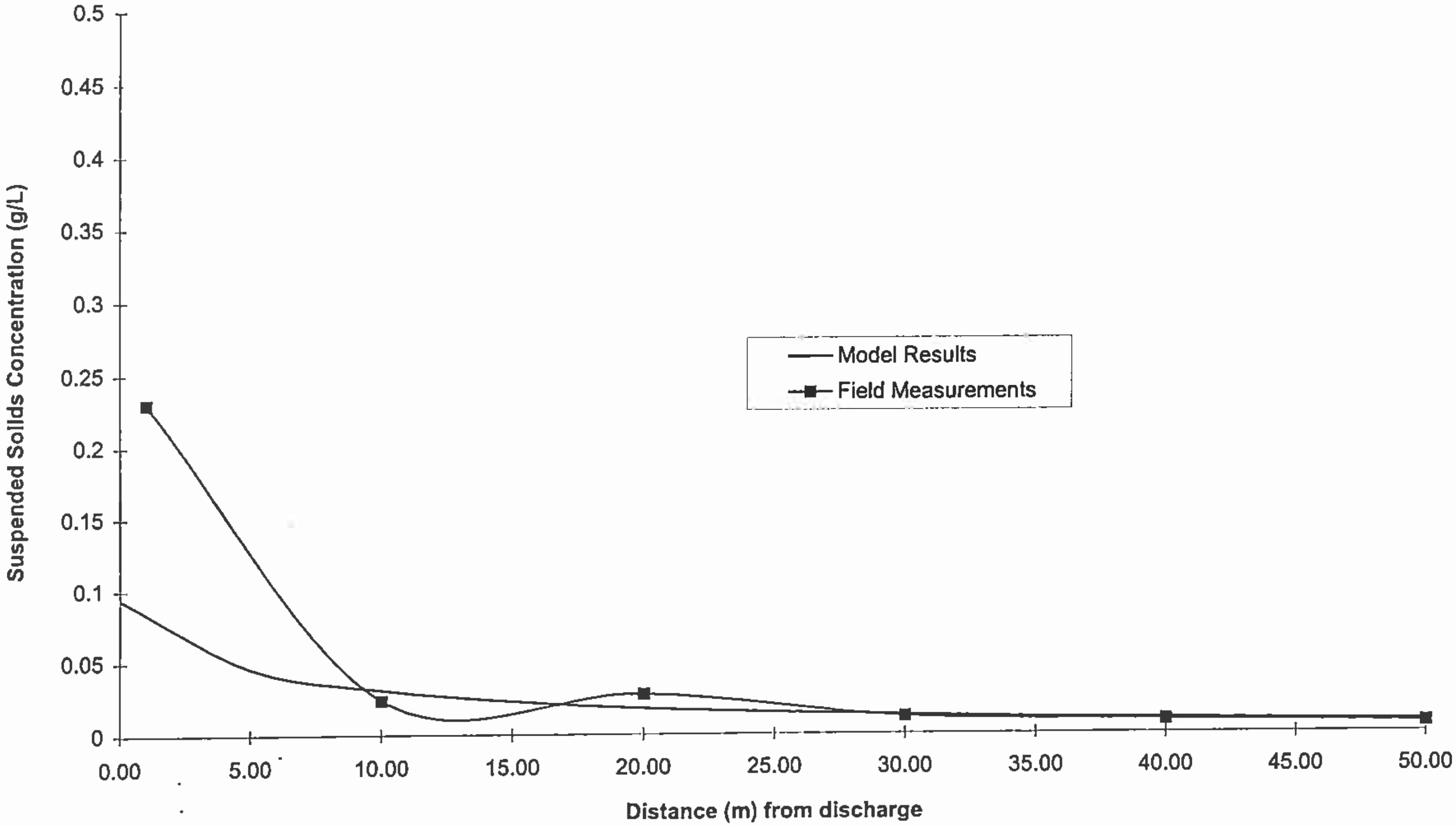
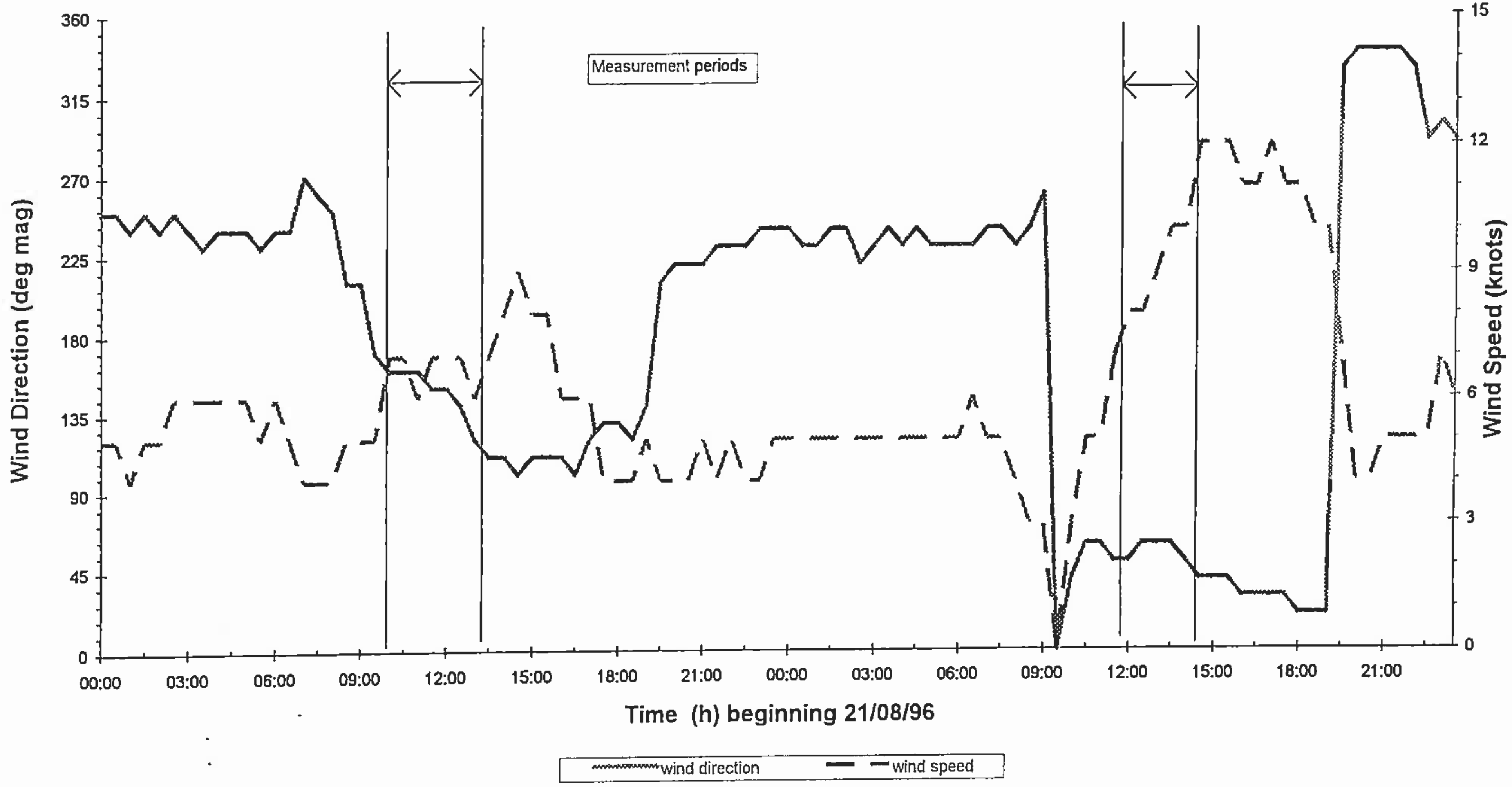
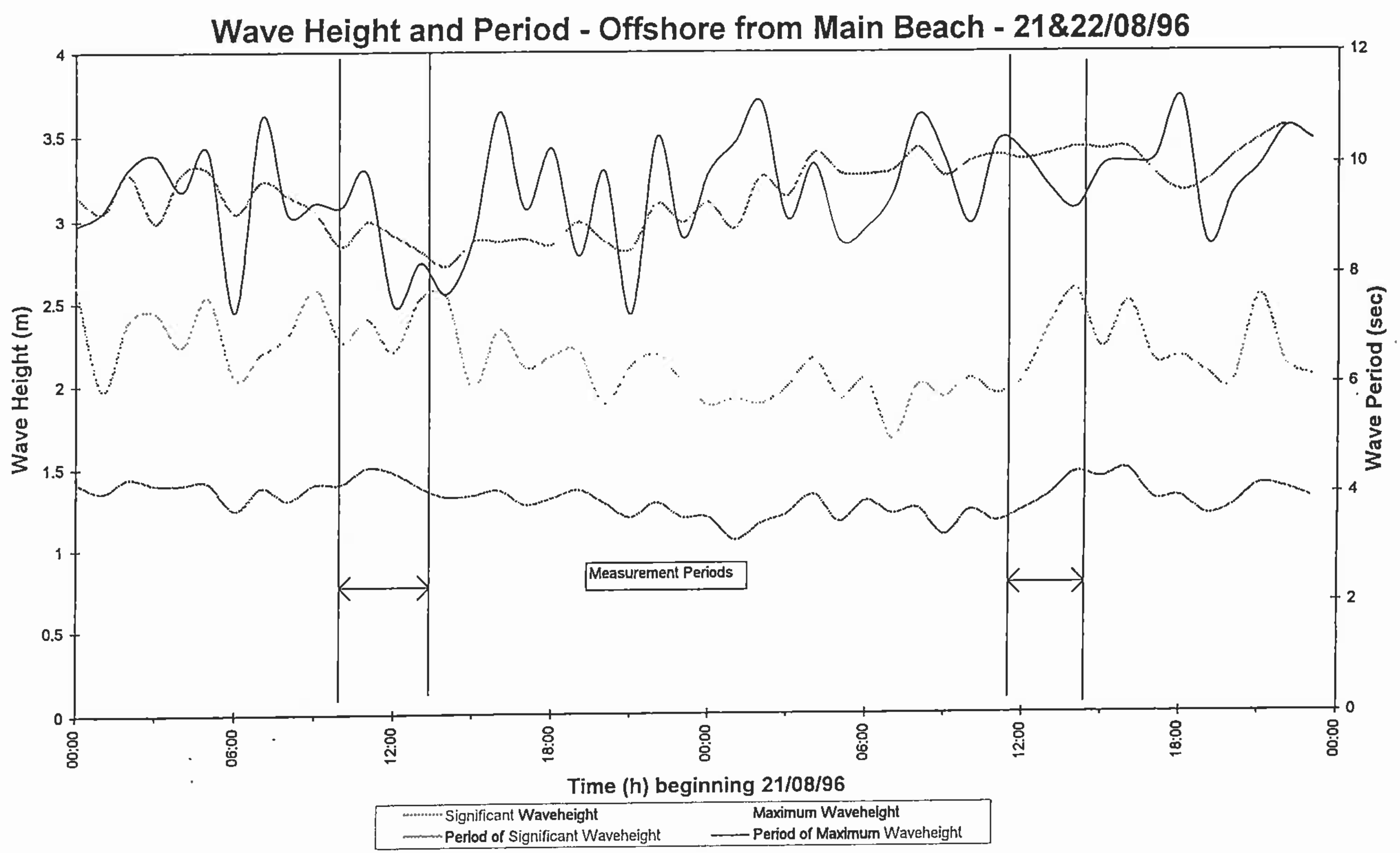


Figure C.2 Measured and Modelled Suspended Solids Concentrations at 0.5m Depth for the Discharge to the Sub -tidal Zone - Sand By-passing Jetty



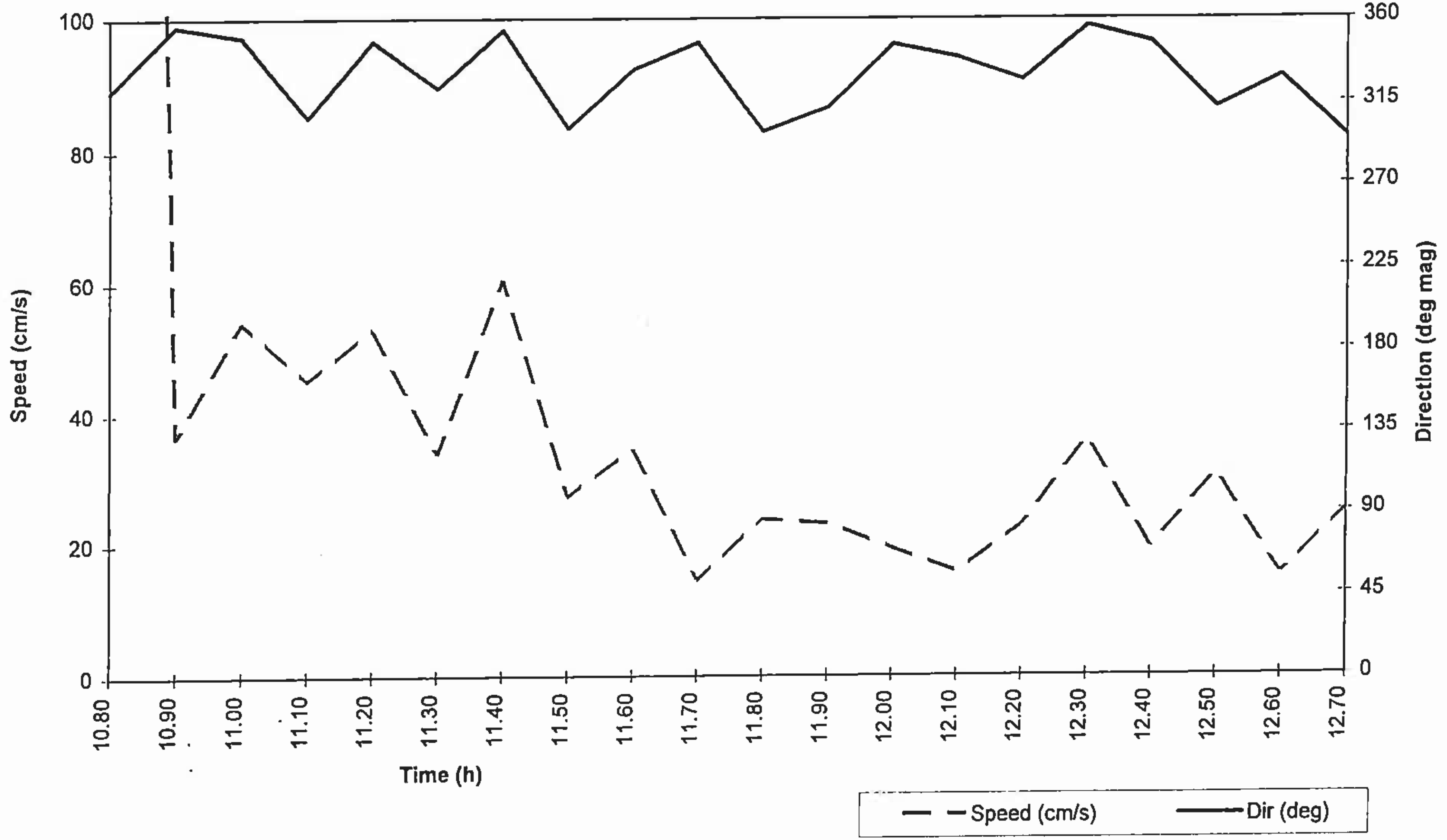
Wind Speed And Direction - Gold Coast Seaway - 21&22/08/96



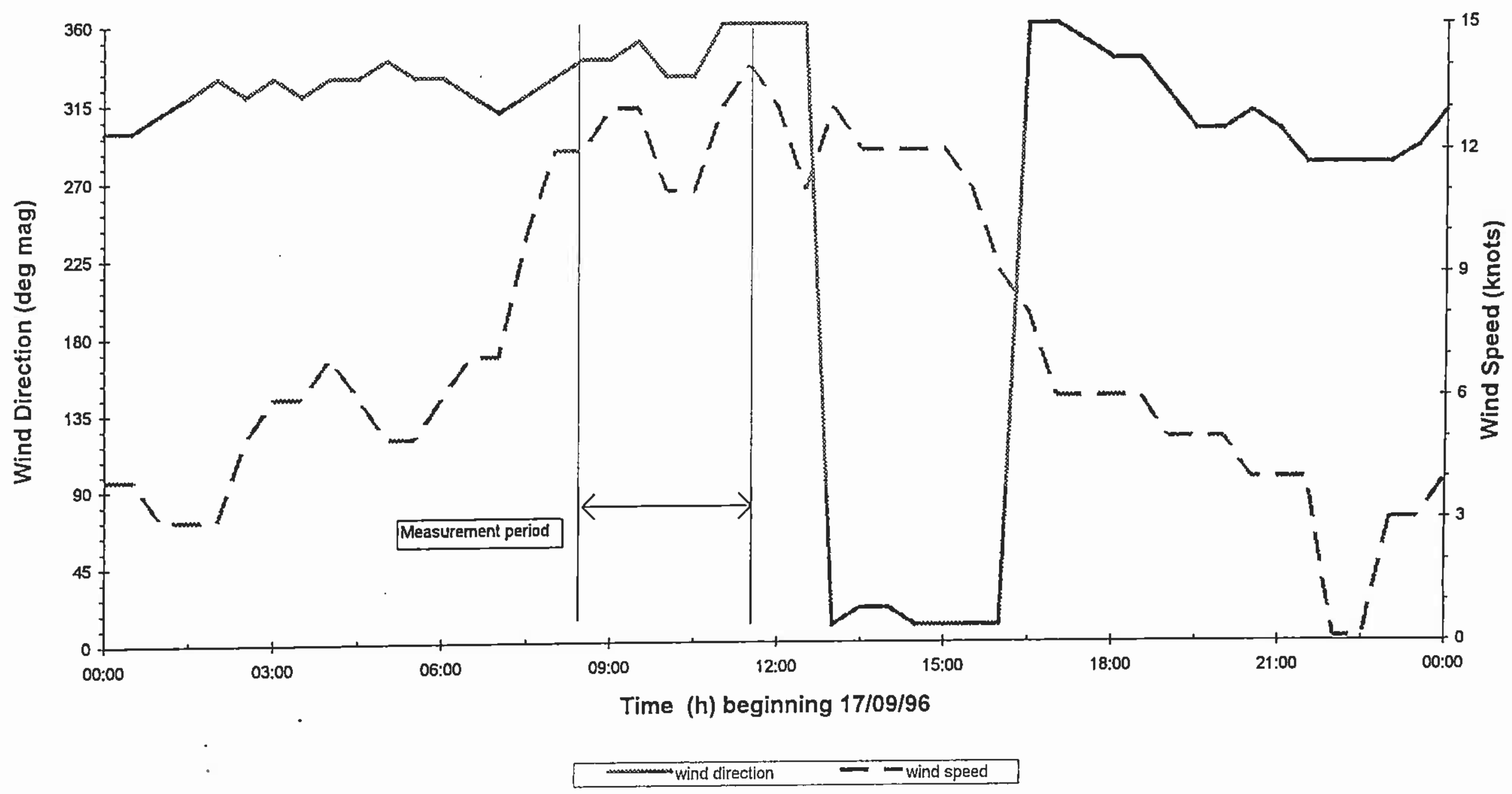


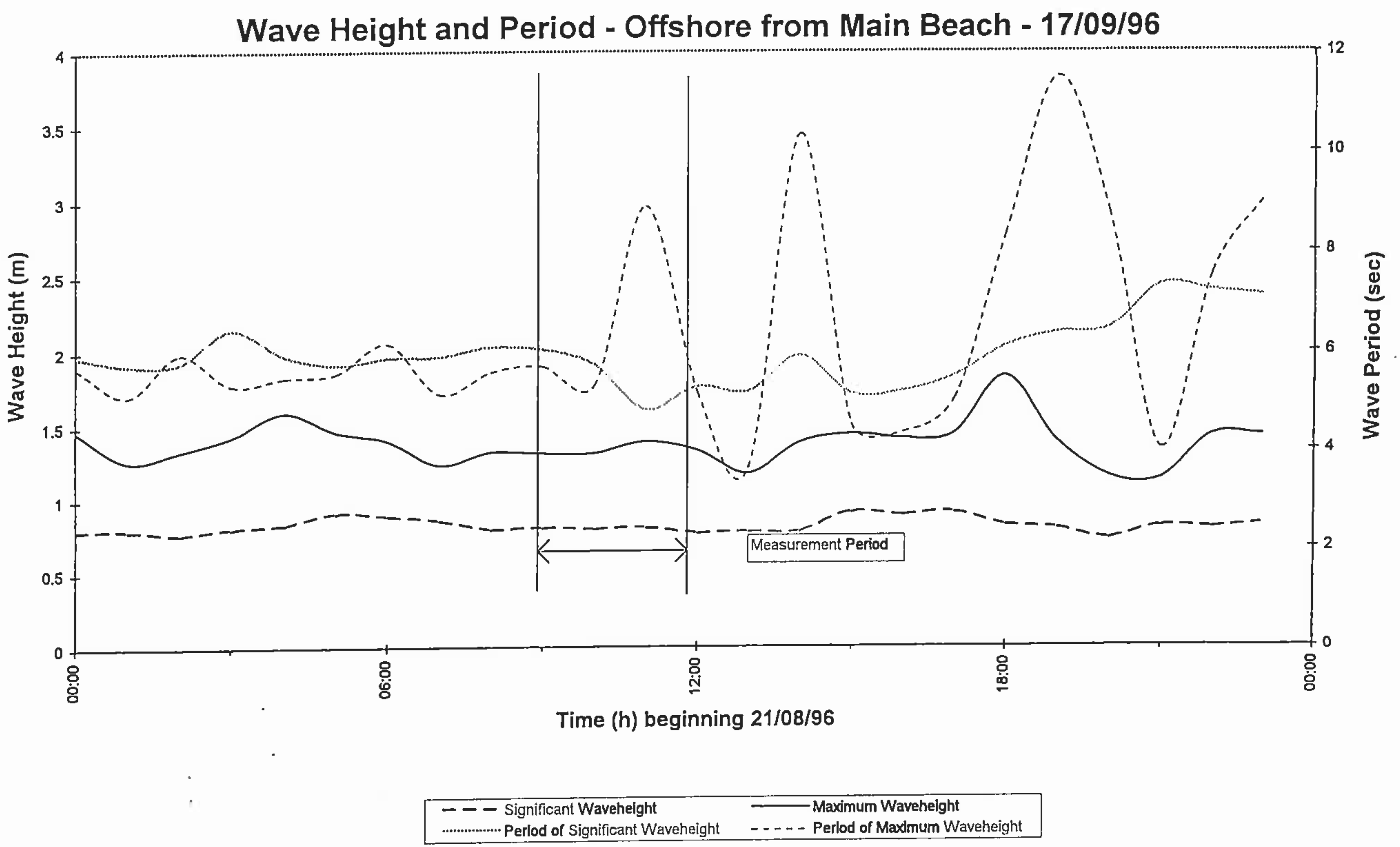
Wave Height and Period - Offshore from Main Beach - 21&22/08/96
Wave Height (m)
4
3.5
3
2.5
2
1.5
1
0.5
0
Wave Period (sec)
12
10
8
6
4
2
0
Measurement Periods
00:00
06:00
12:00
18:00
00:00
06:00
12:00
18:00
00:00
Time (h) beginning 21/08/96
Significant Waveheight
Period of Significant Waveheight
Maximum Waveheight
Period of Maximum Waveheight

Current Measurements Offshore from Discharge - South Stradbroke Island 21/08/96



Wind Speed And Direction - Gold Coast Seaway - 17/09/96





Wave Height and Period - Offshore from Main Beach - 17/09/96
Wave Height (m)
Wave Period (sec)
4
3.5
3
2.5
2
1.5
1
0.5
0
12
10
8
6
4
2
0
00:00
06:00
12:00
18:00
00:00
Time (h) beginning 21/08/96
Measurement Period
Significant Waveheight
Maximum Waveheight
Period of Significant Waveheight
Period of Maximum Waveheight

Current Measurements at Sand By-Passing Jetty 17/09/96