Appendix F

Hydrodynamic and Water Quality Modelling

Port of Hay Point Apron Areas and Departure Path Capital Dredging

Hydrodynamic and Water Quality Modelling

Report

July 2005

Contents

Table Index

Figure Index

Figure 5.9	Threshold orbital velocity for motion of sediment by waves	44
Figure 6.1	Location of environmentally sensitive areas	45
Figure 6.2	Movement of plumes from the Apron Area and Departure Path	52
Figure 6.3	Suspended sediment concentration in vicinity of Round Top Island	53
Figure 6.4	Suspended sediment concentration in vicinity of Victor Islet	54
Figure 6.5	Worst condition for Round Top Island during spring tide (sediment plume)	56
Figure 6.6	Worst condition for Victor Islet during spring tide (sediment plume)	57
Figure 6.7	Reduced sediment plume (neap tide condition)	58
Figure 6.8	Suspended sediment concentration in vicinity of Round Top Island	59
Figure 6.9	Suspended sediment concentration in vicinity of Victor Islet	60
Figure 6.10	Worst condition for Round Top Island during spring tide (sediment plume after 31 days)	61
Figure 6.11	Worst condition for Victor Islet during spring tide (sediment plume after 33 days)	62
Figure 6.12	Sediment plume after 39 days (neap tide condition)	63
Figure 6.13	Sediment deposition after 50 days of dredging at the Apron	65
Figure 6.14	Sediment deposition after 50 days of dredging at the Apron and Departure Path	66
Figure 6.15	Selected wave climates (stroked red triangles) for assessment of the impact of changes in the bathymetry on wave transformation patterns	67
Figure 6.16	Plot of wave height change between existing and post-dredging conditions in relatively high energy wave climate	69

Appendices

1. Introduction

1.1 Background

Ports Corporation of Queensland (PCQ) is a Government Owned Corporation and port authority under the Transport Infrastructure Act 1994. PCQ is responsible for managing and developing eight trading ports throughout Queensland, including the Port of Hay Point located approximately 38 kilometres south of Mackay.

The Port of Hay Point is Queensland's largest coal export port (Figure 1.2). Two coal terminals export coal through the port, the Dalrymple Bay Coal Terminal (DBCT) and the Hay Point Services Coal Terminal (HPSCT). DBCT is the larger of the two coal terminals. It is owned by DBCT Holdings (DBCTH) and operated by Dalrymple Bay Coal Terminal Pty Ltd (DBCTPL) under contract to the lessee, Prime Infrastructure Limited (PIL). HPSCT is owned by Central Queensland Coal Associates (CQCA) and is operated by Hay Point Services Pty Ltd (HPS).

The Port of Hay Point exported close to 80 million tonnes of coal in 2004 with export volumes planned to increase significantly in the next 5 years. Many ships departing Hay Point do so with restriction on the ship's draft which means ships visiting the port potentially could have carried more coal than was actually shipped. This has an impact on the efficiency of exports through the port and increases the number of ship visits required to export the coal.

PCQ is proposing to undertake capital dredging works at the Port of Hay Point to create a ship manoeuvring apron and a departure path from the apron area to the open sea. The departure path will increase the allowable sailing draft of ships departing the Port. This will have a significant benefit for the overall operation and efficiency of the Port. It is proposed to undertake the dredging works between May and September 2006.

PCQ has prepared an Environmental Impact Statement (EIS) in order to meet Federal and State assessment requirements. GHD Pty Ltd has been commissioned by PCQ to prepare the EIS for this project.

The project includes two key aspects:

- **Dredging:** Capital dredging of 9 million cubic metres will be required. The dredging will include the following works:
  - Provision of a ship-manoeuvring apron immediately adjacent to and parallel to the existing DBCT and HPSCT dredged berths. The apron will be at least 500 metres wide. The apron will be dredged to achieve a minimum declared depth of RL –14.9 metres LAT. Actual dredging depth will need to be marginally greater to maintain the minimum declared depth in between maintenance dredging cycles.
  - Provision of a departure path from apron to sea (refer to Figure 1.1). The path width is to be 500 metres wide for the first 500 metres, then taper to a width of 300 metres over the next 3,000 metres. There will be a transition zone

between the apron and path. The remainder of the path will be 300 metres wide and will continue until a minimum natural depth of RL -14.9 metres is achieved. The total path length is expected to be approximately 9,500 metres long. The widths referred to relate to the base of the apron and path. Both have sloped sides and hence, width dimensions at the original (pre-dredge) sea bed level will be greater and will vary depending on the actual depth of material removed. Dimensions of the works will be developed and presented in the EIS.

  - All of the path remains within port limits, though a large part will also lie within the Great Barrier Reef Marine Park (GBRMP) due to an overlap of the two areas.

- **Disposal of dredged material:** Dredged material will need to be disposed at sea. This material is clean marine sediment and has undergone full sediment testing as required by the National Ocean Disposal Guidelines. The new spoil ground within the GBRMP although still within port limits.

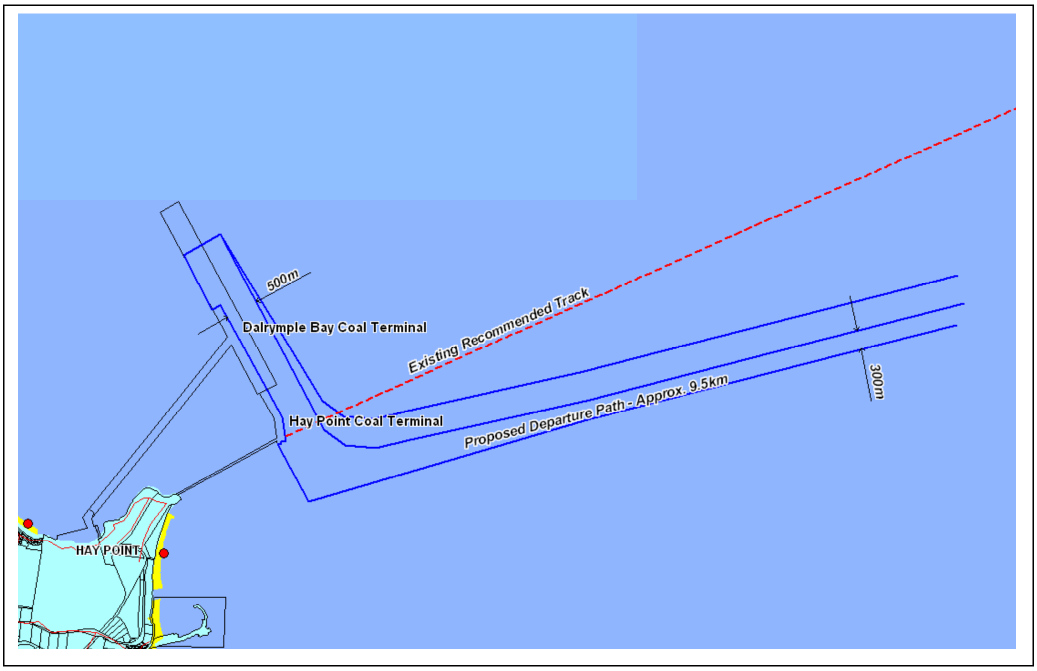


Figure 1.1 Proposed capital works

1.2 Scope of Work

The study is to provide input to the assessment and design of dredging and disposal activities, and the EIS. The following outcomes were nominated as study requirements.

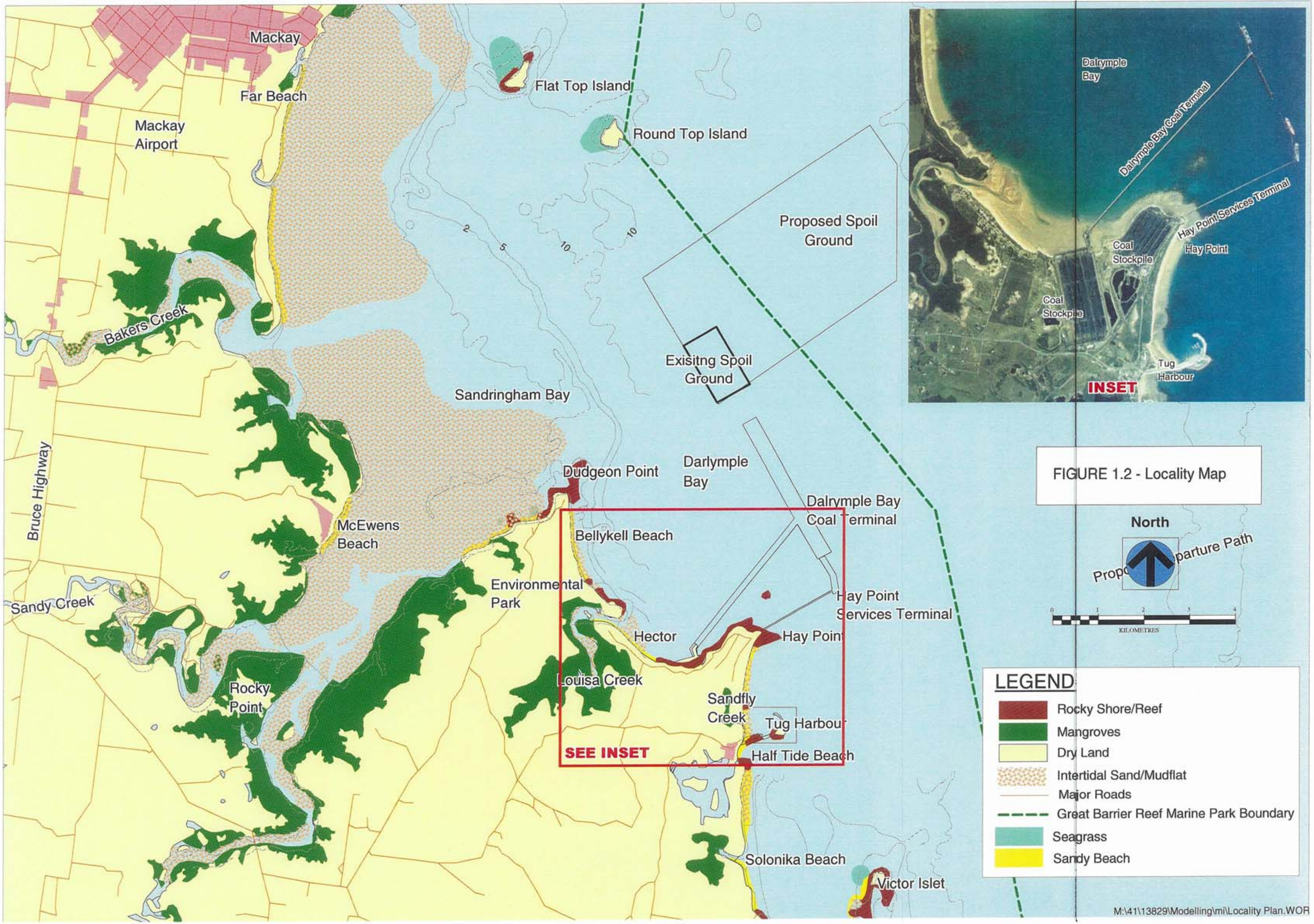
- Quantification of the current regime at the dredged berths, ship manoeuvring apron, proposed departure path and spoil ground. Current magnitude, direction and resulting bed shear stress have been nominated for inclusion in the assessment of the current regime.

- Quantification of the potential impacts of sediment suspension and deposition during dredging and spoil disposal and the effects of tides on the fate and concentration of generated plumes.

1.3 Modelling Scope

Descriptions of the cases modelled in this study are listed below.

- Hydrodynamic modelling of the coast of Hay Point for a period of 50 days (11 July 03 to 29 August 03) with pre-dredge bathymetry.
- Hydrodynamic modelling of the coast of Hay Point for a period of 50 days with post-dredge bathymetry.
- Modelling of the sediment plume generated by the combined effects of dredging at the apron and disposal at the proposed spoil site for a period of 50 days.
- Simulation of the sediment plume generated by the simultaneous dredging of the apron, and departure path (i.e., 2 dredges) with disposal at the proposed spoil ground (located along northwest boundary) for a period of 50 days.



Mackay
Far Beach
Mackay Airport
Flat Top Island
Round Top Island
Proposed Spoil Ground
Exisitng Spoil Ground
Bakers Creek
Sandringham Bay
Bruce Highway
Dudgeon Point
Darlymple Bay
Dalrymple Bay Coal Terminal
McEwens Beach
Bellykell Beach
Environmental Park
Sandy Creek
Hay Point Services Terminal
Hector
Hay Point
Louisa Creek
Rocky Point
Sandfly Creek
Tug Harbour
SEE INSET
Half Tide Beach
Solonika Beach
Victor Islet
2
5
10
10
Dalrymple Bay
Dalrymple Bay Coal Terminal
Hay Point Services Terminal
Coal Stockpile
Hay Point
Coal Stockpile
Tug Harbour
INSET
FIGURE 1.2 - Locality Map
North
Proposed Departure Path
0
1
2
3
4
KILOMETRES
LEGEND
Rocky Shore/Reef
Mangroves
Dry Land
Intertidal Sand/Mudflat
Major Roads
Great Barrier Reef Marine Park Boundary
Seagrass
Sandy Beach
M:\41\13829\Modelling\mi\Locality Plan.WOR

2. Review of Previous Studies

The purpose of the review is to locate, identify and catalogue as many of the existing reports and available data as practical. The focus is on studies, data and data sources related to physical oceanography (tides, winds, waves, currents, bathymetry) and other coastal processes (eg sediment, turbidity etc). In general, the data sources used as a basis of the present study have been generated within the last 5 years.

Table 2.1 Recent studies

Previous Study Reports	Key Findings
Hydrobiology Pty Ltd (2004), Maintenance Dredging SAP Implementation (May 2004) for the Departure Apron Area, Port of Hay Point, prepared for PCQ	◗ Dredged material is suitable for an assessment of dredge material suitability for unconfined sea disposal. ◗ Dredged material (generally gravely sands) consists of 16% gravel (> 2 mm), 72% sand (0.06 -2 mm), 4% silt (0.06 - 0.002 mm) and 6% clay (< 0.002 mm).
Lawson & Treloar (March, 2004), Hay Point Current Study, report prepared for PCQ	◗ Two months of current data were collected using an ADCP fixed at the seabed; presumably, the currents at the deployment location (21°51.36' S, 149°18.38' E) are similar to the currents measured at the berths. ◗ The currents at Hay Point are based predominantly on a semi-diurnal tidal signature, with residuals mainly caused by wind events. ◗ Tidal constituents have been calculated and provided to Maritime Safety, Queensland. ◗ Current window analysis carried out for port planning purposes, i.e., when and for how long the current speed lies below specified threshold speeds.
WBM (2004) Spoil Ground Site Selection Port of Hay Point, report prepared for PCQ	◗ This report details physio-chemical characteristics of the environment (eg, wave, tide, current, sediment, contaminants, etc). ◗ Investigated eight sites and identified three possible sites for spoil disposal.

Previous Study Reports	Key Findings
Lawson & Treloar (March, 2001), DBCT Stage 6 Expansion - Berth 3 – Design Met-Ocean Parameters, Report prepared for Connell Wagner Pty Ltd, Report J1935/R1928	◗ The report describes the data, methods and results of an investigation of storm tide, waves height and wind speed in the Hay Point region. ◗ An analysis of historical cyclones since 1955 was undertaken to provide statistical description of cyclone parameters. ◗ Establishment of storm surge and wave models. ◗ Monte Carlo simulation applied to predict ARI wave heights, storm tide and wind speed.
WBM (2001a) Aerial Surveillance of Dredging Plumes Associated with the Expansion of the Dalrymple Bay Coal Terminal, Hay Point	◗ Findings of aerial surveillance of the dredging and placement plumes during the initial days of dredging (17th - 19th of June 2001) indicate that the combined dredging and placement plume was observable within the 3 km radius of Round Top Island or Victor Islet or the 1 km landward boundary subject to the stage of the tide.
WBM (2001b) Second Round of Aerial Surveillance of Dredging Plumes, DBCT 27/6/01, report prepared for PCQ	◗ Findings of aerial surveillance of the dredging and placement plumes toward the middle of the dredging (27th of June 2001) indicate that the combined visible plume evident from the dredging and placement activities was approximately 13 km in length reaching north from the DBCT to approximately 3 km north east of Round Top Island.
Lawson & Treloar (July, 2000), DBCT Expansion Ocean Current Study Numerical Modelling, report prepared WBM (2000) study	◗ The report describes numerical current modelling investigations undertaken for the proposed expansion of DBCT facilities using a MIKE21 model for an area 45 km x 65 km. ◗ Calibration using data 16-17 April 2000 and 25 April 2000. Calibration against water levels and ADCP transects current measurements. ◗ Currents are strong, generally aligned with the berths and change direction quickly when the tide changes from ebb to flood. ◗ Investigated plume dispersion during construction; dispersion causes rapid dilution of suspended sediments. ◗ Model predictions show small changes in current speed due to dredging of the new berth and departure path.

Previous Study Reports	Key Findings
WBM (June, 2000) DBCT expansion – Coastal process investigation, report prepared for URS and PCQ	◗ The coastal processes at the site are dominated by a large tidal range generating relatively high tidal currents, the presence of the Outer Great Harbour Reef limits day-to-day wave heights and tropical cyclones can generate elevated water levels and high waves.
WBM (June, 2000) DBCT expansion – Coastal process investigation, report prepared for URS and PCQ (Continued)	◗ Surficial seabed sediments are comprised of mostly silts and fine silty sands. Bed sediments are only mobilised under moderate to high wave conditions. ◗ Tidal currents typically flow parallel to the depth contours at speeds up to around 0.5 m/s during spring tides. Winds can have a significant effect on the current speed and direction. ◗ Up to 1,700,000 m^3 is to be deposited at the existing spoil ground. This represents and average raising of the bed level at the spoil ground by about 1.3 m reducing the average depth to around 10 m below LAT. Coarser sandy material is rarely mobilised while the finer loose silty material has the potential to be suspended by moderate to high waves and carried by the prevailing currents. ◗ A reduction in water depth of about 1.3 m through additional spoil disposal is predicted to cause only a minor increase in the sediment transport potential with a corresponding slight increase in the potential for the fine material to be transported out of the spoil ground. ◗ Turbid plume dispersion: concentrations within the plume will quickly reduce under the action of transport and dispersion reaching 5-10% of the initial concentration within about 0.5 hours and return to essentially background conditions within 2-3 hours of the initial generation of the plume. ◗ Siltation of dredged areas: Minor siltation expected to the extent of a few centimetres/year on average. Maintenance dredging requirements are expected to be infrequent and small in quantity. ◗ Impacts of hydrodynamics and adjacent shoreline: Negligible changes to current velocities outside of the works area with only small reductions in depth averaged velocities in the dredged areas. ◗ Changes to the overall sediment transport processes and their impact on the shoreline are expected to be minimal.

3. Project Data

A range of data for the purposes of creating and calibrating the hydrodynamic model was obtained from different sources as described below.

3.1 Water Levels

Hay Point is located on the mainland coast at the northern end of the macro-tidal regime of Broad Sound (Cook and Mayo, 1978). The maximum tidal range is 7.14 m with the mean spring tidal range being 4.88 m. The tides are semidiurnal (refer below) with a small diurnal inequality (AGSO,1998), with a form number of less than 0.25. The form number is determined on the basis of the ratio of the amplitudes (K1+O1)/(M2+S2) as shown in Table 3.1.

Table 3.1 Tide classification by form number

Form Number	Tidal Type
< 0.25	Semidiurnal
0.25 – 1.5	Mixed, mainly semidiurnal
1.5 – 3.0	Mixed, mainly diurnal
> 3.0	Diurnal

Tidal planes at Hay Point, as documented by Queensland Department of Transport (2002), are presented in Table 3.2.

Table 3.2 Hay Point tidal planes

Tidal Plane	Tidal Level (m LAT)
Highest Astronomical Tide (HAT)	7.14
Mean High Water Springs (MHWS)	5.78
Mean High Water Neaps (MHWN)	4.46
Australian Height Datum (AHD)	3.34
Mean Low Water Neaps (MLWN)	2.22
Mean Low Water Springs (MLWS)	0.90
Lowest Astronomical Tide (LAT)	0.0

Water level records for Hay Point and the surrounding area were obtained from Maritime Safety Queensland (MSQ). MSQ provided both time histories of water level, and tidal constituents (Table 3.3).

Table 3.3 Water level data

Station ID	Station Name	Longitude		Latitude		Type of Data[1]	Data Source
		(Deg)	(Min)	(Deg)	(Min)		
028008A	Laguna Quays Storm Surge	148	40	-20	36	HC & TSA	MSQ
054004A	Mackay Storm Surge	149	13	-21	6	HC, TSA & TSP	MSQ
59460	Carlisle Island	149	18	-20	47	HC & TSP	MSQ
59480	St. Bees Island	149	27	-20	54	HC & TSP	MSQ
59490	Scawfell Island	149	37	-20	52	HC	MSQ
59500	Penrith Island	149	54	-21	0	HC	MSQ
59531	Prudhoe Island	149	40	-21	18	HC	MSQ
060008A	Hay Point Storm Surge	149	18	-21	16	HC & TSP	MSQ
100056	Oom Shoal - Mackay	149	16	-21	3	1.) HC 2.) TSP	1.) MSQ 2.) NTC
060010A	Half Tide Tug Harbour	149	18	-21	17	TSA	MSQ
054003A	Halliday Bay	148	59	-20	53	HC & TSP	MSQ

Note:

[1] HC = Harmonic Constituents; TSA/P = actual/predicted time series at 10 minute intervals.

[2] MSQ = Maritime Safety Queensland; NTC = National Tidal Centre.

3.2 Bathymetry

The bathymetry of the Hay Point coastal area was developed using data from the following sources:

- Digitised marine charts:
  - AUS 249 (Approaches to Hay Point and Mackay, Scale 1:75,000);
  - AUS 250 (Plans of Hay Point and Mackay Harbour, Scales 1:15,000 and 1:10,000, respectively);
  - AUS 823 (Percy Isles to Mackay, Scale 1:150,000) and
  - AUS 824 (Penrith Island to Whitsunday Island, Scale 1:150,000).
- Hydrographic survey of berth areas, departure path area, Dungeon Point and the spoil ground.

3.3 Currents

Current data for the project was derived from plots contained in Lawson & Treloar (2004). The data was recorded using an Acoustic Doppler Current Profiler and covers a two-month period (20 October 2003 to 24 December 2003). The location of the current meter deployment is shown in Figure 4.2.

The Australian Geological Survey Organisation (AGSO, 1998) reports that strong currents flowing parallel to the coast in the area may reach speeds of up to 2 knots (approximately 1.0 m/s) on springs.

Typical characteristics of the tidal currents as identified in previous reports are as follows:

- Peak current velocities vary from about 0.20 m/s during neap range periods to about 0.50 m/s for spring tides; and
- The tides generally flood towards the south-southeast (165° true) and ebb towards the north-northwest (345° true) with slight variations from tide to tide.

3.4 Winds

Lawson & Treloar collected wind data (speed and direction) at Hay Point as part of the Hay Point Current Study for PCQ in 2004. The wind data (30 minute intervals) was collected for the period from 10th October 2003 to 15th January 2004 from an anemometer operated by the Bureau of Meteorology (BoM) at Hay Point.

Additional wind data was collected from the BoM at Mackay Airport (033119) and is presented in Figure 3.1. The dominant wind direction is that originating from the south to southeast.

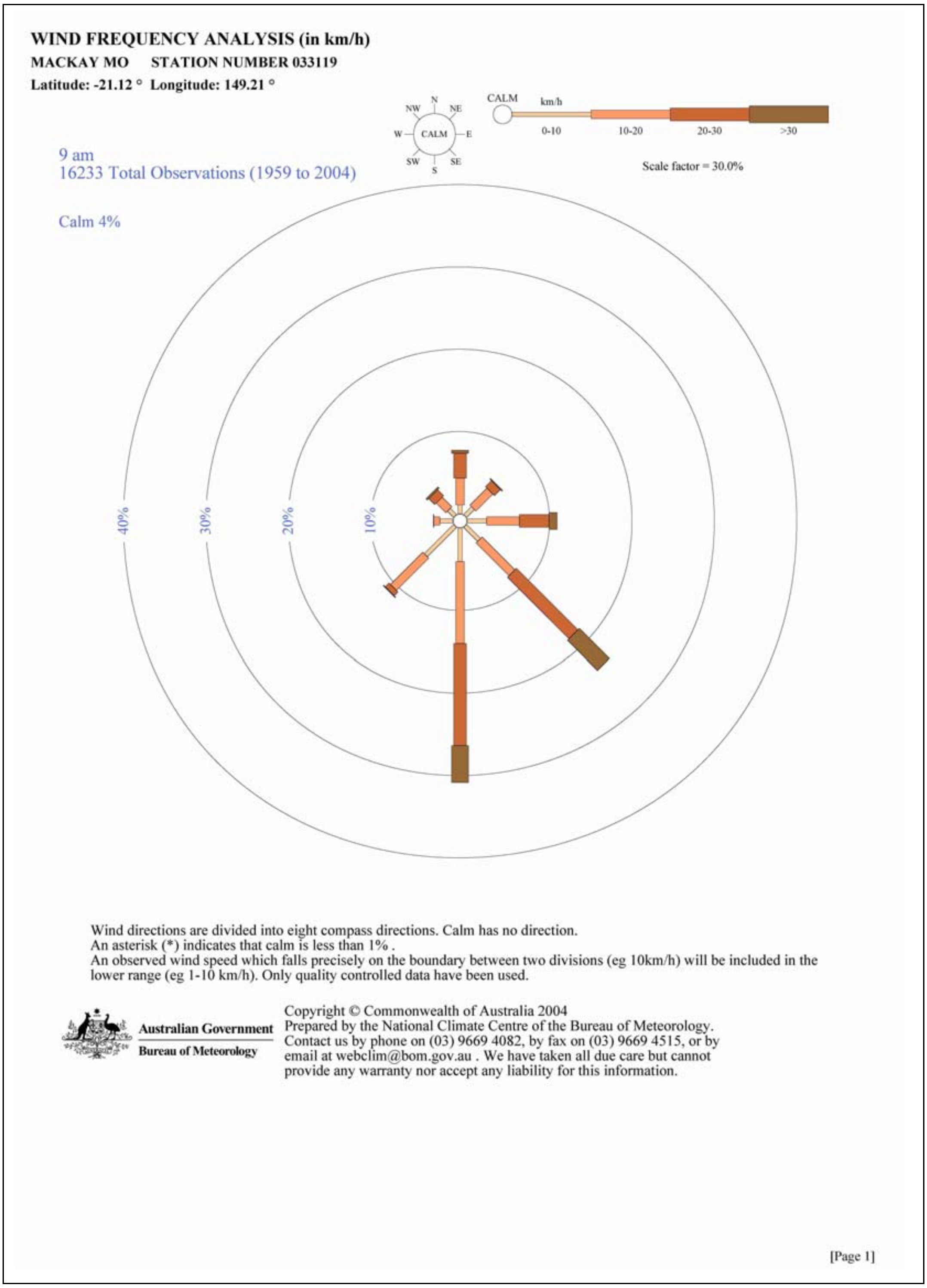


Figure 3.1 Wind frequency analysis for Mackay Airport (Stn 033119)

3.5 Waves

Wave data deserves particular attention owing to the key role that waves can play in the process of sediment transport.

The following data was acquired for the project:

- Wave data recorded at 30-minute intervals at the Hay Point wave recording station between 24 March 1977 and 29 September 2004.
- Wave climate statistics established by the Environmental Protection Agency (EPA, Queensland wave climate annual summary for season 2002-2003).

The former dataset was primarily used to generate scatter plots combining both height and period data (Figure 3.2 and Figure 3.3) and to provide a comparison between wave records and results from the wave modelling exercise.

The latter dataset gives an estimate of the cumulative probability distribution, i.e., the probability that the wave height from a randomly chosen member of the dataset will be less than some specified height.

Based on the above datasets and the reviewed literature, the following comments can be made with respect to the wave climate at Hay Point:

- The site is exposed to a varying wave climate which is influenced by the Great Barrier Reef, the Northumberland Isles and associated with shoals to the south-east and the occurrence of tropical cyclones (WBM, 2000).
- The site is subject to wind-waves and swell with spectral peak periods ranging from about 2 seconds to 18 seconds (Figure 3.3). Wind waves predominate and typically have a spectral peak period from 3 to 6 seconds. During significant meteorological events, the maximum height of wind-waves could reach as high as 4.5 to 5.0 m with a corresponding peak period of 6.0 to 6.5 seconds.
- Overall, waves (swell and wind) affecting the area (Figure 3.2) lie predominantly in the range 2 to 8.5 seconds with significant wave heights not exceeding 2.5 m. For all wave heights (H_{sig}), the most common mean wave periods (T_p) lie in the 3 to 5 s range representing 62% of waves in winter and 67% in summer with a total of 64% for all data.
- Time exceedence curves of wave heights for all wave periods indicate that a wave height of 1 m is exceeded less than 11% of the time during the winter period and approximately 12% of the time during the summer period.
- The 5% exceedence values for significant wave height in summer and winter are 1.4 m and 1.3 m respectively; 1% exceedence values are in the 1.6 m - 1.7 m range for both seasons.

The Hay Point wave recording station was re-deployed during the 2002-2003 season with presumably minor implications in relation to the quality of the data. The deployment periods and corresponding locations are given in Table 3.4.

Table 3.4 Waverider buoy

Latitude	Longitude	Depth (m) LAT	Deployment date	Removal date
-21°16.14'	149°18.83'	11.0	17/05/2002	15/05/2003
-21°16.41'	149°18.73'	11.5	15/05/2003	25/11/2003

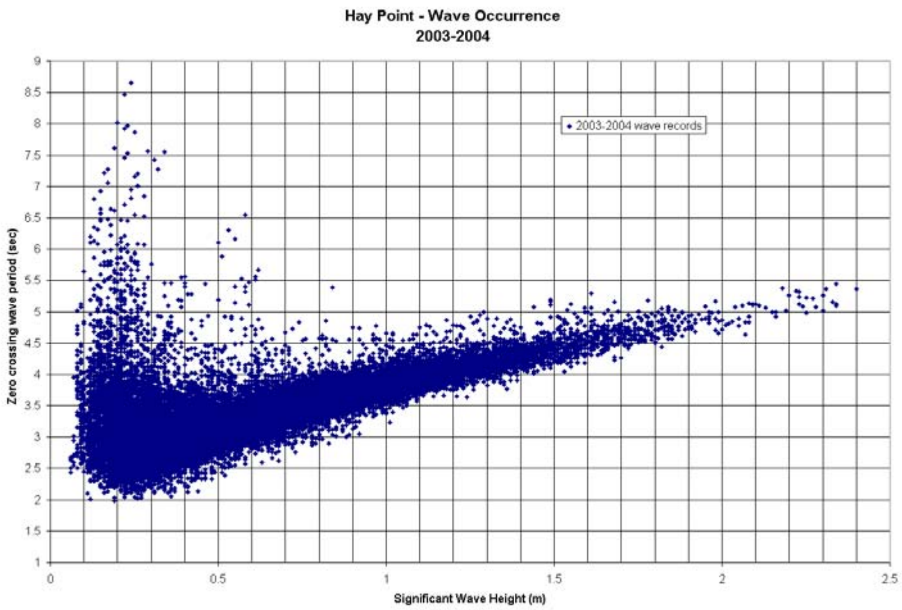


Figure 3.2 Scatter plot illustrating the relationship between significant wave height and zero-upcrossing period for the 2003-2004 season

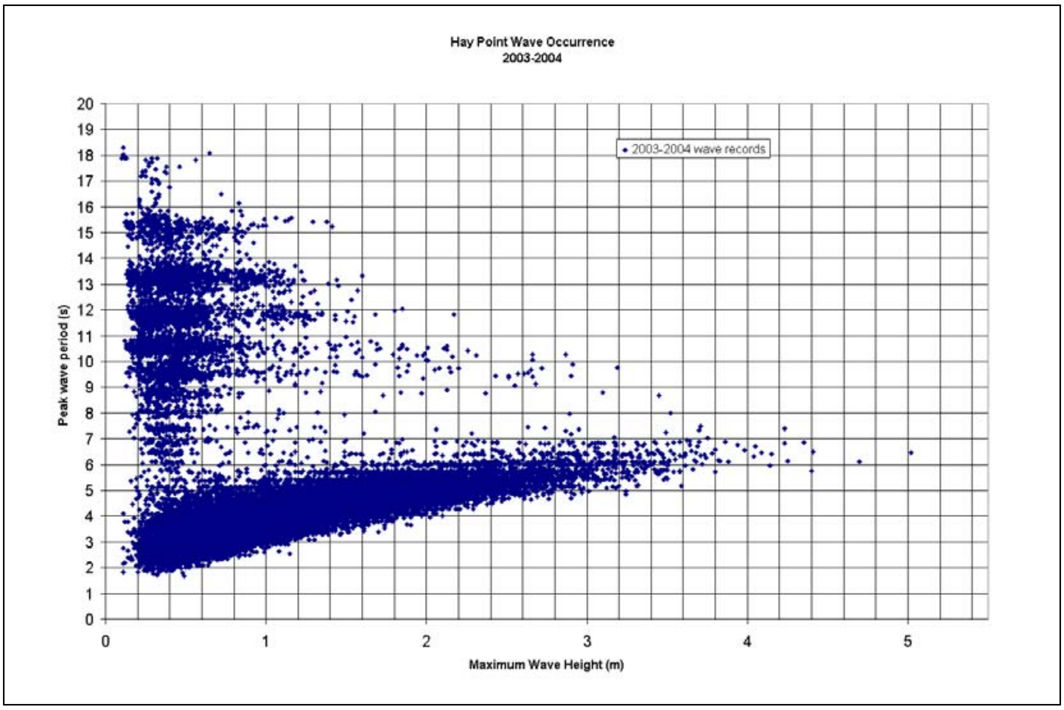


Figure 3.3 Scatter plot illustrating the relationship between maximum wave height and peak wave period for the 2003-2004 season

3.6 Sediment

3.6.1 Overview

On a broad scale, strong tidal currents have produced linear sand banks and dunes throughout the area, with notable complexes being the Blackwood Shoals (at the southern end of Whitsunday Passage) and the Viscount Shoals, which extend northward to a latitude of 21° 20'S. Such features occur along the coast between the Whitsunday Islands and Broad Sound (Cook and Mayo, 1978) to a depth of about 20 m (AGSO, 1998).

3.6.2 Sediment Data

On a local scale, a review of the nature of the sediment on the seabed adjacent to the port indicates that the sediment consist primarily of terrigenous sands. This is confirmed by the samples collected in the departure apron area during a field campaign undertaken by Hydrobiology in 2004. Samples were collected from a total of 26 sites. On average the dredged material was found to consist predominantly of gravely sands. The break down of samples across all sampling locations indicates the presence of approximately 16% gravel (> 2 mm), 72% sand (0.06 -2 mm), 4% silt (0.06 - 0.002 mm) and 6% clay (< 0.002 mm).

WBM (2000) give the following description of the nature of the sediment:

- Predominantly fine to very fine silts in the existing berth pockets;

- High level of variability in the relative proportions of the sands, clays and rocky fractions that occur across the dredging area and with sub-surface depth.

This high level of variability is illustrated in Table 3.5 listing the particle size classes in the main depth zones that have been sampled by borehole at the DBCT terminal (WBM, 2000). For the sake of continuity between the various studies, a row has been appended to the bottom of the table that provides a reference to the arithmetic means for each particle size class produced as a result of the most recent sediment sampling campaign undertaken in 2004 by GHD (Figure 3.4).

Table 3.5 Relative proportion of the four main particle size classes with depth

Depth	Clays (%)	Silts (%)	Sands (%)	Gravel/Rock (%)
0.0-1.0 m (WBM)	14-24	8-23	39-71	3-12
1.0-3.0 m (WBM)	11-20	11-26	26-34	12-39
3.0-5.0 m (WBM)	3-32	3-26	39-69	2-34
0.0-0.5 m (GHD)	23	9	59	10
0.0-1.0 m (GHD)	25	11	53	11
1.0-2.0 m (GHD)	21	9	57	14
Hydrobiology	6	4	72	16

Crabb (1986) noted that dredging operations, associated with the construction of a jetty facility at Hay Point in 1981, required the removal of a "stiff clay". Such observations indicate that Holocene unconsolidated deposits form a mobile, thin patchy veneer over cohesive-clayey Pleistocene sequences on the inner shelf (to 20m depth). These seafloor characteristics have been confirmed by later studies (URS 2000 referenced in WBM 2004) which also indicate that the surficial layer of silt and silty fine sands varies in the 1 to 30 cm range.

3.6.3 GHD Sediment Data

In late 2004, GHD conducted a sediment sampling campaign to obtain seafloor material characteristics in support of planned capital dredging operations. Samples were collected from a total of 68 sites (Figure 3.4). As seen from the figure, the coverage of the study area is widespread, uniform and at relatively high density designed to minimize information loss. Particle size analysis was undertaken on a subset of the samples collected during the sediment sampling campaign to determine:

- Commonly used percentiles (i.e., in order of increasing size: D5, D16, D25, D35, D50, D65, D75, D84, D90 and D95) and
- Percentages based on grain size analysis (percent gravel, sand, silt and clay).

The purpose of the analysis was to provide data for input in the sediment transport numerical model and to reduce the inherent uncertainty resulting from assigning estimates for material characteristic values.

The results from the analysis indicate:

- **Along the proposed departure path:** A perceptible general (throughout all layers) trend of coarsening of the mean particle size in the seaward direction (Table 3.6) with the trend particularly evident in the surface sediment layer (0.0 m-0.5 m);
- **In the Apron Area:** Coarsening of the material across zones A3 to A1 throughout all layers;

Table 3.6 Range of mean particle size per sampling zone

Zone	Layer 0.0-0.5 (m)	Layer 0.5-1.0 (m)	Layer 1.0-2.0 (m)
A1	0.027-0.082	0.013-0.301	0.165
A2	0.118-0.166	0.019-0.045	-
A3	0.035-0.365	0.020-0.467	0.102
DP1	0.013-0.035	0.102-0.281	-
DP2	0.021-0.059	0.037	0.551
DP3	0.048-0.160	0.127-0.155	-

Sediment samples are classed as well sorted if they contain a narrow range of grain sizes and well mixed if they contain a wide range. As a rough guide, if a sediment sample has D84/D16<2, then it is well sorted, whereas if it has D84/D16>16, then it is well mixed. In line with this classification, the sediment is well mixed throughout the surveyed area with the exception of zone DP3 where the sediment is well sorted.

The GHD and Hydrobiology surveys provided estimates of the specific gravity (density) of the sediment. Both surveys indicate that specific gravity varies in the 2.70 to 2.73 range in the Apron Area and could reach as low as 2.65 along the proposed departure path.

Data on bulk density, void ratio, erosion shear stress and erosion rates was not obtained from the surveys. One method of selecting reasonably representative values for the latter material characteristics is to look at data obtained from previously completed projects in the same geographical area or areas with similar characteristics. In this case, a comparison to data from work in the Port of Darwin was made.

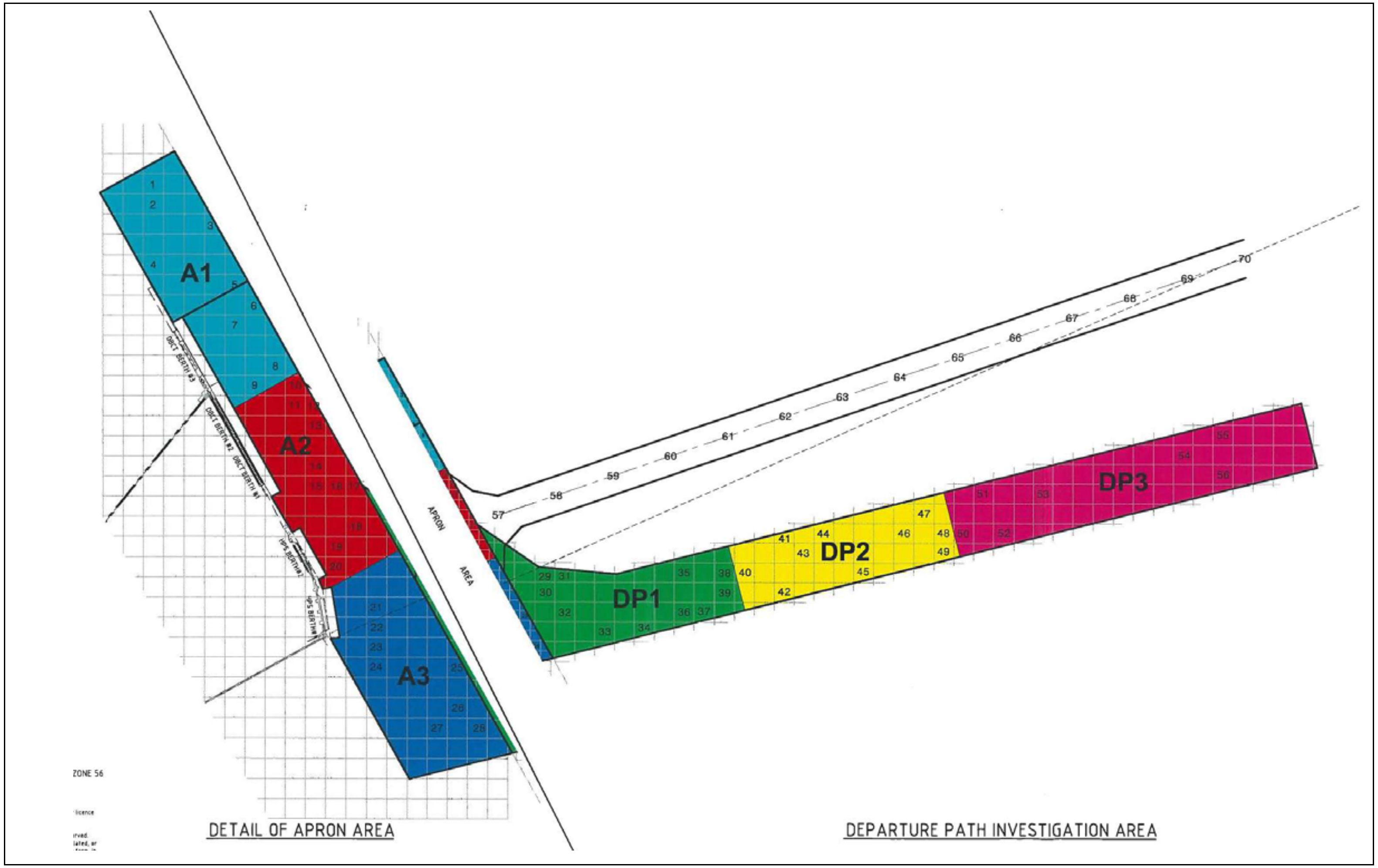


Figure 3.4 Sediment sampling locations

4. Hydrodynamic Modelling

4.1 Introduction

The purpose of this chapter is to provide an overview of the model development process, with emphasis on hydrodynamics (i.e. in this case, tidally generated currents). The model provides a means to predict what currents will arise in the future, and hence, how a sediment plume may behave. An accurate assessment of hydrodynamics provides a stronger understanding of the waterbody, and hence can provide greater levels of confidence in subsequent predictions.

4.2 Selection of Model

Several factors can contribute to the selection of the preferred modelling technique (finite difference versus finite element) and modelling system (RMA, Delft3D, Mike 21, etc). In this case, there were no dominant reasons demanding the use of one package over another, and hence it was decided to utilise the RMA suite of models. RMA2 is a 2-dimensional finite element model capable of modelling hydrodynamic processes in coastal systems.

It is noted that:

- The use of a finite element grid gives the flexibility to vary the element size from very small elements in the area of interests (i.e. departure path and spoil ground) to larger elements elsewhere.
- RMA is capable of modelling both hydrodynamics (RMA2/RMA10) and water quality/sediment transport processes (RMA11) in 2D or 3D mode.
- It was considered unlikely that prevailing wave conditions would lead to the resuspension of material from the sea bed. Therefore, the need for 'coupled' wave and tide models was considered to be low, especially with respect to the assessment of siltation.

4.3 Model Generation

The Hay Point hydrodynamic model covers an area approximately 34 kilometres offshore and 71 kilometres alongshore in extent (refer to Figure 4.1). The extent of the model was defined as per the scope of the project. The model datum is AHD.

The size of the elements used varies from 1.5 hectares to 2,000 hectares in area. In the area of interest, such as the vicinity of the departure path and spoil ground, smaller elements were used to better represent the area. Further offshore, larger elements were adopted. This modelling approach reduces the computational requirements.

The Manning roughness adopted for the seabed is 0.023, whilst a higher value of 0.025 was adopted along the coastline.

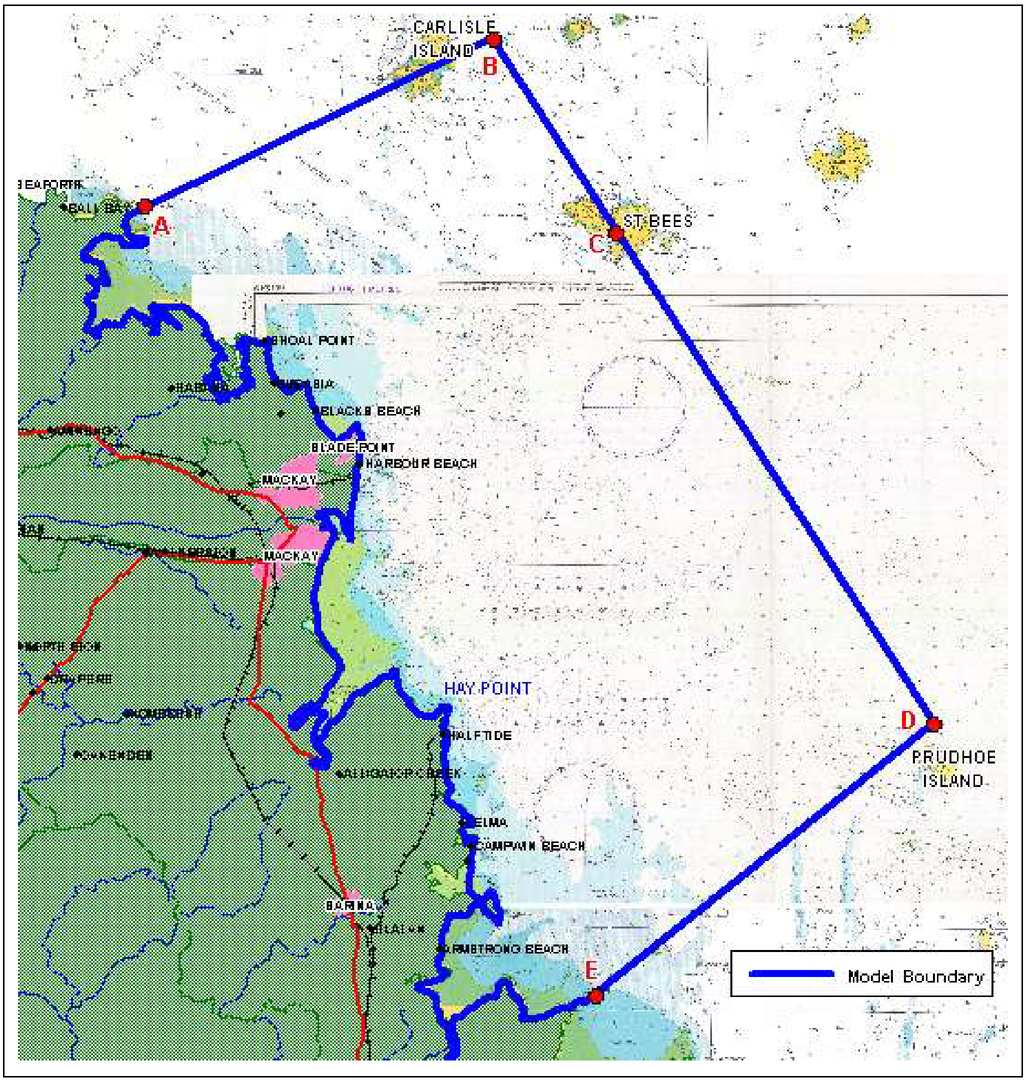


Figure 4.1 Extent of model and time-series boundary

4.4 Boundary Conditions

MSQ supplied time-series of predicted tide levels for the model boundary. The predicted tide levels were based on harmonic constituents derived from several years of tide records.

The predicted tides were sourced from tidal stations A, B, C and D as shown in Figure 4.1. The description of each station is given below:

- A – Halliday Bay (054003A).
- B – Carlisle Island (59460).
- C – St Bees Island (59480).
- D – Prudhoe Island (59531).

In addition, tide data for Prudhoe Island (59531) was used to generate tide data at Location E as no other stations could be sourced in this area. To account for the tidal transformation, a phase shift of +10 minutes was applied, with the tide amplitude increased by 7%.

As explained in Section 4.5.2, despite a good faith effort to operate the model with these boundary conditions, comparison of modelled and measured currents proved unsatisfactory. A large-scale coastal model was therefore adopted that provided sufficiently accurate boundary signal for the intended purpose.

4.5 Model Calibration

The model was calibrated for water level, current magnitude and current direction. The locations of the tidal station (Oom Shoal Mackay 100056) and the current meter (ADCP) used in the calibration are illustrated in Figure 4.2.

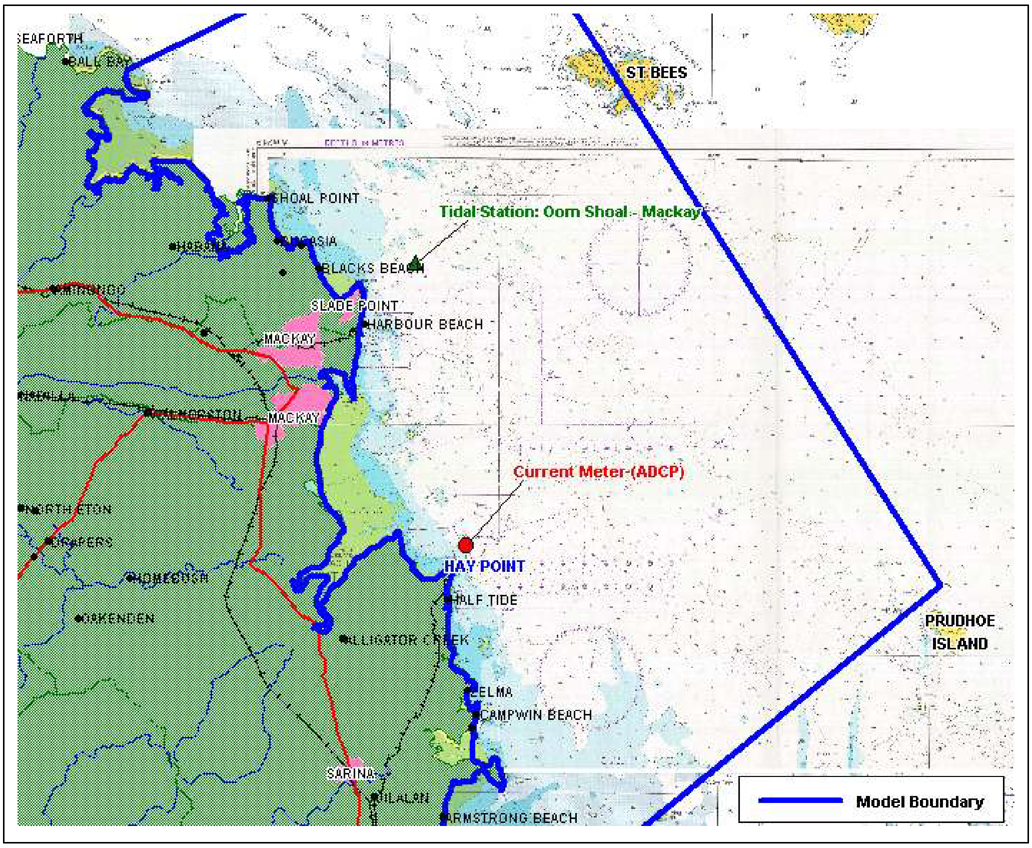


Figure 4.2 Locations of Oom Shoal Tidal Station and ADCP

4.5.1 Tide

The National Tidal Centre (NTC) supplied predicted tide levels for Oom Shoal Mackay (100056). A comparison of the tides predicted by NTC and the tides predicted by the RMA model shows excellent agreement (refer to Figure 4.3). It should be noted that strong calibration has been achieved over an extended period of time.

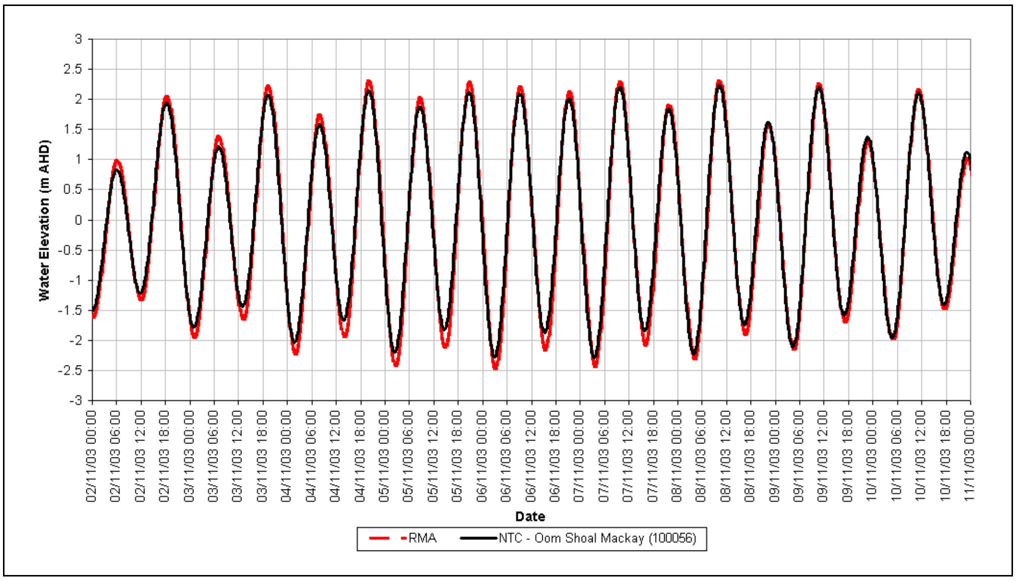


Figure 4.3 Comparison of predicted tides at Oom Shoal Mackay

4.5.2 Tidal Current

Current data was collected during a previous study for a period of two months (20/10/2003 to 24/12/2003) using an Acoustic Doppler Current Profiler (ADCP) at the location shown in Figure 4.2. Details on the ADCP deployment and the data collection procedures are described in Lawson and Treloar (2004).

Comparison of predicted (modelled) versus measured current velocities and direction were undertaken for both spring and neap tide cycles. It was found that:

- During spring tide, reasonable agreement was achieved between the modelled and measured current velocities and directions (refer Figure 4.4 and Figure 4.5).
- However during neap tide, the model results did not match as well compared to the measured currents. This can be explained as follows. Whilst predicted tides were available at 4 locations (A to D), the level of accuracy was different for each one. This set up an imbalance between the 5 tidal boundaries applied, which whilst not noticeably affecting water level predictions, did cause a significant change to predicted currents. In addition, it was difficult to accurately estimate the phase and amplitude of the tide at Point E. Hence, an alternative approach was required to ensure that the tide at each of the 5 boundary locations was correct in a relative sense (i.e. phases and amplitudes relative to each other). Correction of this issue

was required to allow currents to be more accurately predicted, which was considered more important than relying on tidal magnitude only.

To correct for this potential source of error, time series of tides were obtained from a separate coastal model developed by GHD that covers a significant area of the southeast coast of Australia. The time series were used as boundary condition in the RMA model and as a result, a stronger calibration of current magnitude and direction was achieved for both spring and neap tide cycles (refer Figure 4.6 and Figure 4.7).

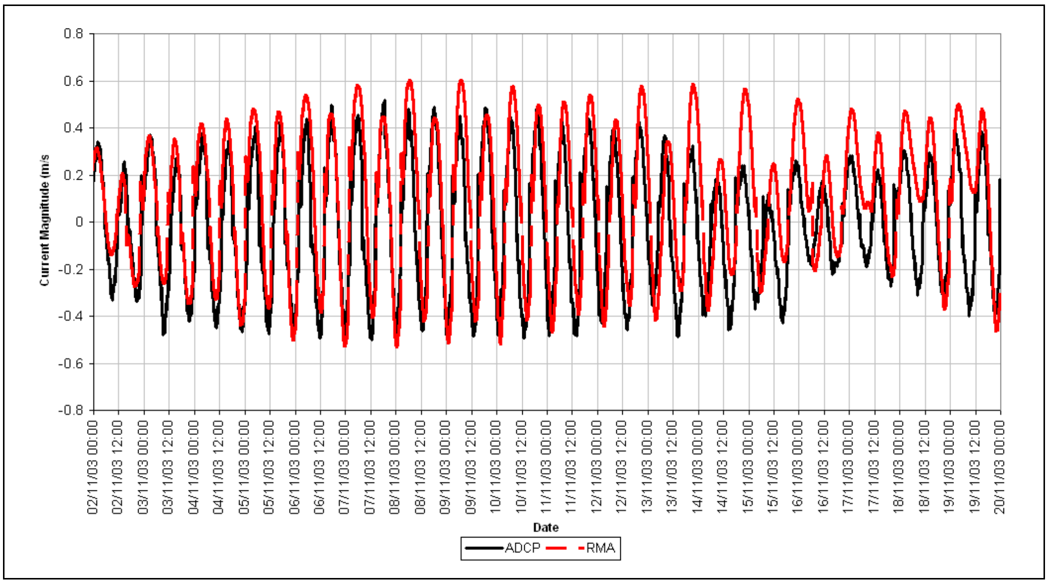


Figure 4.4 Predicted and measured current velocity during spring tide (initial)

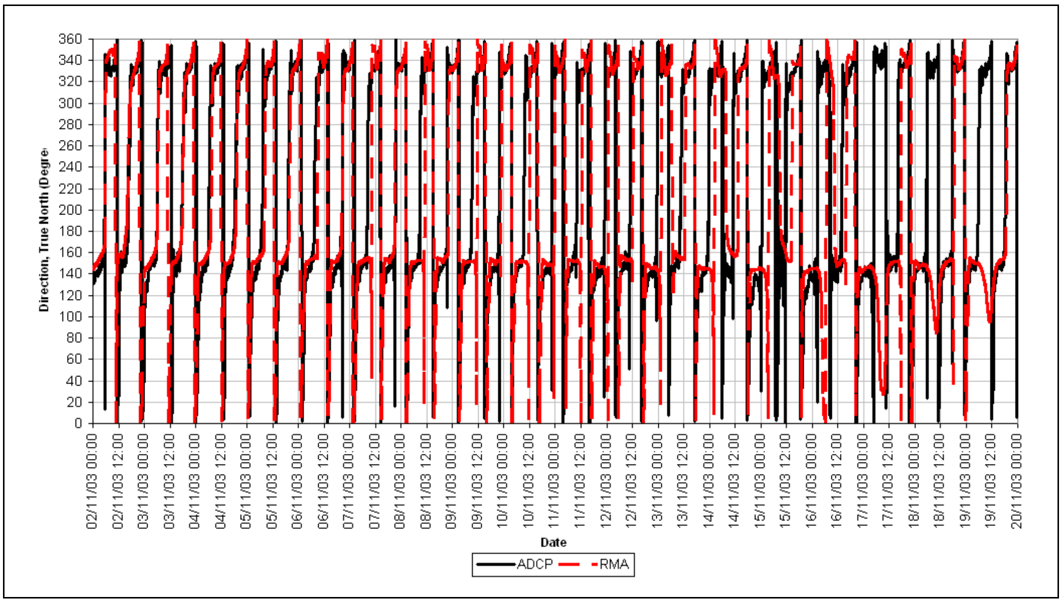


Figure 4.5 Predicted and measured current direction during spring tide (initial)

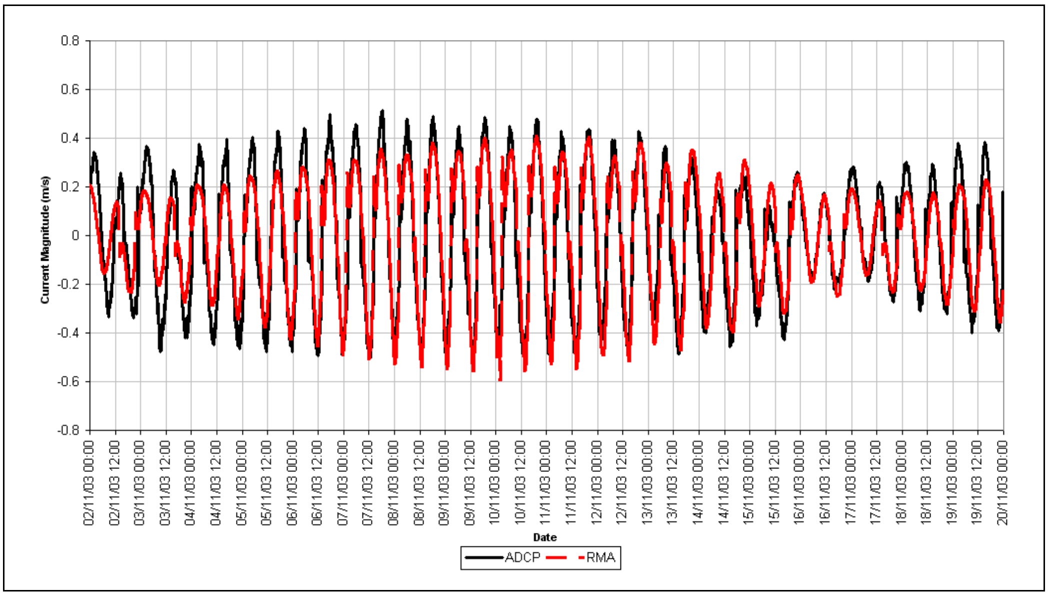


Figure 4.6 Predicted and measured current velocity during spring and neap tides (final)

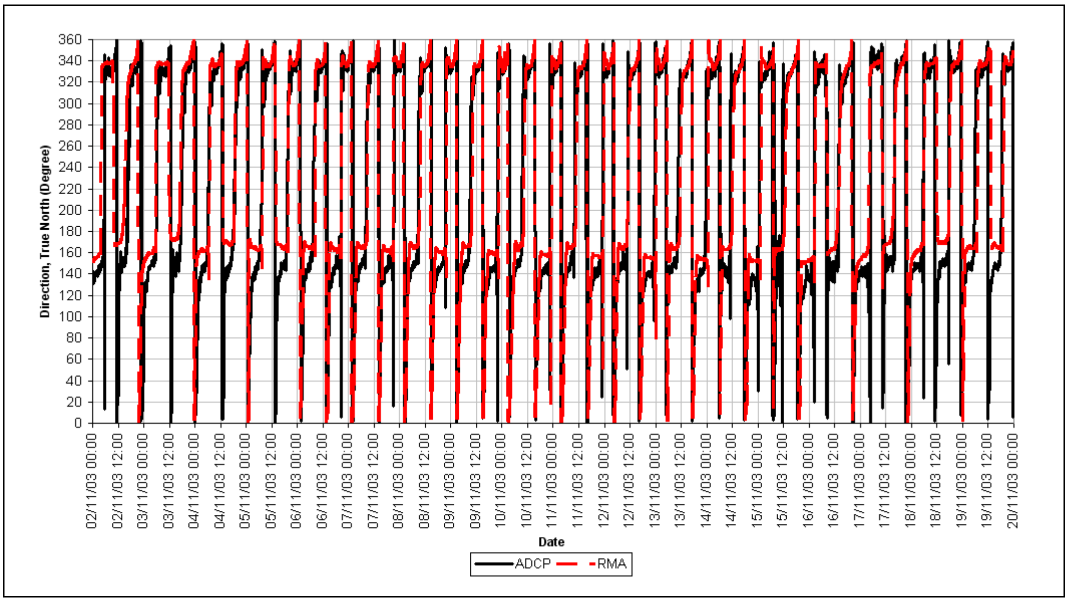


Figure 4.7 Predicted and measured current direction during spring and neap tides (final)

4.6 Model Results

4.6.1 Tidal Currents

The modelling exercise produces results for two distinct physical processes; hydrodynamics and sediment transport. Hydrodynamic results in the form of predicted currents are presented in this chapter in order to allow an appreciation of how sediment plumes might behave. More importantly, a review of the results and a comparison of spatial trends provide an additional form of verification that the model is accurately reproducing the key driving forces.

Tidal currents are plotted;

- Figure 4.8: Spring tide during flood phase.
- Figure 4.9: Spring tide during ebb phase.
- Figure 4.10: Neap tide during flood phase.
- Figure 4.11: Neap tide during ebb phase.

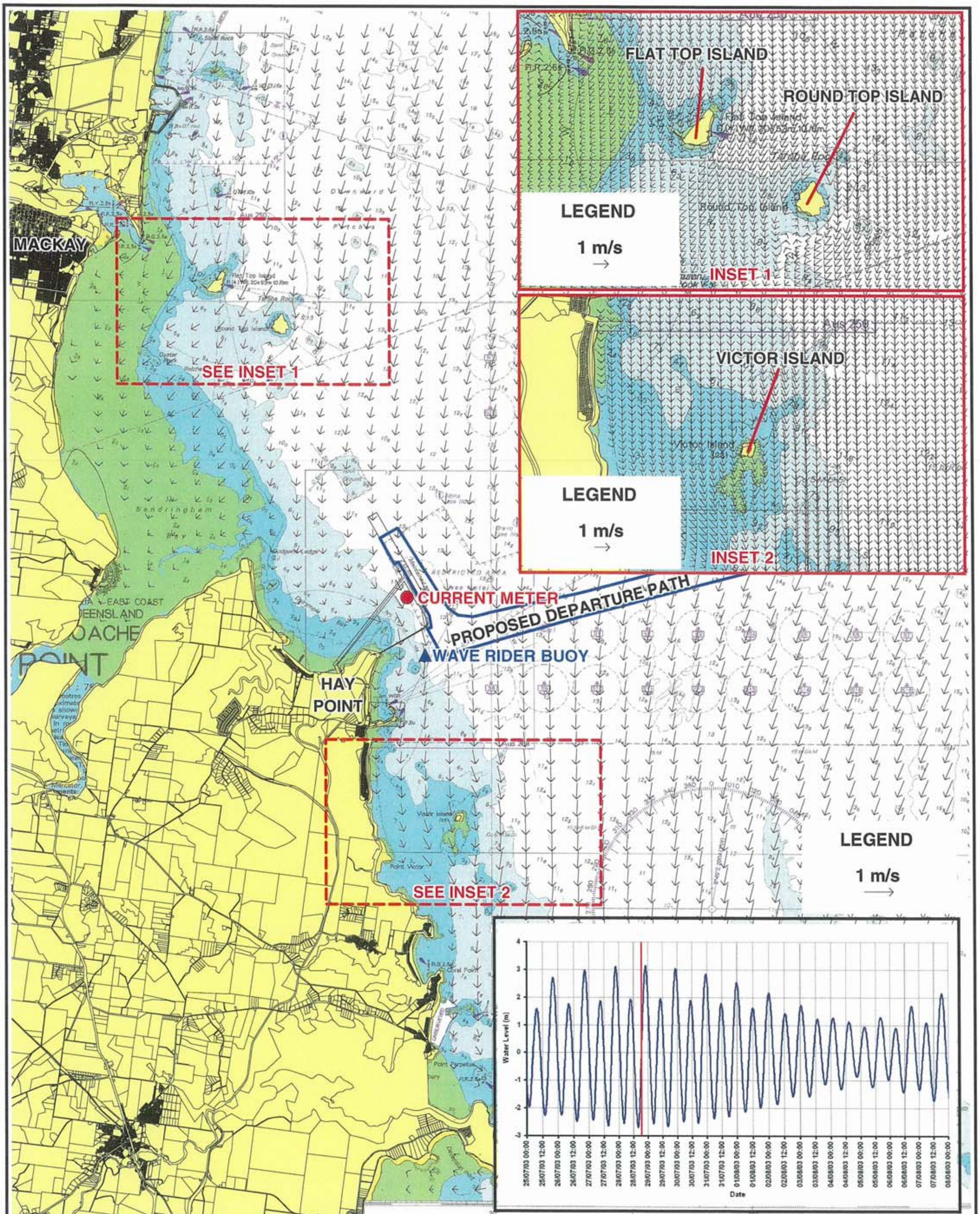
Figure 4.8 shows the general directions of the offshore current during spring flood tides are south southwest. An eddy is shown to occur in the wake of Round Top Island. Low velocities can be expected around Dalrymple Bay and the tidal flat in Sandringham Bay.

Figure 4.9 shows the general directions of the offshore current during spring ebb tides are north northeast. Low velocities are shown in the wake of the islands, and around Dalrymple Bay and Sandringham Bay.

Figure 4.10 shows the general direction of the offshore currents during neap flood tides is south. A small eddy is shown to form in the wake of Round Top Island. Low velocities can be expected around Dalrymple Bay and the tidal flats in Sandringham Bay.

Figure 4.11 shows the general direction of the offshore current during neap ebb tides is east. Low velocities are shown in the wake of the islands, Dalrymple Bay and around the tidal flats in Sandringham Bay.

Animations of tidal currents were also created and viewed as part of the verification process. t should be noted that whilst the following figures indicate the prevailing direction of tidal flows, different directions of flow occur during the change of tide (i.e., from flood to ebb and ebb to flow).



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CURRENT MAGNITUDE AND DIRECTION SPRING - FLOOD TIDE 27 JULY 2003

FIGURE 4.8

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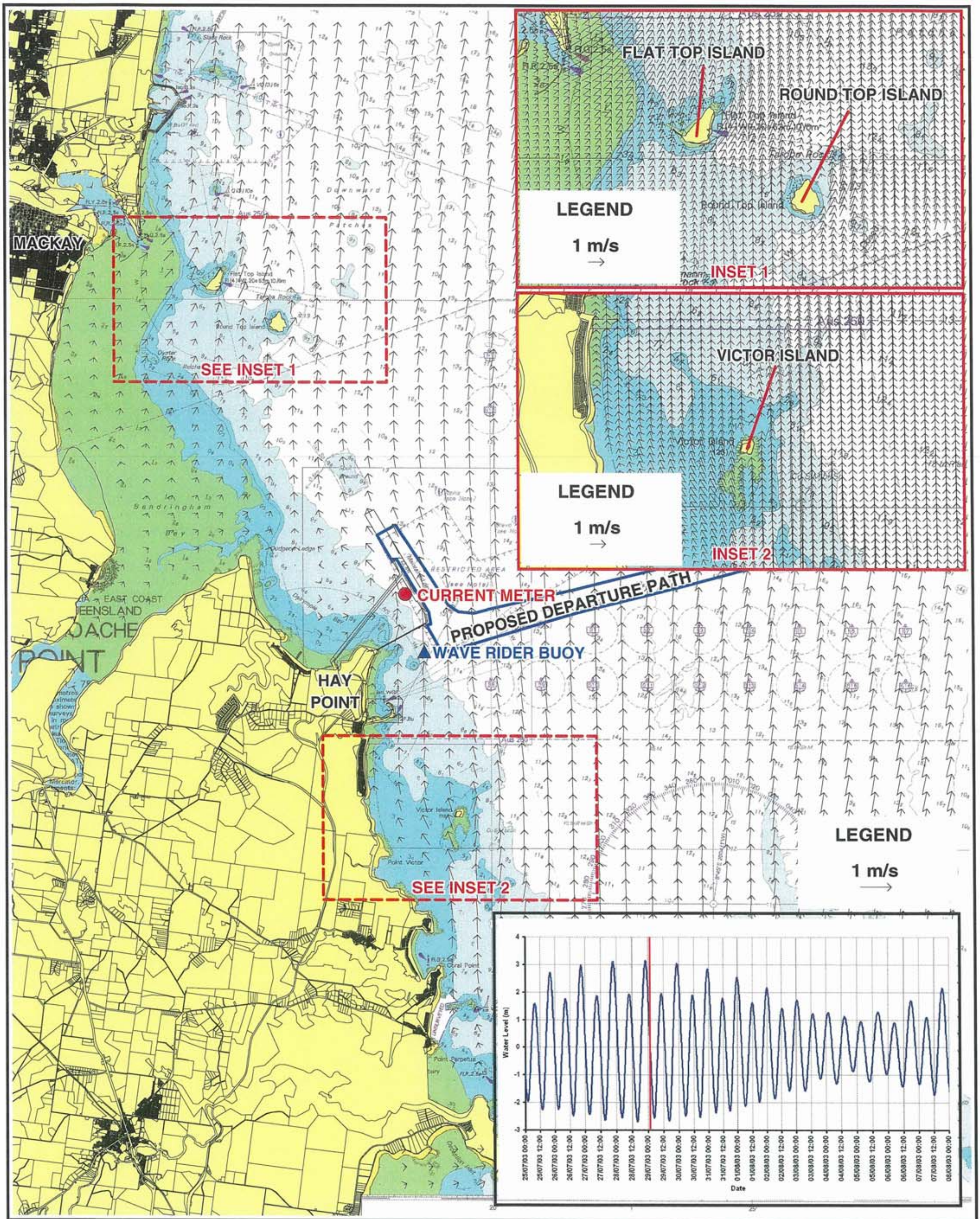

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CURRENT MAGNITUDE AND DIRECTION SPRING - EBB TIDE 27 JULY 2003

FIGURE 4.9

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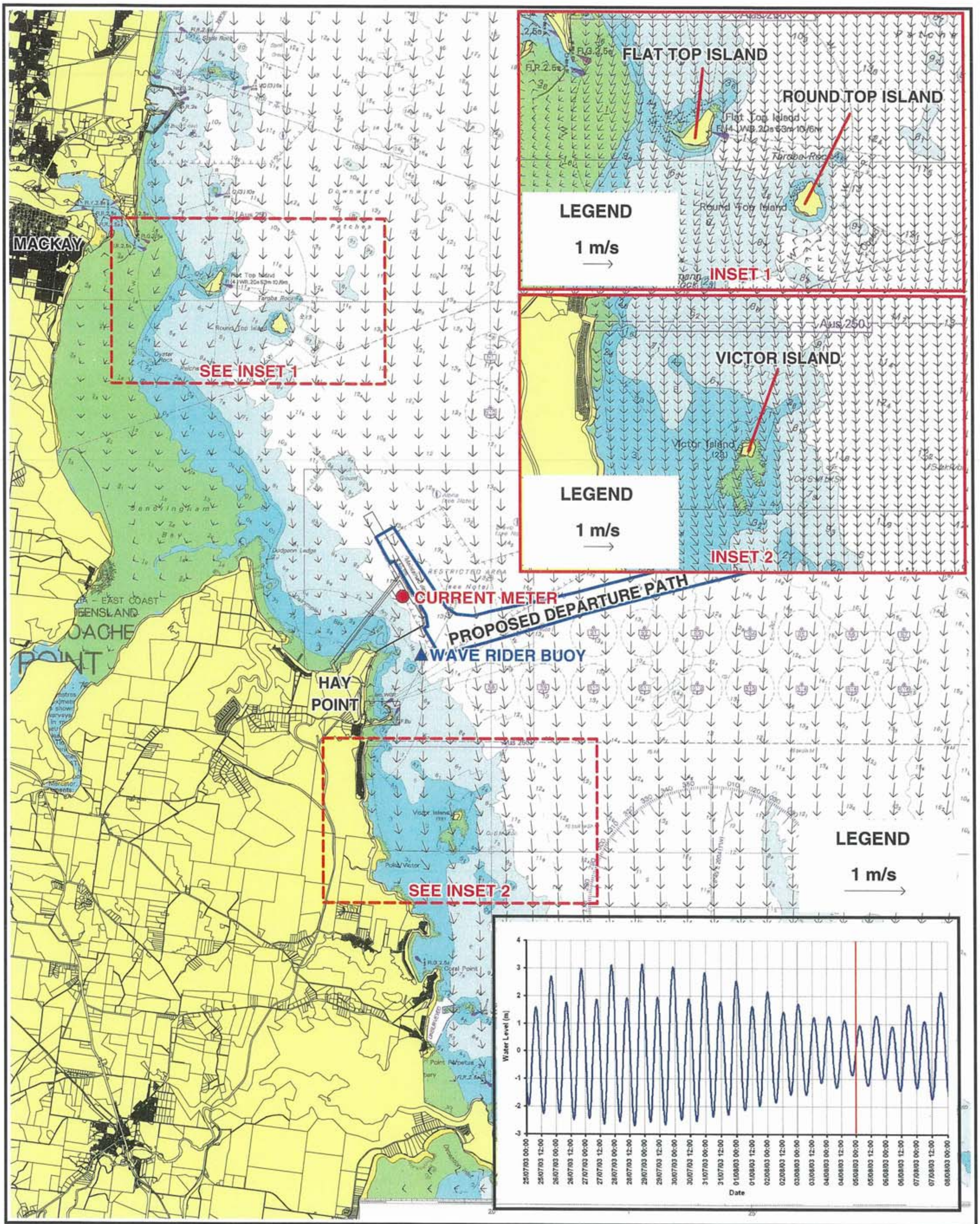

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FIGURE 4.10

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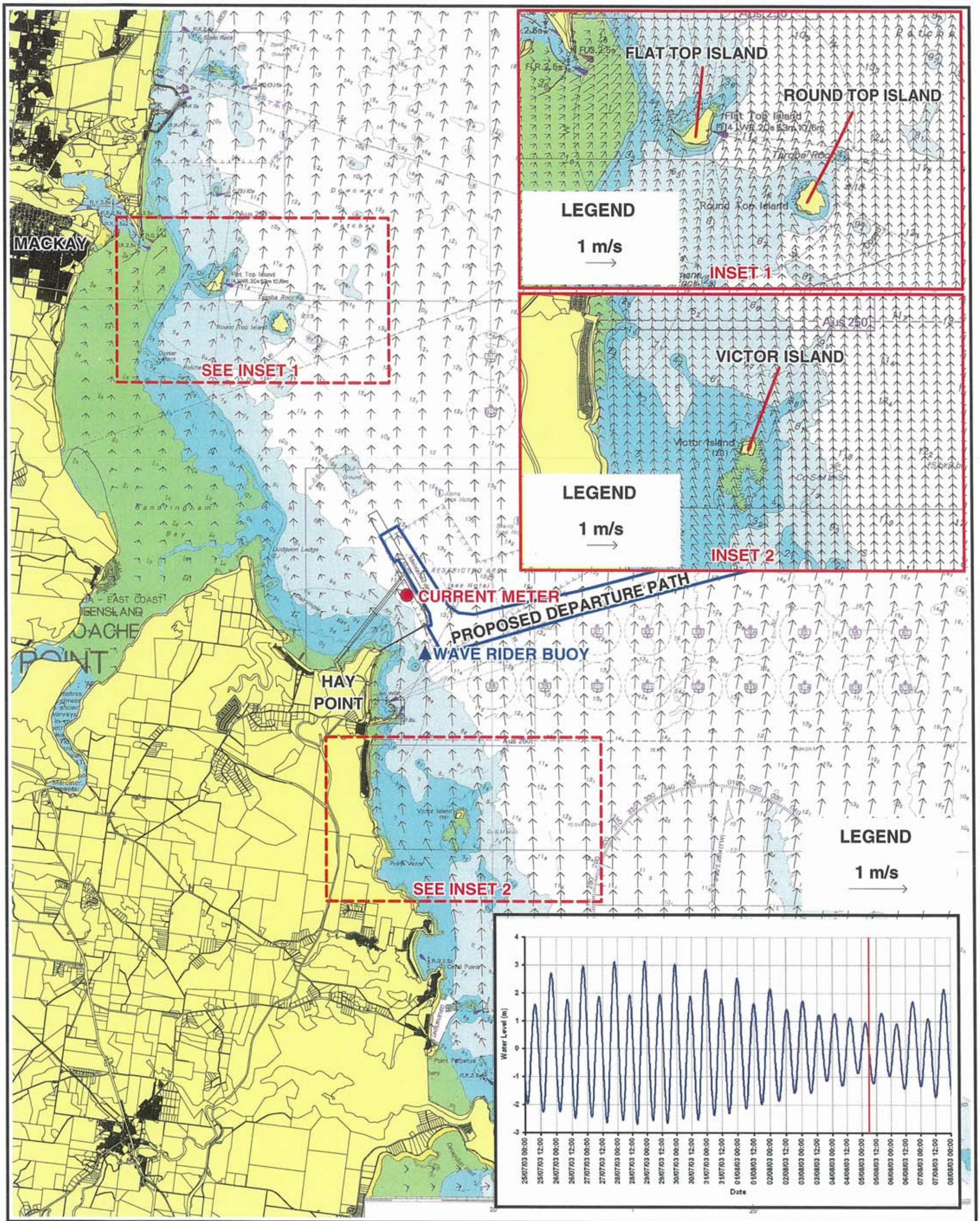

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NEAP - EBB TIDE
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FIGURE 4.11

PCQ Ports Corporation of Queensland

4.6.2 Impact of 'Post-dredge' Bathymetry on Coastal Processes at Hay Point

As a consequence of capital works dredging, there will be two major changes to the bathymetry in the vicinity of Hay Point. These changes are listed below and selected representative cross-sections plotted in Figure 4.12:

- The formation of the departure path and apron (invert -14.9 m LAT), and
- A raised spoil ground (+820 mm) at completion of the dredging campaign.

The potential effects of those changes on hydrodynamics (currents) were assessed through the creation of a difference map obtained by subtracting 'post-dredge' from 'pre-dredge' results (refer to Figure 4.13 to Figure 4.16).

It is apparent from Figure 4.13 to Figure 4.16 that changes to the coastal processes in Hay Point are minimal. The following conclusions are reached:

- Maximum change in velocity does not exceed 0.06 m/s and maximum change in direction does typically does not exceed 6 degrees over the area of interest with one or two maximums reaching 30 degrees;
- The changes in current magnitude are confined to the vicinity of the departure path and spoil ground;
- Maximum changes to current direction are observed during the flood phase of the tide near the coast at Hay Point (Figure 4.14) and during the ebb phase of tide in Dalrymple Bay (Figure 4.16). It is worth noting that these changes are associated with low current magnitudes (less than 0.01 m/s) developing at the core of the two eddies presented in Figure 4.9 and Figure 4.10 respectively. For the purpose of the present study, changes in current direction at the core of the eddies are considered minor instabilities that can be safely neglected. These changes are not a trustworthy indicator of the potential impact of bathymetric changes on the hydrodynamics. It is also noted that the intensity of the changes decreases with the increase of current magnitude towards the outer boundary of the eddies; and
- Dredging of the departure path results in a decrease in current magnitude.

In summary, it is concluded that the change in bathymetry as a result of the dredging operations will not have any significant impact on current magnitudes and directions at the port.

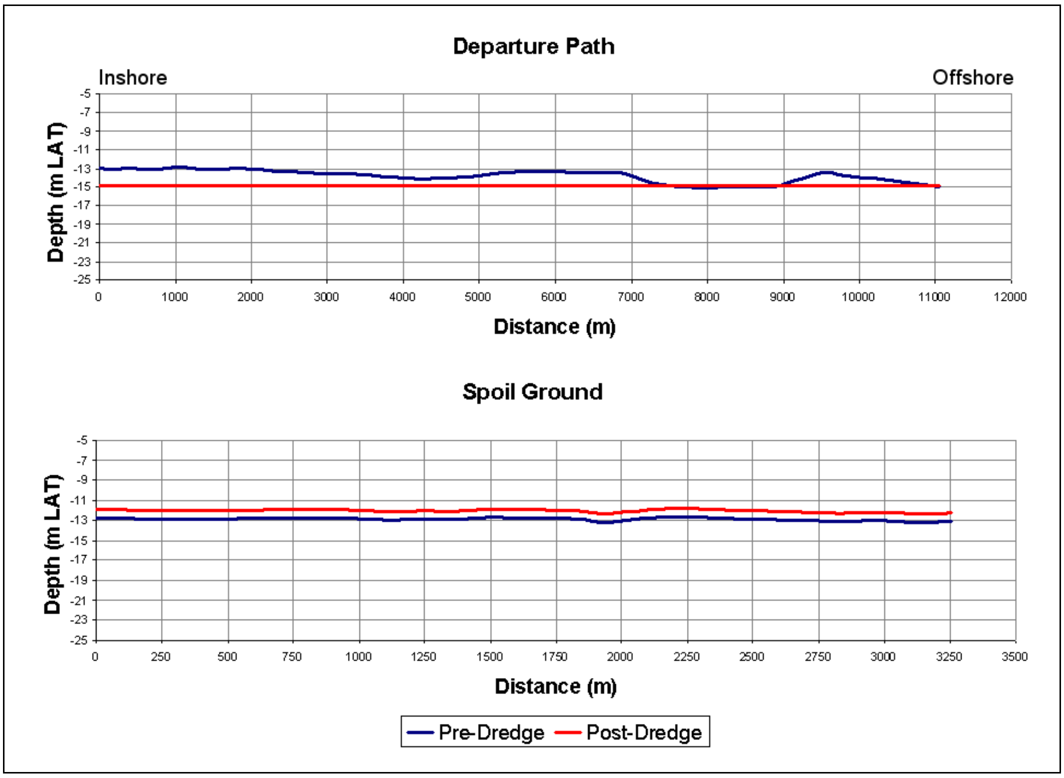
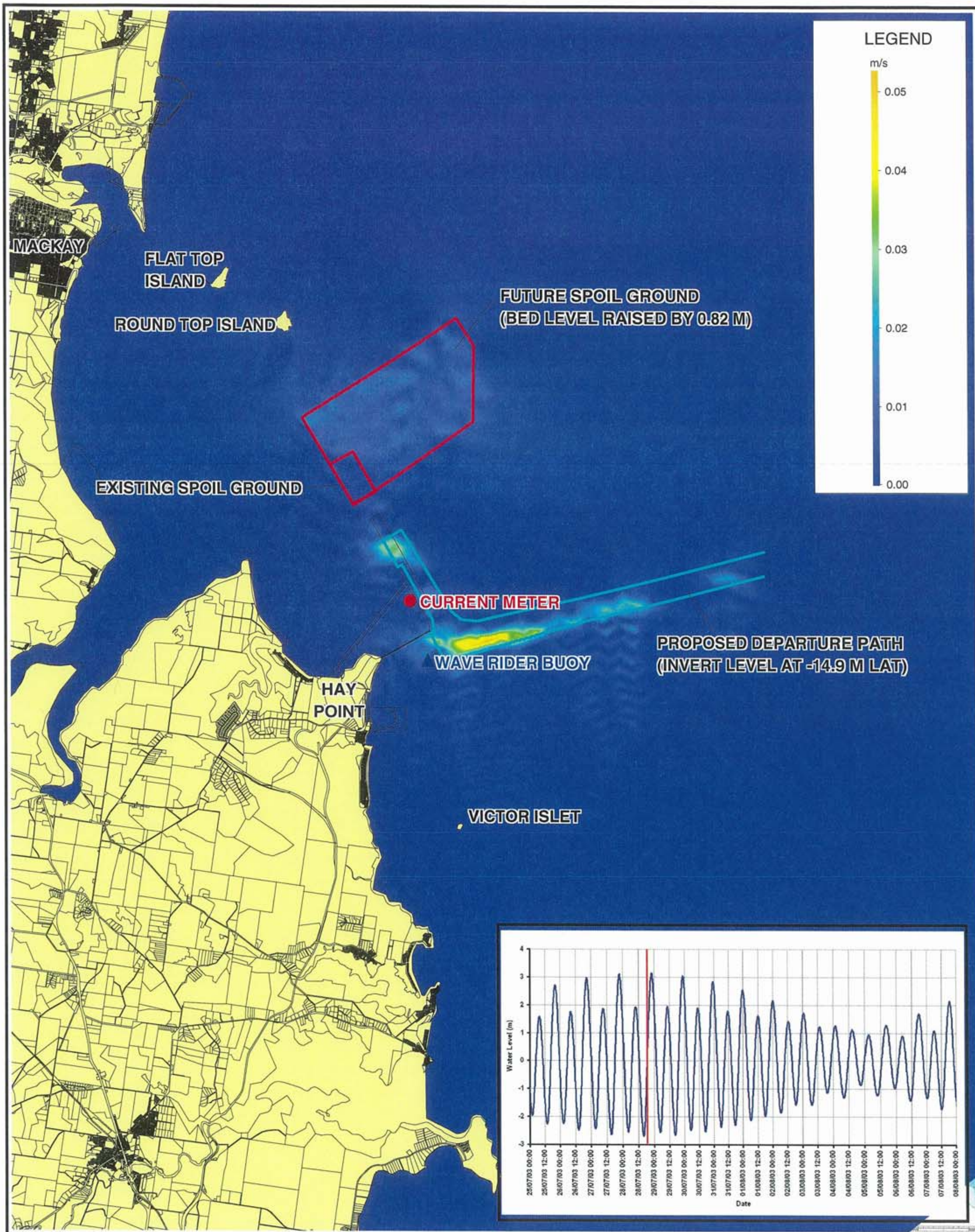


Figure 4.12 Change in bathymetry for Departure Path and Spoil Ground



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DIFFERENCE IN CURRENT MAGNITUDE DURING FLOOD PHASE OF THE SPRING TIDE, 27 JULY 2003

FIGURE 4.13

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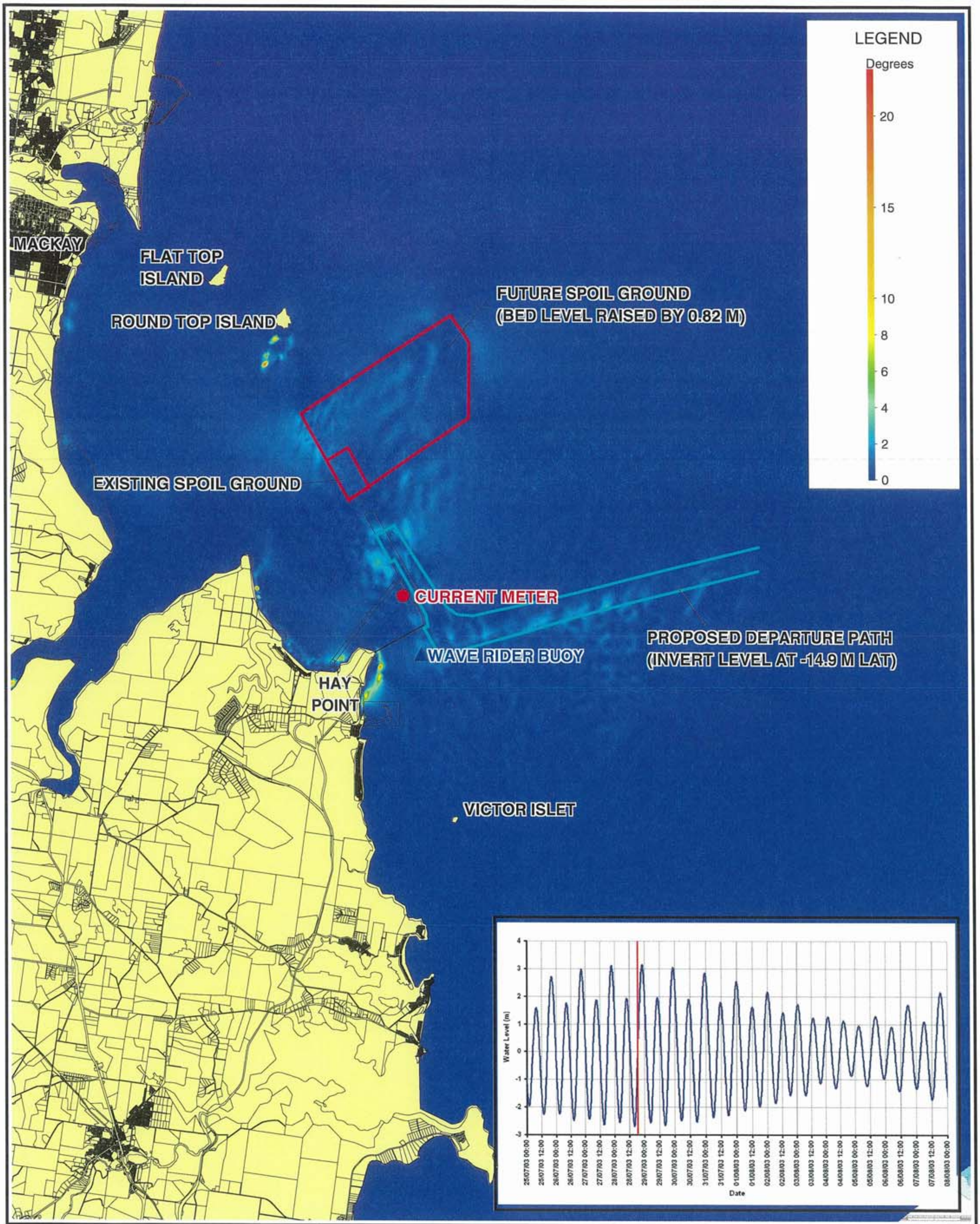

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DIFFERENCE IN CURRENT DIRECTION DURING FLOOD PHASE OF THE SPRING TIDE, 27 JULY 2003

FIGURE 4.14

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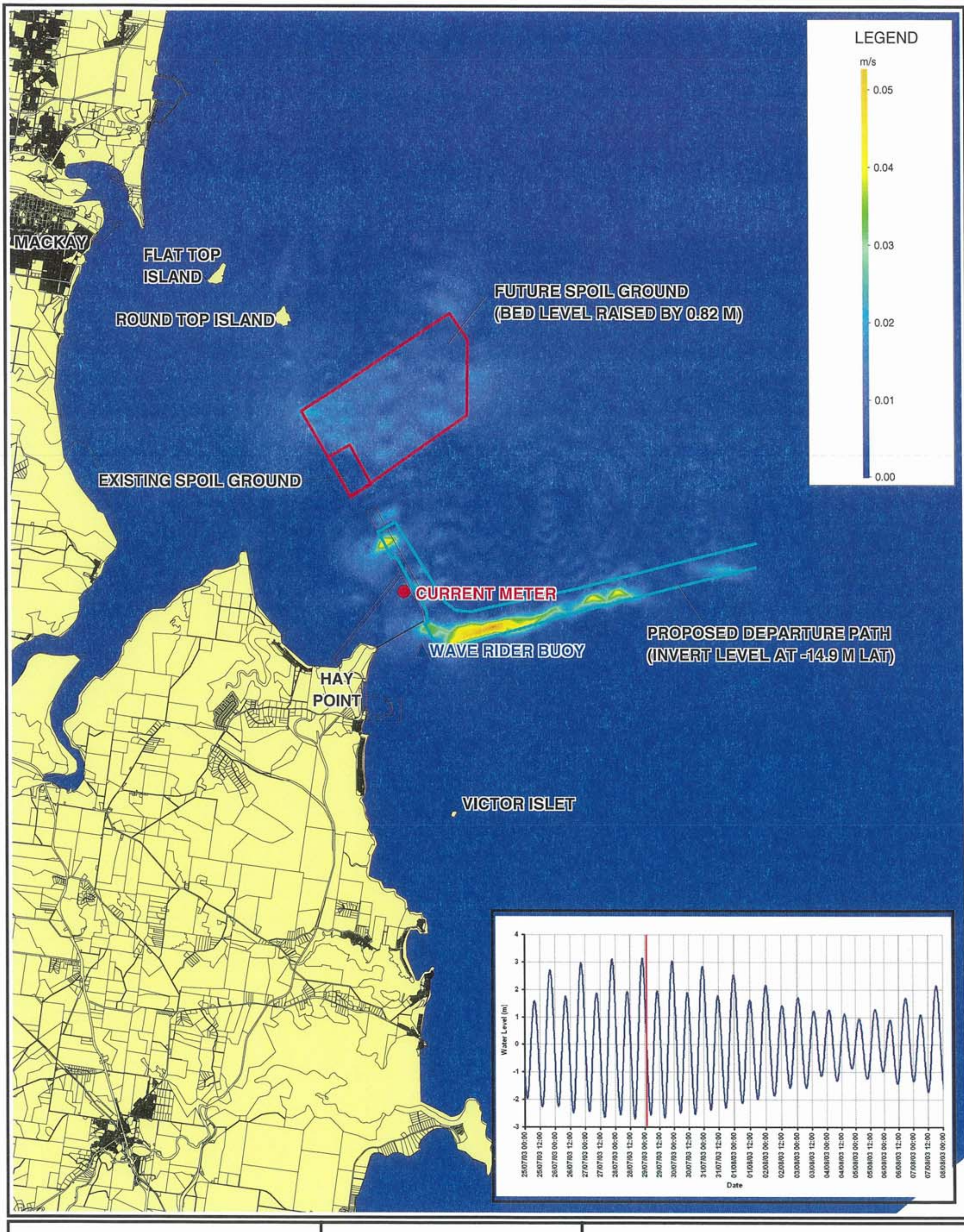

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DIFFERENCE IN CURRENT MAGNITUDE DURING EBB PHASE OF THE SPRING TIDE, 27 JULY 2003

FIGURE 4.15

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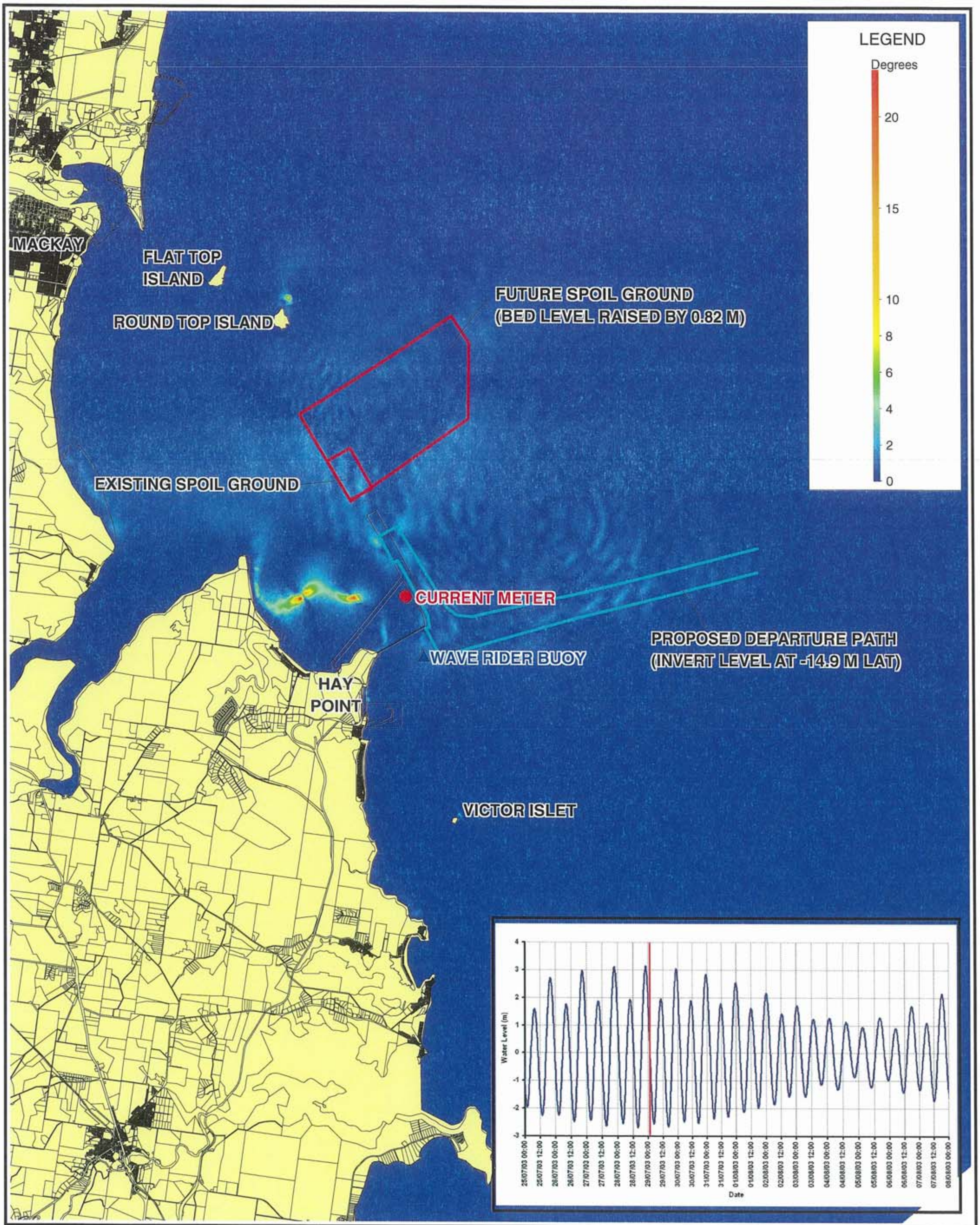

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DIFFERENCE IN CURRENT DIRECTION DURING EBB PHASE OF THE SPRING TIDE, 27 JULY 2003

FIGURE 4.16

PCQ Ports Corporation of Queensland

5. Wave Modelling

In addition to tidal currents, wave processes often provide another important physical mechanism for moving sediment through the coastal zone. This chapter evaluates the impact of waves on sediment transport at Hay Point.

5.1 Purpose of Wave Model

An implementation of the fully spectral, third generation SWAN wave model (developed by Delft University of Technology) has been used for the wave modelling carried out in this study. The purpose of the modelling was to:

- Represent the nearshore wave transformation process (resulting from refraction, shoaling and breaking) for the typical wave climate near Hay Point; and
- Evaluate the near-bed wave orbital velocity (a key parameter for re-suspension of bed sediment) and compare against the threshold orbital velocity for motion of sediment by waves.

5.2 Data

Wave data for the project was obtained from EPA's Datawell 0.7 m Waverider Buoy installed at Hay Point (Latitude: 21° 16.40'S; Longitude: 149° 18.70'E) (refer Figure 5.1) and consisted of:

- annual time history plots;
- curves showing the percentage (of time) exceedence of wave heights for all wave periods and;
- histograms correlating the occurrence of wave heights to wave periods.

The data is presented in Appendix A with the most significant aspects of it summarised below.

In total, 17397 records collected during the 2002-2003 period have been used in the analysis. For all data collected during this period, the most frequent significant wave height H_S is in the range of 0.2-0.4 m (27% of the time), followed by the 0.4-0.6 m range (22%) and the 0.6-0.8 m range (18%). With respect to the wave period T_P, the data indicates that wave period in the range of 3.0-5.0 s has the highest percentage of occurrence (64% for all data), followed by the 5.0-7.0 s range (14%) and the 1.0-3.0 s range (9%).

With dredging constrained to the period from May to September, it is noted that monthly averages for wave height during this period exceed only slightly (by 0.03 m) the all data average of H_S = 0.60 m (refer Figure 7.5, Appendix A). In addition, there is minimal seasonal delineation in the data, i.e., the percentage of occurrence of wave period T_P in the range of 3.0-5.0 s is 63% for the winter season and 67% for the summer season. Similarly, the percentage of occurrence of significant wave height H_S

in the range of 0.2-0.4 m is 28% during the winter season and 27% during the summer season.

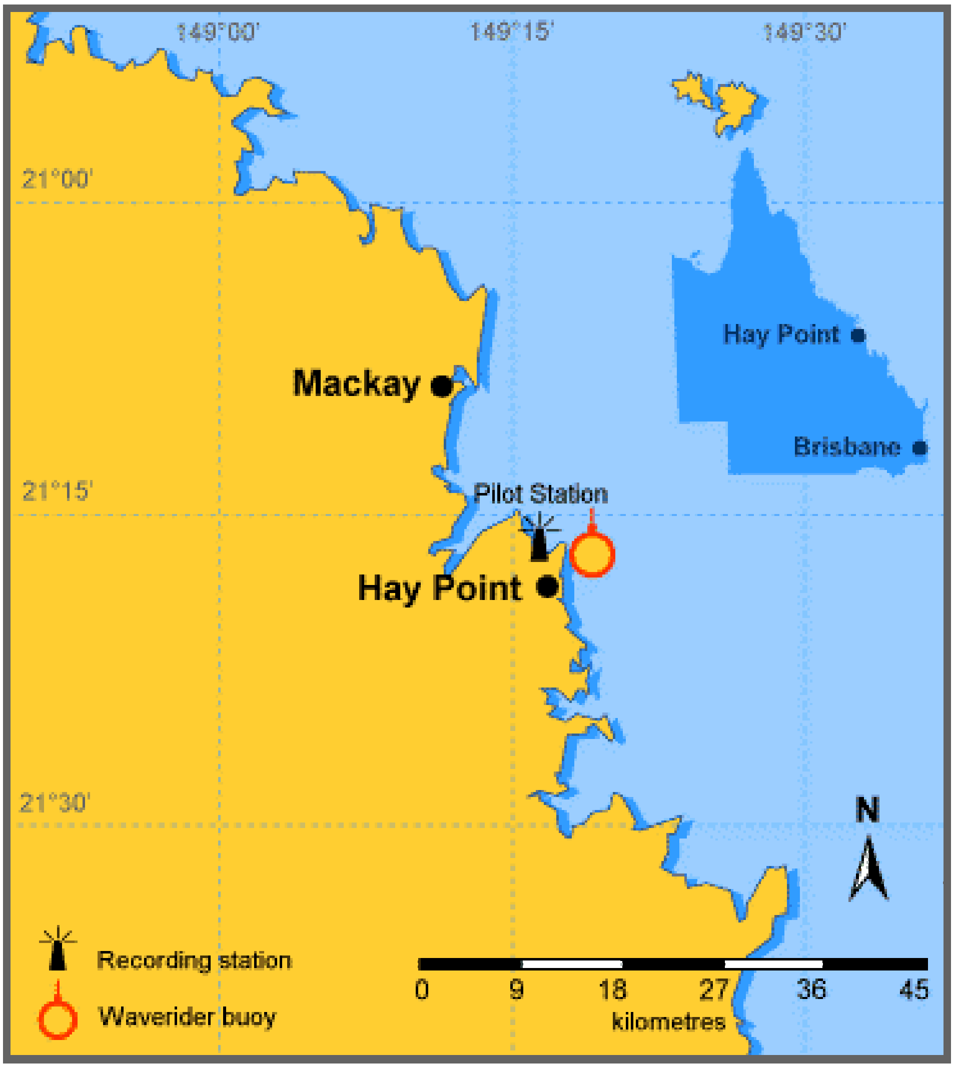


Figure 5.1 Location of the EPA Waverider buoy at Hay Point

Directional wave data from the Mackay Waverider buoy (refer rose of wave height distribution in Figure 5.2) was used to provide incident wave information at the up-wave boundary of the model. In the figure, the colour scale indicates the magnitude of wave height, the circular axis represents the direction of wave approach (coming from) relative to North (0 degrees), and the extending radial lines indicate the percent occurrence within that magnitude and directional band.

The wave climate is characterised by waves incident from the east-southeast (55% of the time) and southeast direction (15%) with only a minor contribution from the north (<

5%). Wave heights from the southeast quadrant lie in the range of 0.5 to 1.5 m for approximately 60 % of the time.

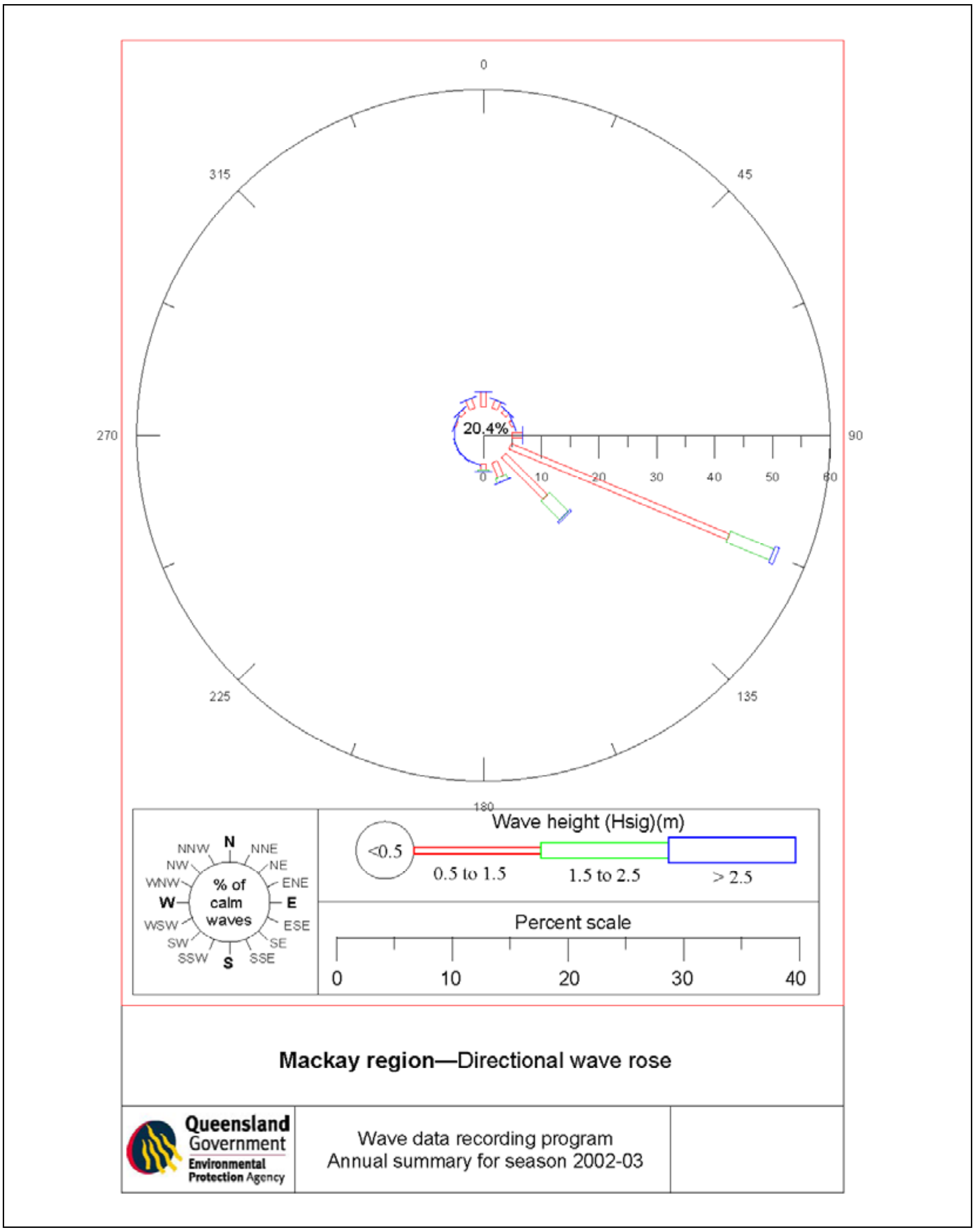


Figure 5.2 Directional wave rose for Mackay

5.3 Model Establishment

A rectangular grid of uniform spacing (200x192 grid cells of 400 m spacing) has been prepared. This stretches from north to south along the Queensland coast between approximately -20° 55' and -21° 30' degrees of latitude and reaches beyond 150°00' east. The extent of the wave model is shown in Figure 5.3.

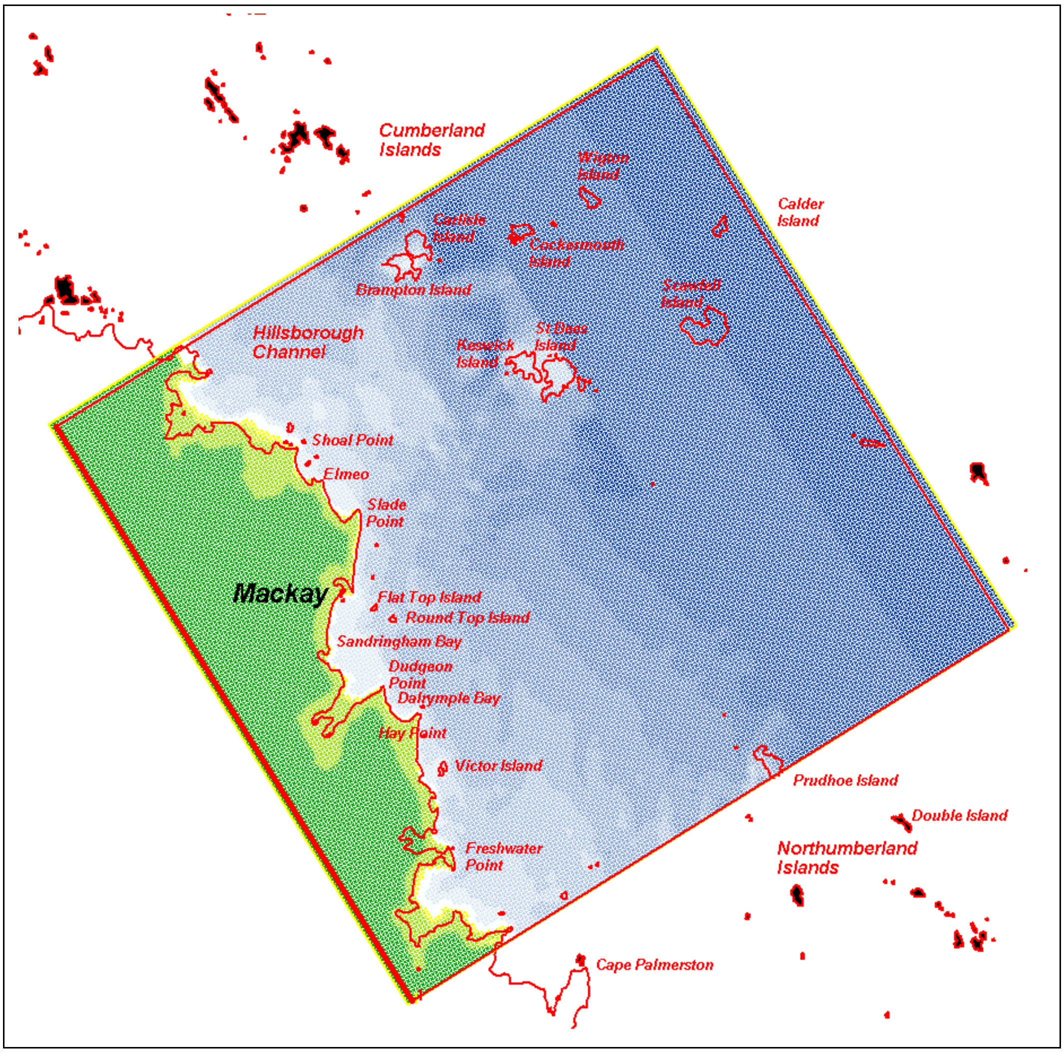


Figure 5.3 Wave model and bathymetry

The primary driving mechanism for the wave model was conceived as a combination of swells and wind fields. Swell conditions at the up-wave boundary (facing SE in Figure 5.3) were defined in terms of:

- a constant significant wave height H_S (the average of the highest one-third of the waves in the record) corresponding to a ten-year wave event;

- a range of mean wave period T_P yielding typically measured wave periods at the wave rider buoy (80% occurrence of time); and
- constant wave direction and directional spread.

The wind fields used in the simulation were spatially and temporally constant. Table 5.1 lists the adopted wave modelling parameters. Six series of 5 runs each for a total of 30 runs have been simulated. As seen from Figure 5.4, each series has been designed to represent a particular wave climate. For example, series 160-164 represents the prevailing wave climate (lower end of significant wave heights) typical for dredging and sediment disposal operations whereas series 140-144 explores wave climates under storm weather conditions used for path design purposes. Wave modelling series 160-164 have been calculated for two wind speeds – 3 and 5 m/s.

Table 5.1 Wave modelling parameters

Item #	Wave Parameter	Adopted Value
1	Significant wave height (m)	0.1 - 2.0
2	Mean wave period (s)	3.0 - 8.0
3	Wave direction (degrees nautical)	120
4	Width energy distribution (degrees)	15
5	Wind direction (degrees nautical)	120
6	Wind speed (m/s)	3.0 - 8.0

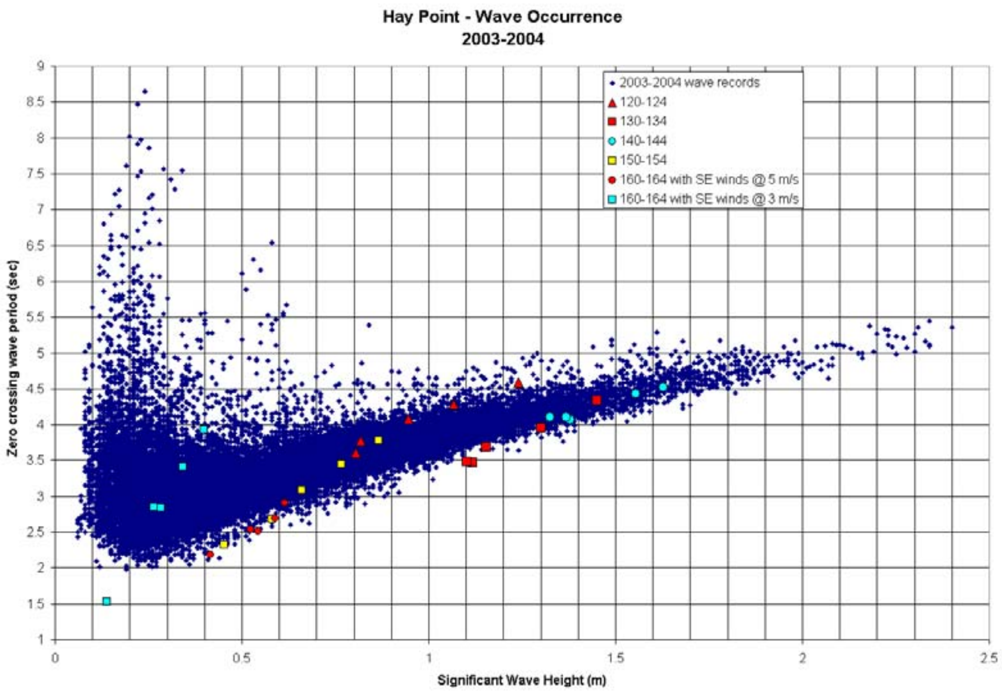


Figure 5.4 Comparison of predicted versus measured wave climates at Hay Point

Additional data set-up was as follows:

- The directional resolution in the spectrum was set to $\Delta\theta = 10^{\circ}$; the frequency resolution was set to $\Delta f / f = 0.1$ between 0.055 Hz and 1.0 Hz.
- A JONSWAP spectrum was adopted at the up-wave boundary with a peak enhancement factor of 3.3. For the bottom friction effects the formulation from JONSWAP is taken with the friction coefficient $\Gamma = 0.067\, m^2 / s^3$ for fully developed wave conditions in shallow water.
- Depth-induced wave breaking is modelled by a spectral version of Battjes and Jansen wave breaking model resulting in a dissipation, which does not affect the shape of the spectrum itself. For the breaking coefficient $\gamma = 0.73$.

5.4 Model Results

Significant wave height, mean wave period and bottom orbital velocity have been calculated along five near-shore transects oblique to the coast and uniformly distributed to capture the trend and rate of transformation of wave parameters within the study area (numbered dotted lines in Figure 5.5). With the area of interest (apron area and departure path) being situated in relatively deep water, transects 3 to 5 do not extend beyond the 15 m depth contour Chart Datum (LAT). All depths have been assumed relative to mean sea level.

Typical results of the calculation (series 160-164@ 3m/s, low energy wave conditions, Transect 3) are presented in Figure 5.6 through Figure 5.8. The definition of low energy wave conditions is in accordance with Appendix A (Figure 7.3) indicating that significant wave heights of H_S = 0.2 to 0.4 m have approximately 27% probability of occurrence during the winter season. This is the highest probability of occurrence followed by a probability of occurrence of 21% corresponding to the range of significant wave heights of H_S = 0.4 to 0.6 m.

Based on the presented results, the following remarks can be made:

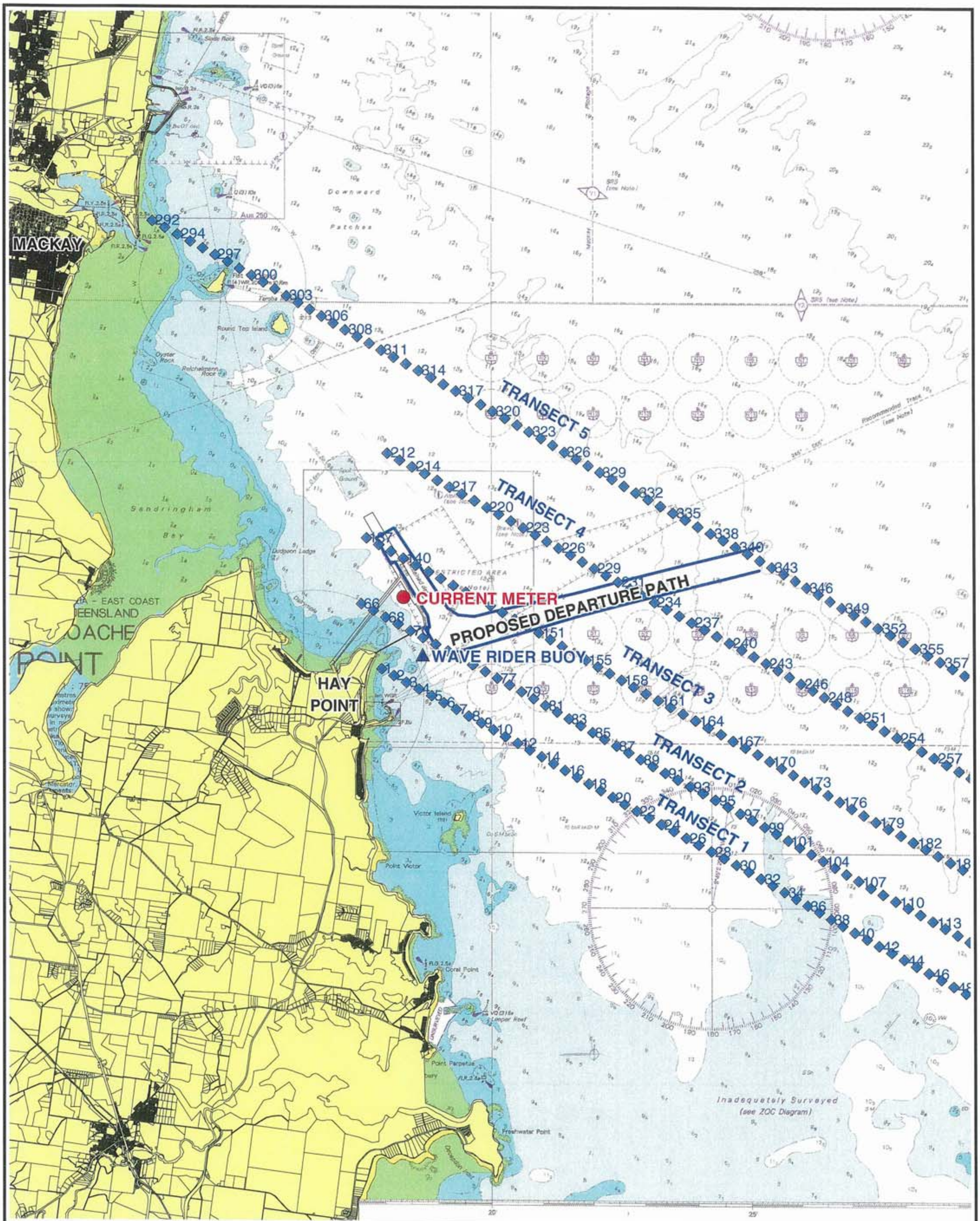
- In general, wave heights along transect 3 (Figure 5.5) are in the range of H_S = 0.15 m to H_S = 0.40 m for mean wave period varying in the T_P = 1.5 s to T_p = 4.0 s range in the study area (equivalent to T_p = 5.0 s to T_p = 6.0 s range at the up-wave boundary); there is minor energy dissipation as waves advance toward the shoreline, i.e., there is little variation of wave height along the transect;
- Computed mean wave period is in the range of T_p = 3.0 s to 4.0 s corresponding to approximately 65% of the wave period measured at the wave rider buoy (refer Figure 5.6).
- Maximum bottom orbital velocities do not exceed 0.05 m/s along the transect and experience only a minor increase (< 0.01 m/s) when a transition from 17 m of depth to a depth of 15 m occurs over a distance of approximately 500 m (refer Figure 5.7).

The implications of the wave modelling results with respect to sediment transport can be assessed using the relationship between sediment particle size (non-cohesive material) and threshold orbital velocity for motion of sediment by waves presented in

Figure 5.9. As seen from the figure, under the prevailing low energy wave climate (i.e. typical for the winter period when dredging operations are being undertaken) no sand particles are likely to be re-suspended from the surface of the seabed.

However, finer material (silt and clay), if unconsolidated (i.e., loose particles dispersed on the seabed following a placement operation) may still be subject to re-suspension.

Results for the remaining transects 1, 2, 4 and 5 confirm that there is only minor variation of the above parameters along the transects.



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TRANSECTS UNSED IN WAVE ANALYSIS

FIGURE 5.5

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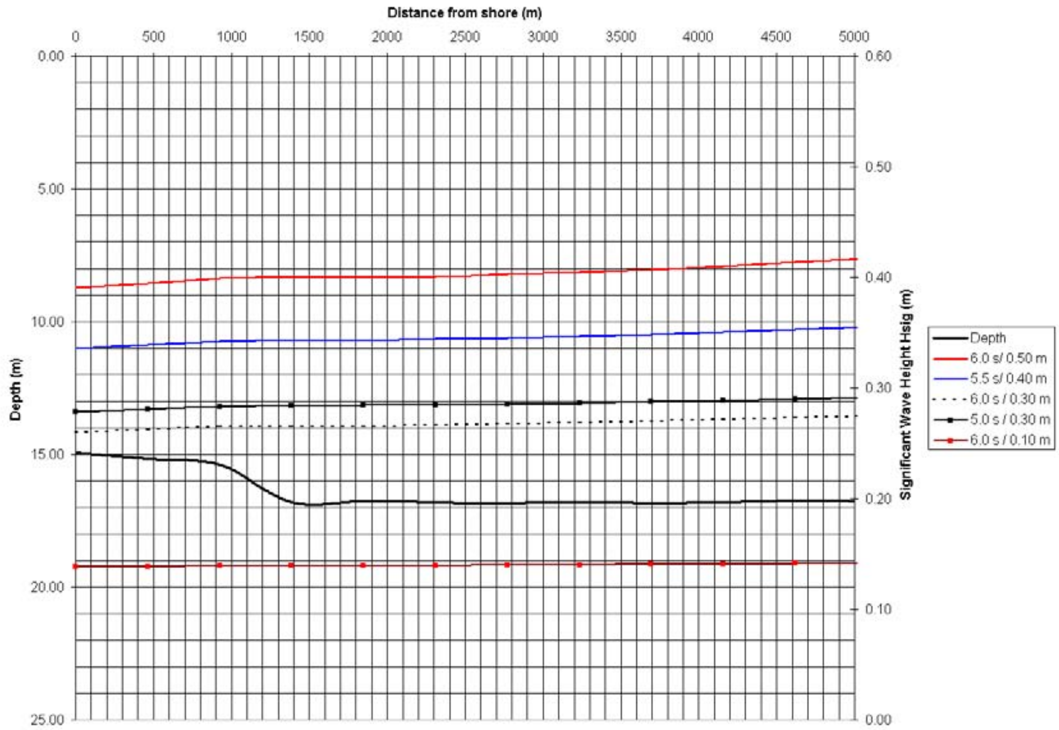


Figure 5.6 Distribution of significant wave height along transect 3 for five combinations of mean wave period T_P and significant wave height H_S at the up-wave boundary

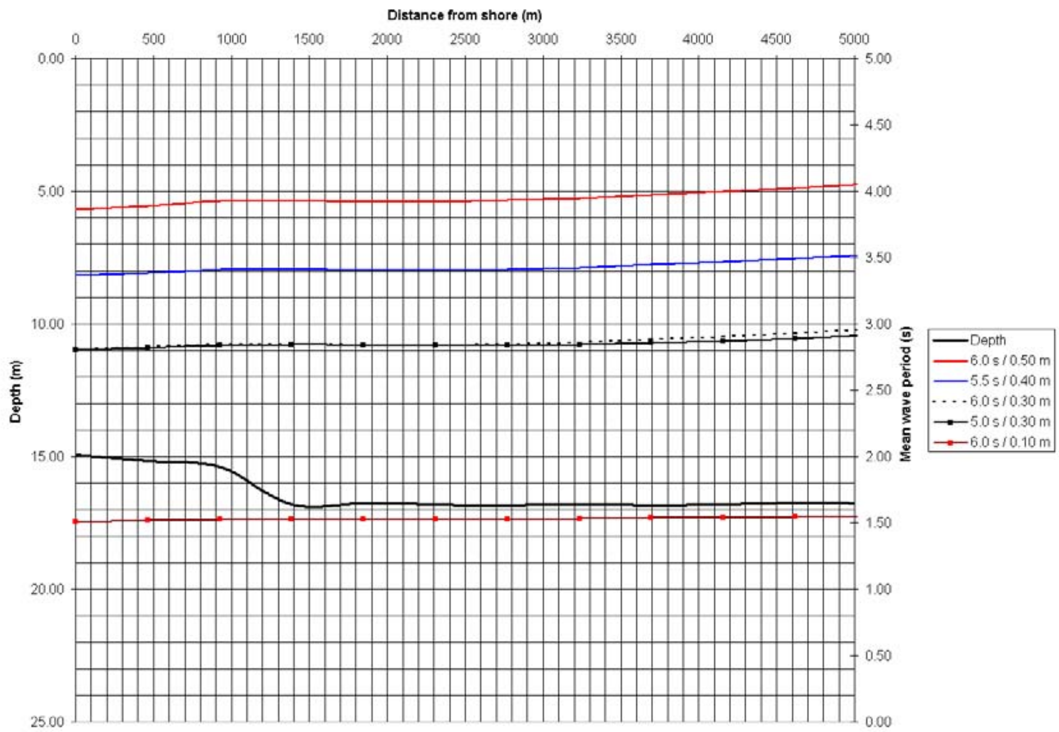


Figure 5.7 Distribution of mean wave period along transect 3

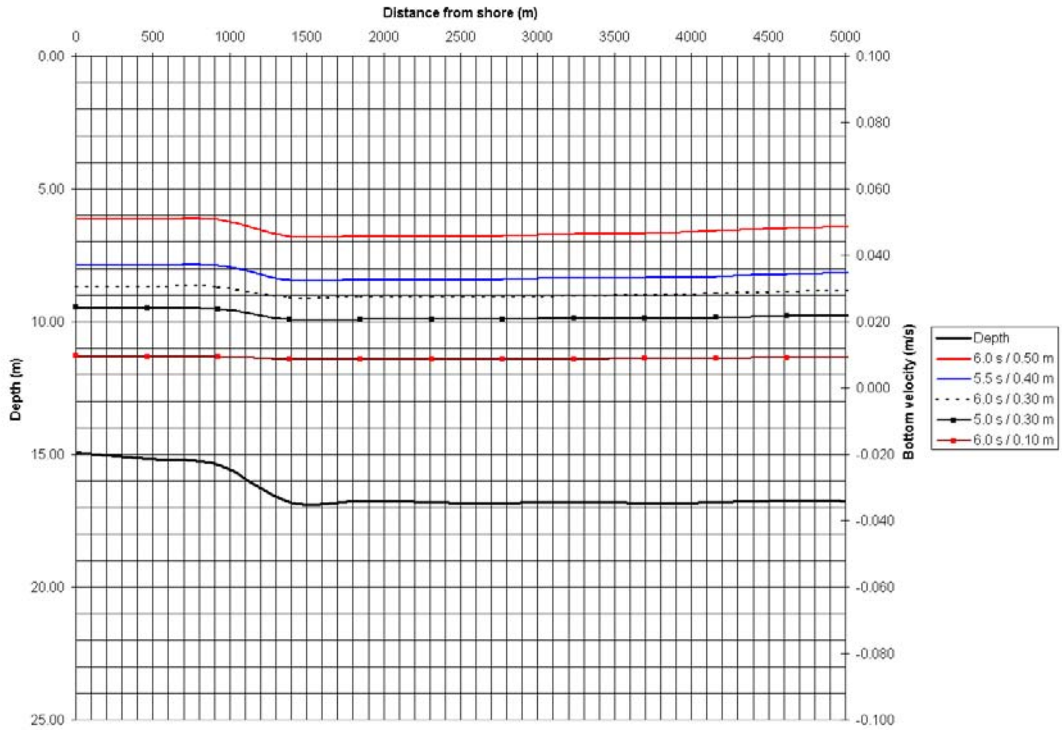


Figure 5.8 Distribution of orbital velocity at the bottom along transect 3

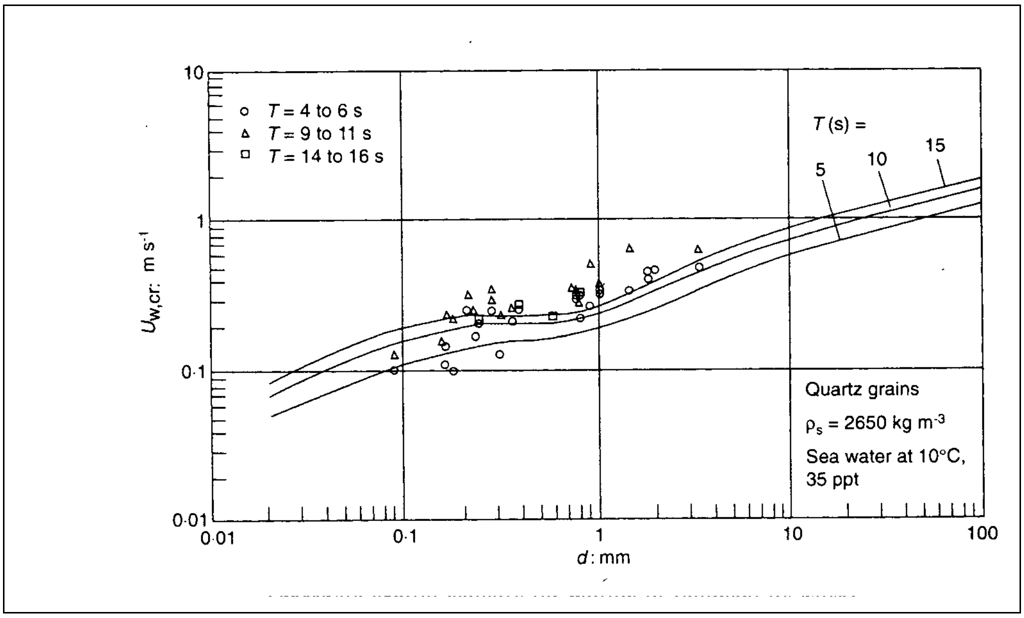


Figure 5.9 Threshold orbital velocity for motion of sediment by waves

6. Sediment Modelling

6.1 Model

Sediment modelling was undertaken using RMA 11, a 2D/3D water quality model. RMA 11 is capable of modelling a range of processes including the sediment transport of non-cohesive (sand) and cohesive sediments (clay or silt).

RMA 11 uses the hydrodynamic results from RMA 2 to produce a solution for the advection diffusion constituent transport equation. Therefore, RMA 11 has been run in 2D mode for this project.

6.2 Environmentally Sensitive Areas

Sediment modelling was undertaken to predict the potential impact of dredging on environmentally sensitive areas in the vicinity of Hay Point. These areas include waters surrounding Round Top Island, Flat Top Island and Victor Islet (refer to Figure 6.1).

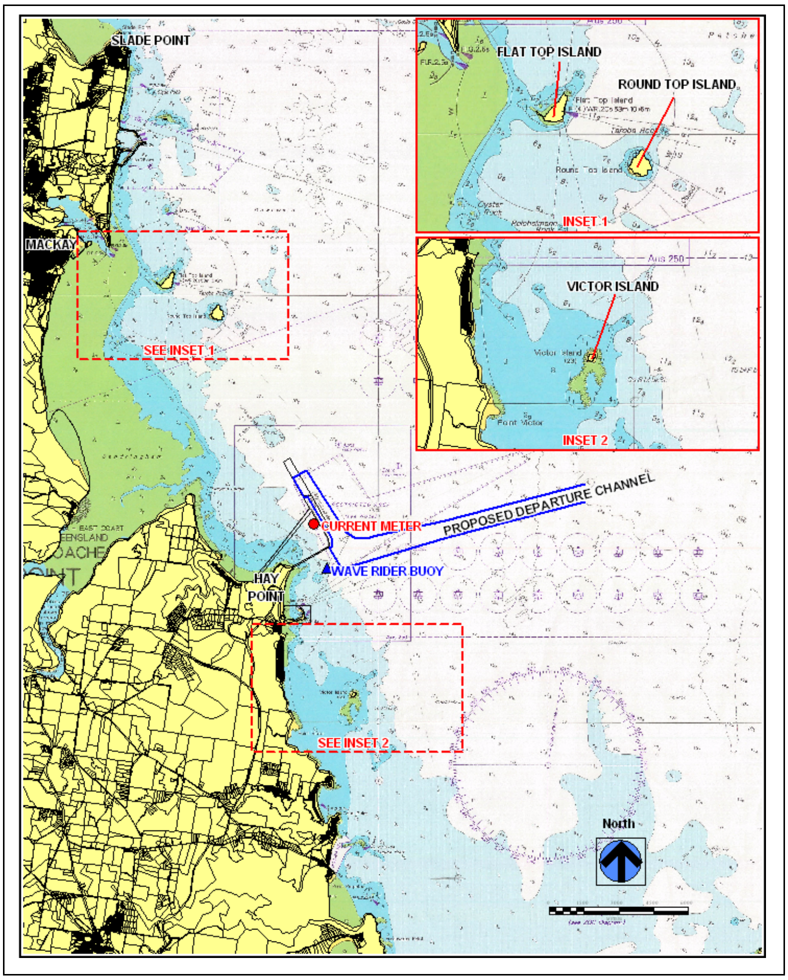


Figure 6.1 Location of environmentally sensitive areas

6.3 Model Parameters

Several input parameters are required by the model in order to predict the plume behaviour for Hay Point. The parameters adopted for the model are provided in Table 6.1.

Table 6.1 Adopted model parameters for Hay Point

Parameter	Value
Constant settling velocity [a]	0.00006
Von Karman's Constant [b]	0.4
Bed height roughness (m) for Rouse distribution calculation [b]	0.002
Number of layers of new deposits formed [d]	2
Critical shear stress for deposition of new layer (N/m^2) [a]	0.1
Density of suspending water (kg/m^3) [b]	1026
Bulk density of top layer (kg/m^3) [b]	1250
Full thickness of top layer (m) [d]	0.005
Density of sediment material (kg/m^3) [c]	2700
Erosion rate constant for bottom layer ($kg/m^2.sec$) [a]	0.00001
Kinematic viscosity of suspending water (m/sec) [b]	1.08E-06
Layer Number [d]	1 & 2
Critical shear stress of layer I (N/m^2) [b]	0.1 & 0.2
Bulk density of layer I (kg/m^3) [c]	1250 & 1300

Note:

[a] Settling velocity, critical shear stress for deposition and erosion rate constant as per UNSW (1999). Further validation of the settling velocity was obtained through laboratory analysis but written results were not available at the time of this report.
[b] Typical values.
[c] Obtained from lab analysis (GHD field campaign, 2004).
[d] Assumed.

6.3.1 Mass-Loading Rate

The source for the sediment plume is introduced into the model as a mass-loading rate at the locations where dredging and spoil disposal area to take place. The mass-loading rate is a function of the size of dredge, type of dredge and type of material being dredged. In reality, the mass-loading rate is difficult to define and not usually measured in the field. Therefore, very little information is known about the mass-loading rate for a specific dredge.

However, what has been measured and documented on occasion for past dredging campaigns is the concentration (NTU) of suspended sediments in the vicinity of the dredge and disposal site. Through knowledge of the approximate "near-field" concentrations, the sediment model can therefore be scaled to produce similar suspended sediment concentrations in the vicinity of the dredge and spoil site.

A review of near-dredge sediment concentrations was undertaken using the reports listed below.

- **WBM 1993**, 'Dredge Spoil Monitoring, Dalrymple Bay Coal Terminal, Berth #2 Extension Dredging' for Ports Corporation of Queensland (PCQ).
- **WBM 2001**, ''Aerial Surveillance of Dredging Plumes Associated with the Expansion of the Dalrymple Bay Coal Terminal, Hay Point' for Ports Corporation of Queensland (PCQ).
- **GHD 2004**, 'Maintenance Dredging Activities at Port of Hay Point, Water Quality Monitoring and Aerial Surveillance', for Ports Corporation of Queensland (PCQ).
- **SKM 2004**, 'Preliminary Advice of Findings of Hay Point (Departure Apron Area) Maintenance Dredging Turbidity Monitoring', for Ports Corporation of Queensland (PCQ).

The measured suspended sediment concentrations in the vicinity of the dredge and disposal site are summarised in Table 6.2.

Table 6.2 Near field concentrations for dredge and disposal site

Campaign	Near Dredge (mg/l)	Disposal Site (mg/l)
WBM 1993	-	7
WBM 2001	150 (Peak) 10 (Residual)	80 (peak) 5-15 (Residual)
GHD 2004	<12	<12
SKM 2004	16	<12
Adopted	30	15

Note: Assumed 1 NTU = 1 mg/l

Table 6.2 shows large variability in near field concentrations measured during past dredging campaigns though this could be attributed to actual distance from the dredge, type of material and type of dredge. For this study, representative near field concentrations of 30 mg/l (on average) for the dredge and 15 mg/l for the spoil site were adopted. It is noted, however, that instantaneous peak concentrations of 100 mg/l and above in the immediate vicinity of the dredge will occur. These are evident in the model as spikes near the dredge.

For the purpose of modelling, only the silt fractions were used to simulate the plume. Based on field experience, sand and clay (in the form of lumps) fractions tend to settle at a higher rate, thus remaining in the immediate vicinity of the dredge and spoil ground. Therefore, the model has been established to reflect a conservative approach to predicting potential impacts.

Based on experience from previous dredging campaigns, a total dredging cycle of 6 hours was adopted. This consists of 4.75 hours of overflow dredging, and 1.25 hours for sailing to the spoil ground and filling of the hopper.

When the dredge is operating in overflow mode, overflowing materials are released. For modern dredgers of the size appropriate for the works this release level would be typically approximately 8 m below water surface. However, for the purpose of modelling, a release at the sea surface has been assessed, which will lead to conservative suspended sediment predictions.

It is recommended that near field concentrations should be determined during the dredging campaign and for the sediment model to be validated accordingly.

6.4 Calibration

Calibration of the sediment model has not been possible as there are insufficient measurements available from past dredging campaigns. A valuable means for model calibration would be to obtain continuous measurements of suspended sediment concentrations for complete spring and neap tide cycles at several locations.

6.5 Results

6.5.1 Dredge Scenarios

The Hay Point model was applied to a number of different dredging scenarios, with greater emphasis placed on those cases most likely to generate the highest concentrations of suspended sediment plumes. Adopted dredge scenarios are summarised in the following tables:

Table 6.3 Preliminary runs

ID	Scenario	Description	Comment
P1	Departure path	Dredging along proposed departure path	Area to be dredged is long and narrow extending to sea (i.e. the proposed departure path). Accounts for 20% of proposed capital dredging.
P2	Apron	Dredging within apron area	Apron area is closer to shoreline, and to identified areas of sensitivity. Approximately 80% of dredging works are proposed in the apron.
P3	Western spoil ground	Apron dredging with disposal at existing (west) spoil ground	Existing spoil ground. Closer to Round Top Island, with currents passing this area passing close to the island.

ID	Scenario	Description	Comment
P4	Eastern spoil ground	Apron dredging with disposal at a new (eastern) spoil ground	Disposal area is further to sea, and hence would nominally be less likely to impact on Round Top and Flat Top Islands.

Table 6.4 Final runs

ID	Scenario	Description	Comment
F1	Apron – single dredge	Dredging of apron dredging combined with deposition at western spoil ground	As for Scenario P3 above (i.e. Western Spoil Ground)
F2	Two dredges	Simultaneous dredging of path and apron, with disposal at both of the spoil grounds under consideration. Dredge along path assumed to be moving, whereas apron dredge assumed to be stationary.	Case is designed to test how much greater suspended sediment concentrations might be if two dredges were to operate simultaneously. The benefit would be a reduction in the length of the dredging campaign.
F3	Post Works	Rerunning of wave and hydrodynamic models to allow an assessment of whether changes to currents were likely	Designed to test whether changes are detectable and/or significant enough to potentially cause changes at the shoreline. With this case applying to the post dredging scenario, there is no relevance in modelling suspended sediment plumes.

The bulk of modelled scenarios assumed the use of a single large dredge (capacity of 18,000 m^3) operating in the vicinity of the apron. This scenario represents the base case, as the results of preliminary modelling suggest that dredging at the apron has a greater potential impact than dredging along the departure path. Other points of relevance when comparing dredging of the apron and departure path are:

- The departure path is effectively further away from Round Top Island.
- Sediments found in the departure path are generally coarser than sediments found within the apron area. Hence, sediments dredged from the apron area will tend to have a smaller settling velocity, and hence remain in the water column for longer.

For the case involving two dredges, the following scenario was modelled:

- A large capacity dredge (say 25,000 m^3) operating along the departure path, and;

- A smaller capacity dredge (say 12,000 m^3) operating within the apron.

The proposed spoil ground covers an area of approximately 18 km^2. The plumes generated from disposal at the spoil ground were represented in the model as point sources located along the northwest boundary. This locates the point sources closest to the environmentally sensitive areas, and hence provides a “worst case” assessment of impact.

6.5.2 Interpreting Results

Modelling results can be influenced by any of a large number of variables, including ambient conditions, direction of wind and waves, type of dredge, physical and chemical properties of sediments, and the duration and timing of dredging. Each of these variables must be predicted as best is possible within the constraints of existing knowledge, data and experience in the area.

Further to this, the coastal environment is complex, with a series of interacting forces operating over 4 dimensions (2 dimensions in plan, plus depth (sea and air), and time)). It is therefore not feasible to represent every single combination of factors when undertaking such assessments, and hence all results must be reviewed with the knowledge of what variables have been considered. In this case, tide and waves have been modelled separately, given anecdotal evidence that for the majority of the time, turbidity levels are low (80% at less than 10 NTU according to GHD field campaign of May 2005), and hence prevailing wave conditions are unlikely to cause significant resuspension of materials.

Should a significant wave event occur during dredging, then a different pattern of suspended sediment concentrations to that predicted is likely to occur. This may take the form of a greater plume extent, albeit weaker in concentration, or the possible merging of separate plumes in the case of the two dredges working simultaneously.

The magnitude of predicted suspended sediment concentrations should also be taken as indicative, rather than absolute. The reader should focus on the predicted values in terms of the tolerance of the receiving environment, and as a means of allowing comparisons between separate cases. Therefore, to take a specific value and regard it as an absolute prediction is to misrepresent the value of the modelling process.

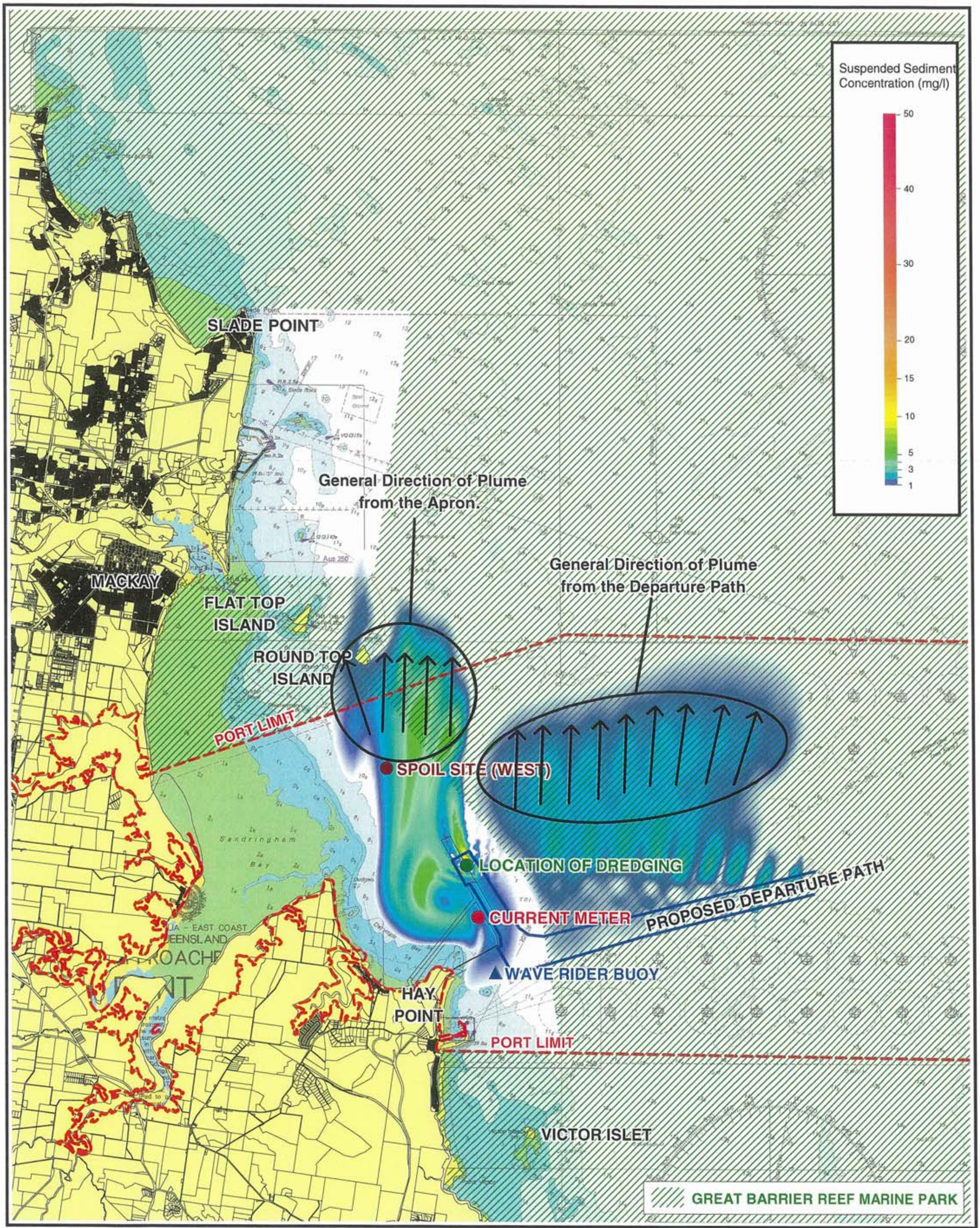
Recognition of the above issues necessitates the making of conservative assumptions (i.e. assuming the worst) in many cases, as described in the following sections of the report.

6.5.3 Preliminary Investigations

At an early stage of the study, preliminary model results indicated that the highest suspended sediment concentrations experienced at Round Top Island and Victor Islet would occur as result of dredging at the apron instead of the departure path. From the assessment of preliminary results, it was found that plume from the apron is transported by ebb currents towards Round Top Island, whilst the flood currents transports the plume towards Victor Islet.

The plume from departure path dredging is also transported north and south with the currents, but is a sufficient distance east of the islands to cause any problems. Figure 6.2 demonstrated the movement of the plumes during and ebb tide resulting from dredging at the apron and the departure path.

An assessment of preliminary results was also undertaken for disposal at the eastern versus western corner of the spoil ground. The results demonstrate that regardless of the location, the plumes from disposal are ephemeral and insignificant in comparison to the dredge plumes.



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Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

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SEDIMENT PLUME AFTER 2 DAYS OF DREDGING MOVEMENT OF PLUME FROM APRON AND DEPARTURE PATH DURING EBB TIDE

FIGURE 6.2

Ports Corporation of Queensland

6.5.4 Dredging at the Apron (Scenario F1)

The model was run for a period of 50 days. The results of the modelling are presented in Figure 6.3 to Figure 6.7 followed by discussion.

The figures are summarised below:

- Figure 6.3 Suspended sediment concentration in vicinity of Round Top Island
- Figure 6.4 Suspended sediment concentration in vicinity of Victor Islet
- Figure 6.5 Worst condition for Round Top Island during spring tide (sediment plume)
- Figure 6.6 Worst condition for Victor Islet during spring tide (sediment plume)
- Figure 6.7 Reduced sediment plume (neap tide condition)

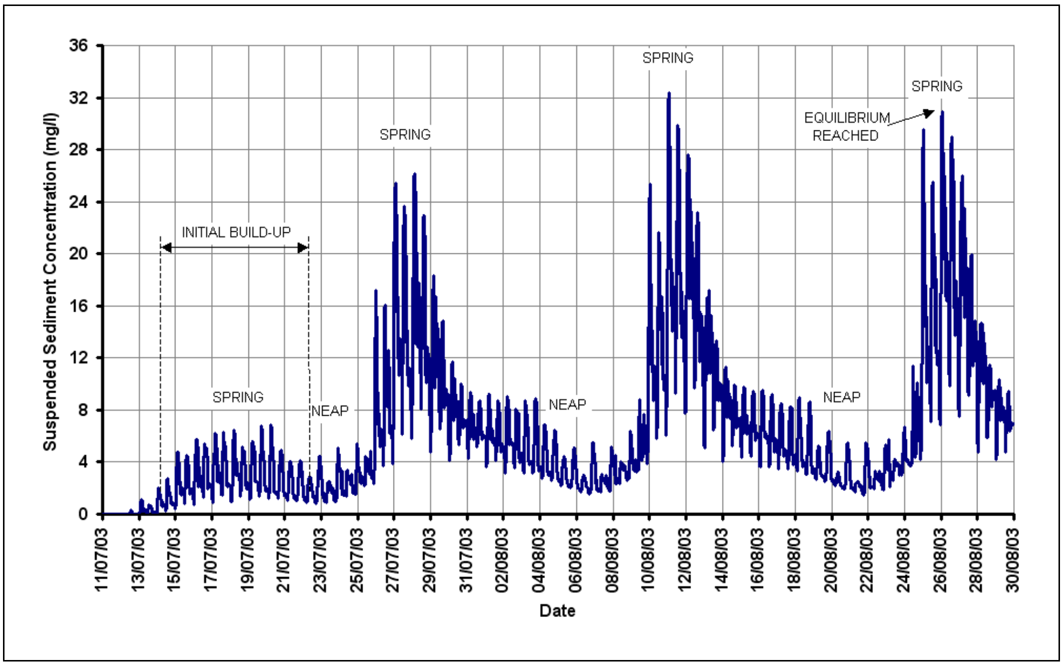


Figure 6.3 Suspended sediment concentration in vicinity of Round Top Island

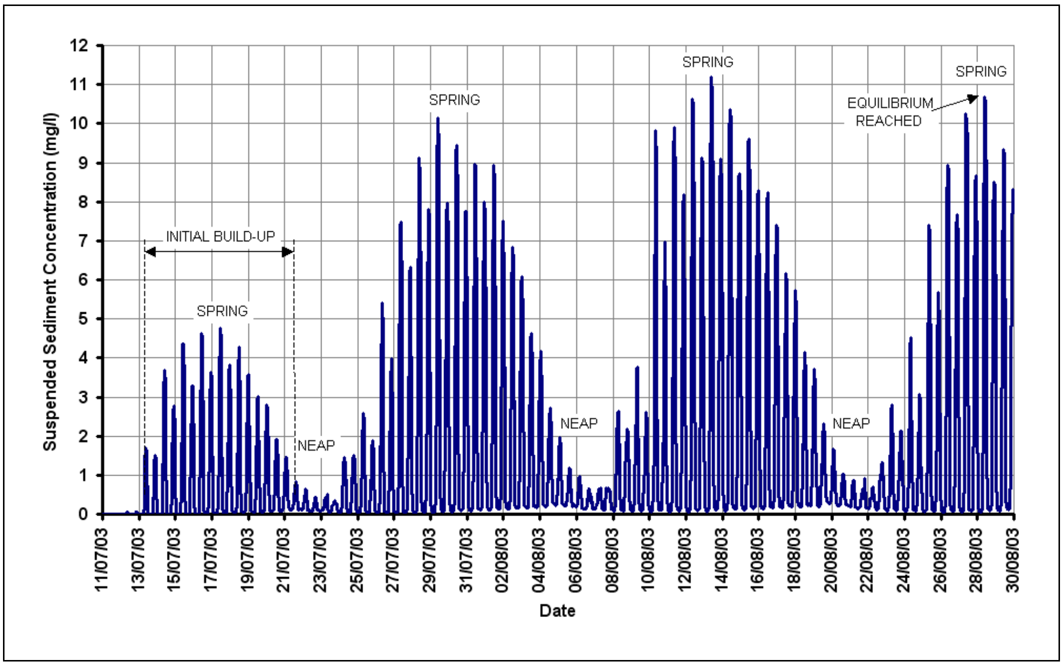


Figure 6.4 Suspended sediment concentration in vicinity of Victor Islet

Figure 6.3 and Figure 6.4 show an initial build-up of suspended sediment concentration for the initial period from commencement of dredging and spoil disposal. After the first few days, peak concentrations are reached with the trend repeated for subsequent spring and neap tide cycles. The peak concentrations around Round Top Island (approximately 32 mg/l) and Victor Islet (approximately 11 mg/l) are highest during spring tide when the plume extent is most significant. The suspended sediment concentration appears to reach equilibrium (i.e. consistent peak concentrations) after 45 days.

Figure 6.5 shows the plume covering a significant area of the coast after 31 days of dredging and spoil disposal (spring tide), representing a worst case scenario. However, the majority of the plume is at a concentration of less than 5 mg/l (approximately 16% of the adopted average concentration of 30 mg/l at the dredging site).

The maximum concentration predicted at Round Top Island for the period of simulation would be of the order of 32 mg/l. The longest continuous time period for which the concentration remains above 20 mg/l is 4 hours during a spring tide phase. However, most of the time concentrations are less than 20 mg/l and would only exceed 20 mg/l for a period of less than 4 hours. It is also evident that mild re-suspension is occurring in the tidal flats of Sandringham Bay where freshly deposited during the dredging operation, non-consolidated material is being entrained from the bottom under the effect of strong currents.

A separation of the plume from the dredge is also evident from the figure. It should be noted that separation from the source is a normal state in plume behaviour and has been observed at Hay Point during previous dredging campaigns. The separation process can be explained as follows.

Figure 6.5 captures an instance (snapshot) of the tide, i.e., slack (high) water in this case. This is a markedly transient hydrodynamic condition during which the currents experience dynamic changes in magnitude and direction over the entire coastal area. In addition to these temporal changes and owing to its significant extent, the plume is also subjected to spatial changes where the plume signature and concentration adapt to the spatially varying current fields (i.e., within the area of plume extent).

As a result of these disparities in the current fields, the plume experiences a rapid reversal in direction in the immediate vicinity of the dredge where currents are relatively strong while in Sandringham Bay, under the effect of weaker currents, the plume responds less dynamically (with less dispersion). In other words, the variability in the conditions characterising the receiving waters impacts the behaviour of the plume leading most naturally to short-lived separation from the source.

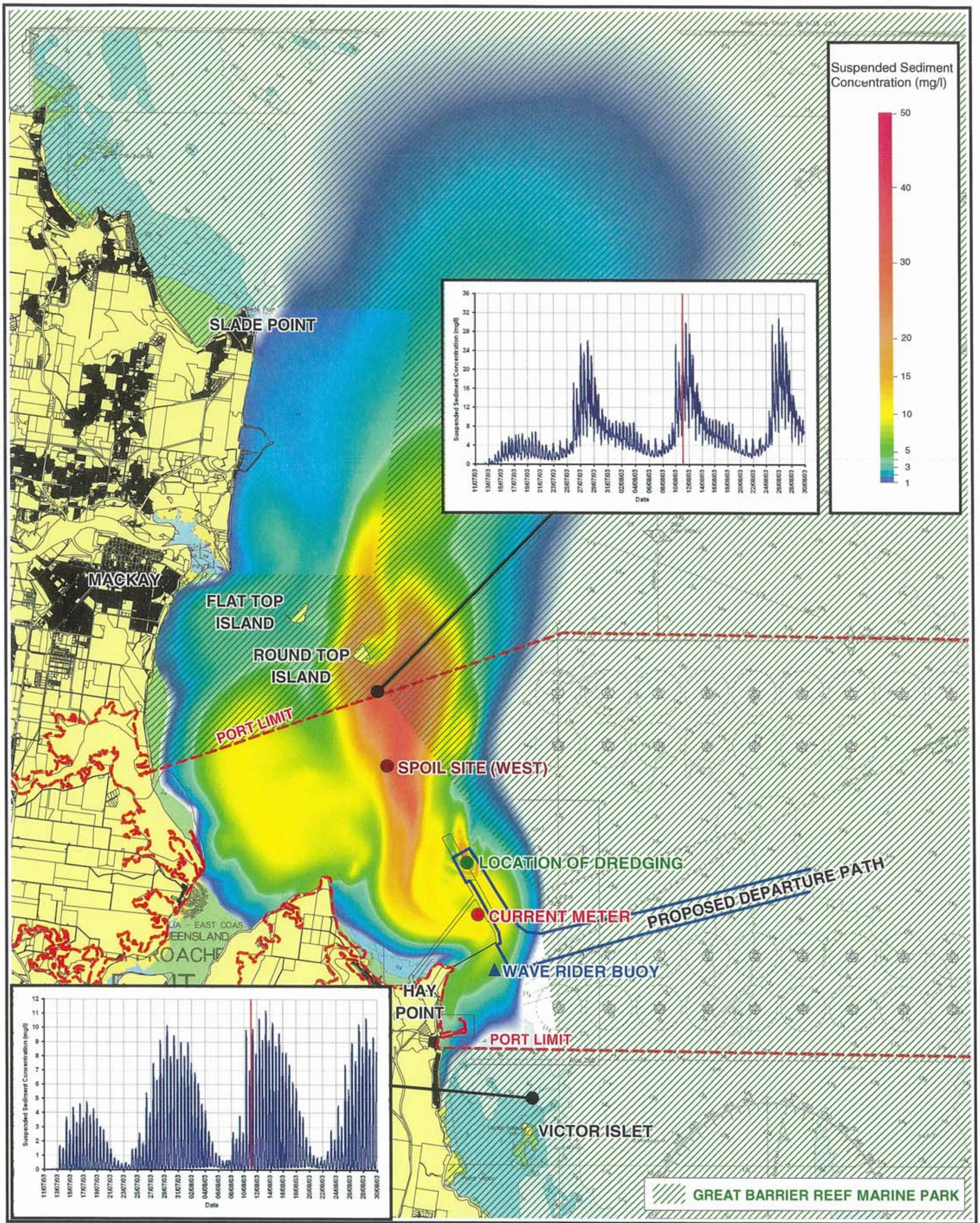
Animated sequences of snapshots showing the behaviour of the plume and the current field at different steps in time than the one represented on Figure 6.5 also indicate that disposal operations at the spoil ground contrive with reduced dispersion to maintain relatively higher plume concentrations. Irrespective of the build-up of concentration, peak plume concentrations remain below approximately 50% of the concentrations modelled in the immediate vicinity of the dredge.

Figure 6.6 (Victor Islet) demonstrates the plume at its most southerly reach during a spring tide. The maximum concentration predicted at Victor Islet was of the order of 11 mg/l. The longest continuous time period for which the concentration remains above 10 mg/l is 2 hours during spring tide. Most of the time, the concentrations are less than 10 mg/l or would only exceed 10 mg/l for a period of less than 2 hours.

Regarding plume separation, the same reasoning as for the previous figure applies.

Figure 6.7 (neap tide period) shows a similar plume extent as Figure 6.5 and Figure 6.6. However, the majority of the plume concentration is less than 5 mg/l, and appears to represent the residual plume generated during the spring cycle.

The higher concentration bands (>10 mg/l) are restricted to a smaller area around the dredge and disposal site. Maximum concentrations reached in the waters surrounding Round Top Island and Victor Islet are generally less than 8 mg/l.



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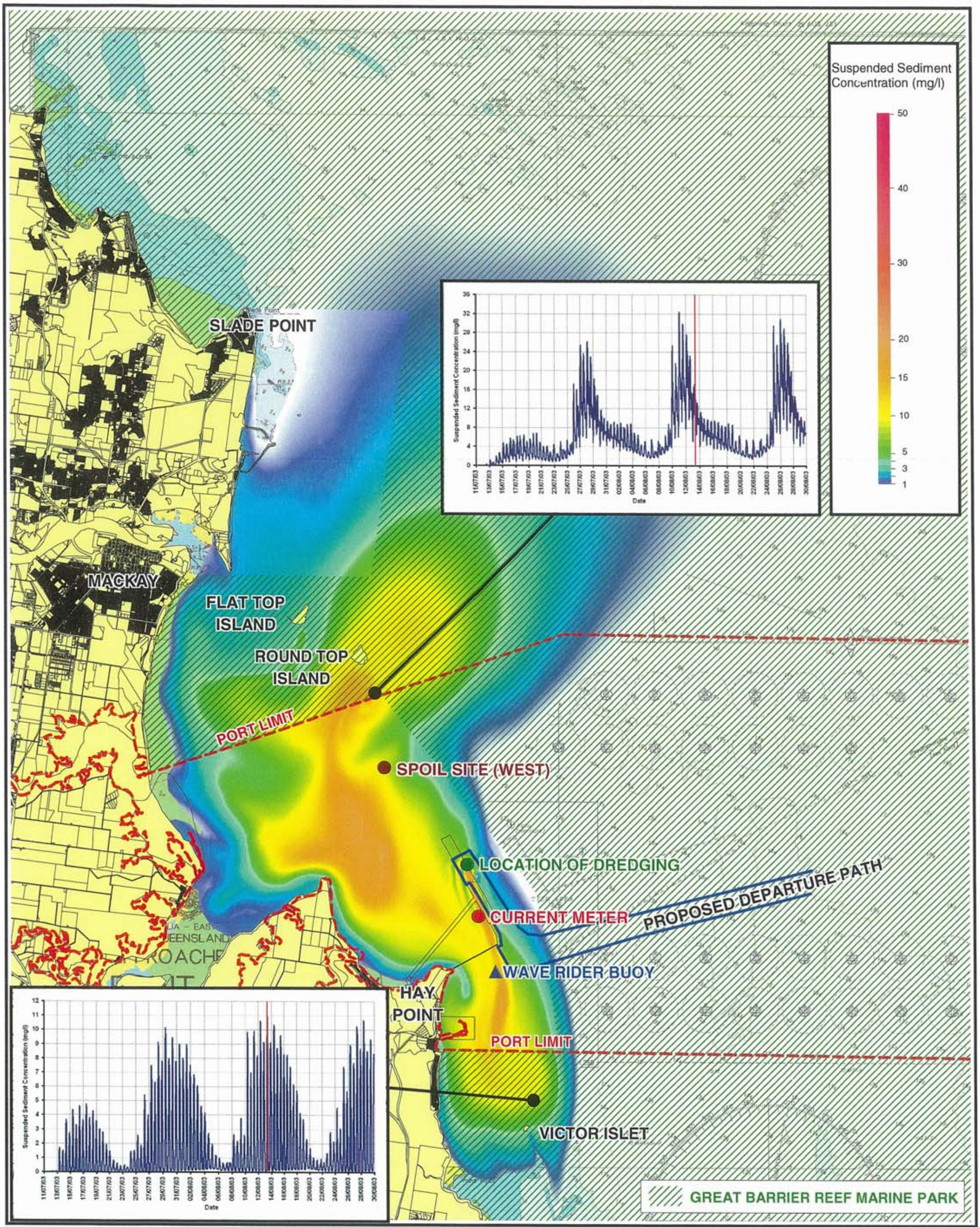
Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

HAY POINT CAPITAL DREDGING EIS

SEDIMENT PLUME AFTER 31 DAYS OF DREDGING WORST CONDITION FOR ROUND TOP ISLAND DREDGING AT APRON & DUMPING AT SPOIL SITE (WEST) DURING SPRING TIDE CYCLE

FIGURE 6.5

Ports Corporation of Queensland



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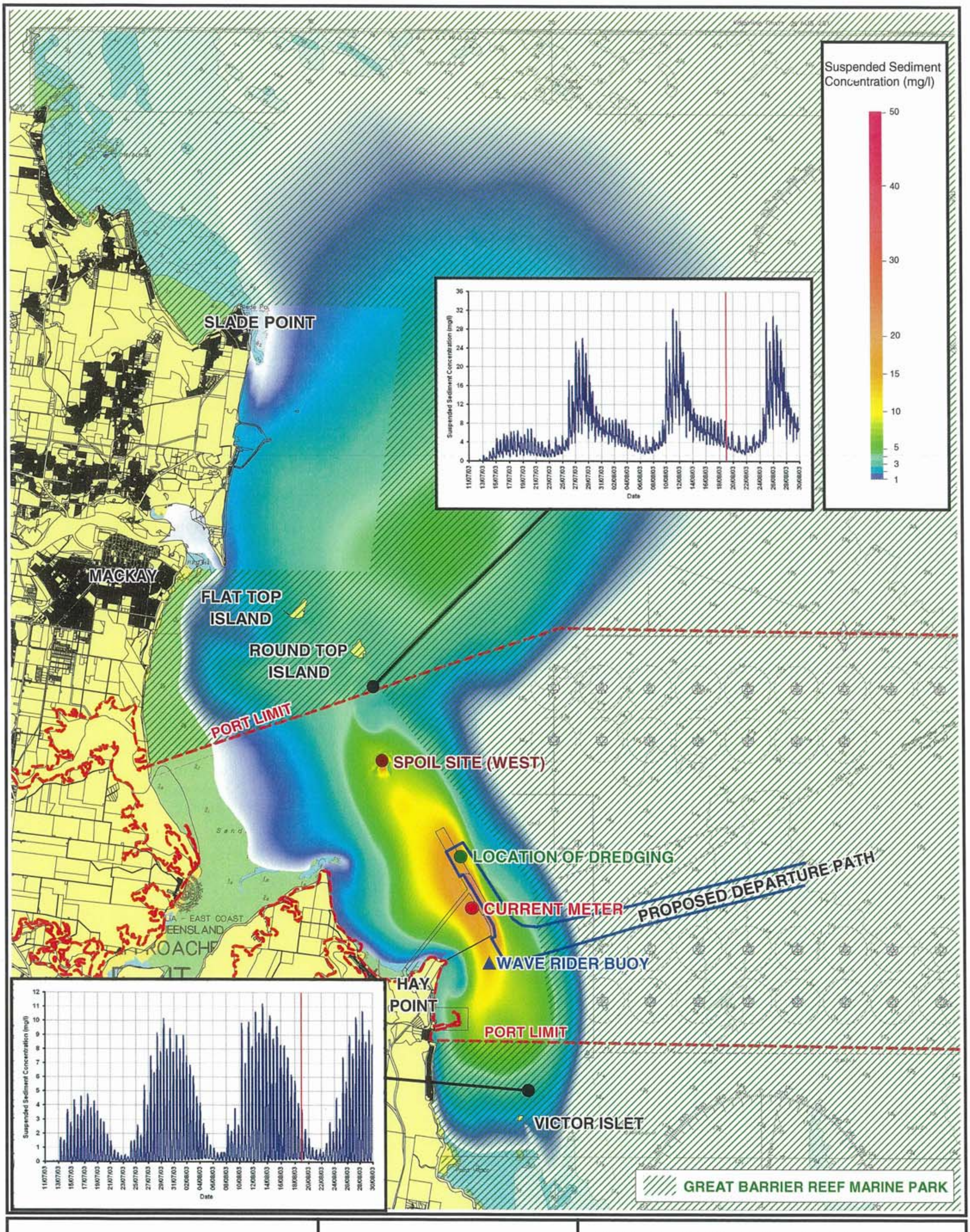
SEDIMENT PLUME AFTER 33 DAYS OF DREDGING
WORST CONDITION FOR VICTOR ISLET
DREDGING AT APRON & DUMPING AT
SPOIL SITE (WEST) DURING SPRING TIDE CYCLE

FIGURE 6.6

Ports Corporation of Queensland



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Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

HAY POINT CAPITAL DREDGING EIS

SEDIMENT PLUME AFTER 39 DAYS OF DREDGING DREDGING AT APRON & DUMPING AT SPOIL SITE (WEST) DURING NEAP TIDE CYCLE

FIGURE 6.7

Ports Corporation of Queensland

6.5.5 Simultaneous Dredging of Apron and Departure Path (Scenario F2)

The model was run with two dredges operating simultaneously for a period of 50 days. Two spoil disposal locations were introduced in the model. Material removed from the apron was disposed at the western corner of the spoil ground (Spoil Site West), while the material removed from the departure path was disposed further east of the spoil ground (Spoil Site East). The results of the modelling are presented in Figure 6.8 to Figure 6.12.

The figures are summarised below:

- Figure 6.8 Suspended sediment concentration in vicinity of Round Top Island.
- Figure 6.9 Suspended sediment concentration in vicinity of Victor Islet
- Figure 6.10 Worst condition for Round Top Island during spring tide (sediment plume after 31 days)
- Figure 6.11 Worst condition for Victor Islet during spring tide (sediment plume after 33 days)
- Figure 6.12 Sediment plume after 39 days (neap tide condition)

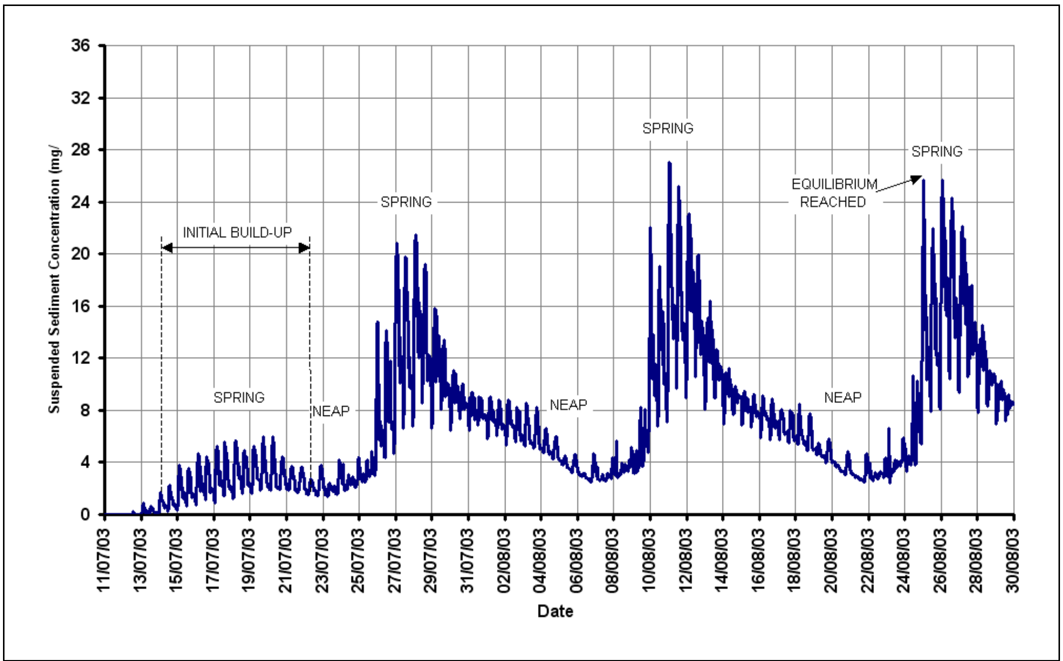


Figure 6.8 Suspended sediment concentration in vicinity of Round Top Island

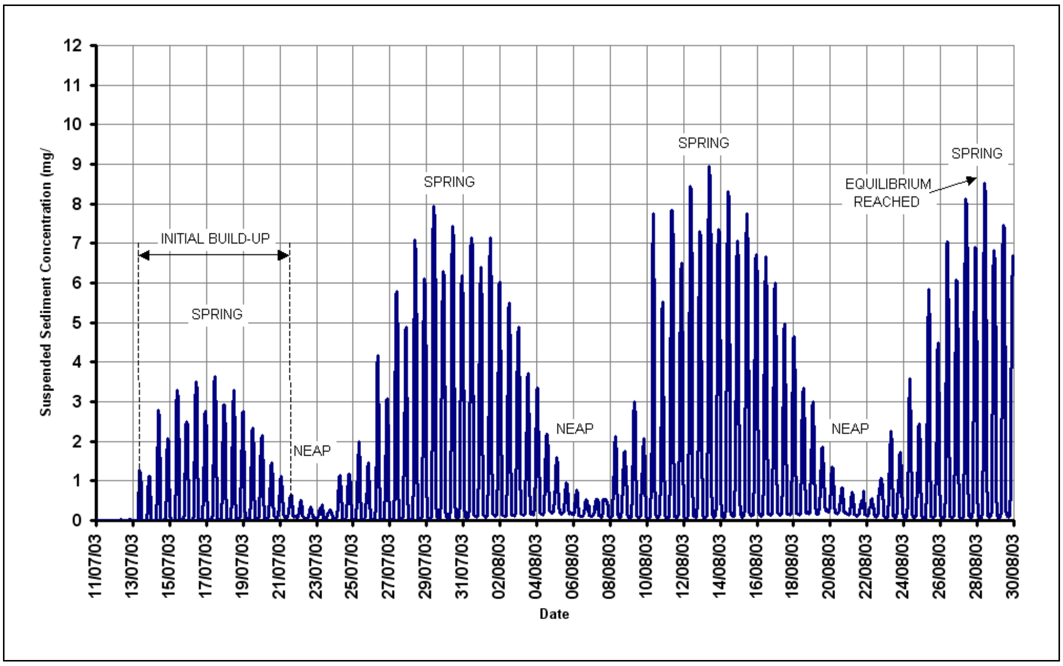


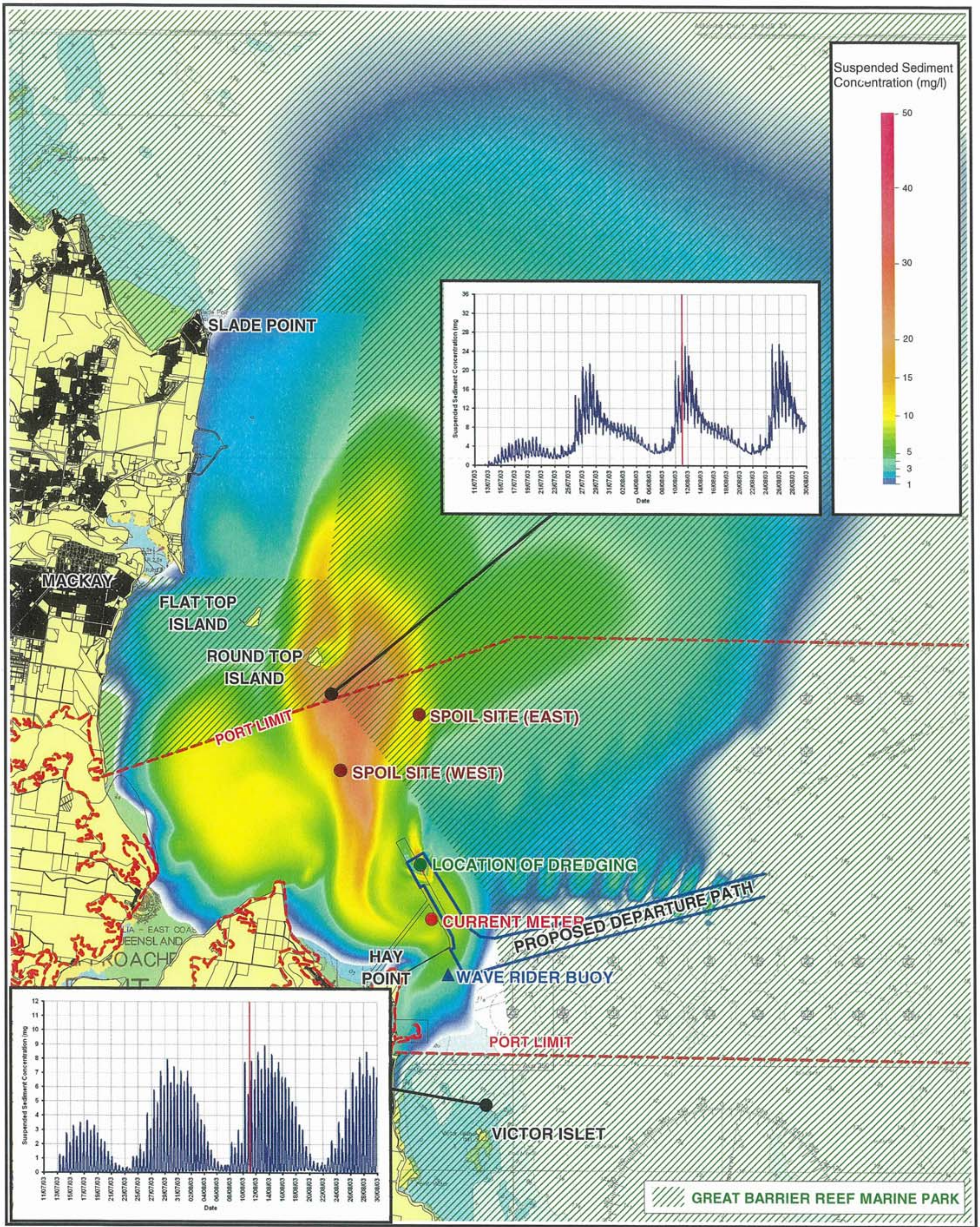
Figure 6.9 Suspended sediment concentration in vicinity of Victor Islet

The suspended sediment concentrations shown in Figure 6.8 and Figure 6.9 exhibit similar trends to the first case investigated (single dredge). However, in both cases peak concentrations are lower in comparison to the first case. The reduction in peak concentrations is the result of using a smaller dredge (12,000 m^3 compared to 18,000 m^3 adopted in the first case) at the apron. Furthermore, the reduction in peak concentration suggests that under low/negligible wind and wave conditions, the two plumes generated by dredging along the departure path and at the apron may not mix or superimpose. Hence, the source of the suspended sediments at a distance of 1 km from Round Top Island and Victor Islet is primarily from dredging at the apron.

The characteristics of the plume shown in Figure 6.10 to Figure 6.12 are similar to that of the first case, with the exception of the additional plume introduced by dredging along the departure path. The plume generated by dredging along the 9.5 km departure path is found to be of lower concentration (compared to plume generated from apron) as it is dispersed at a direction normal to the currents in Hay Point.

It was found that the plume generated from the eastern spoil site did not impact on Round Top Island. The plume moves in a northeast direction (away from Round Top Island) during ebb tide before settling to the seabed. Whereas the plume generated from the western spoil site does impact on Round Top Island at low concentrations.

Whilst these results suggest lower suspended sediment concentrations, this does not equate to a reduction of sediment in the water column. Rather, the two plumes have remained separate, and hence a larger area is affected. In the event of elevated wind or waves, the two plumes may mix, though typically it is expected that such events would act to further disperse the sediment plume, whilst background suspended sediment concentrations would also increase.



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Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

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SEDIMENT PLUME AFTER 31 DAYS OF DREDGING WORST CONDITION FOR ROUND TOP ISLAND DREDGING AT APRON & DUMPING AT SPOIL SITE (EAST & WEST) DURING SPRING TIDE CYCLE

FIGURE 6.10

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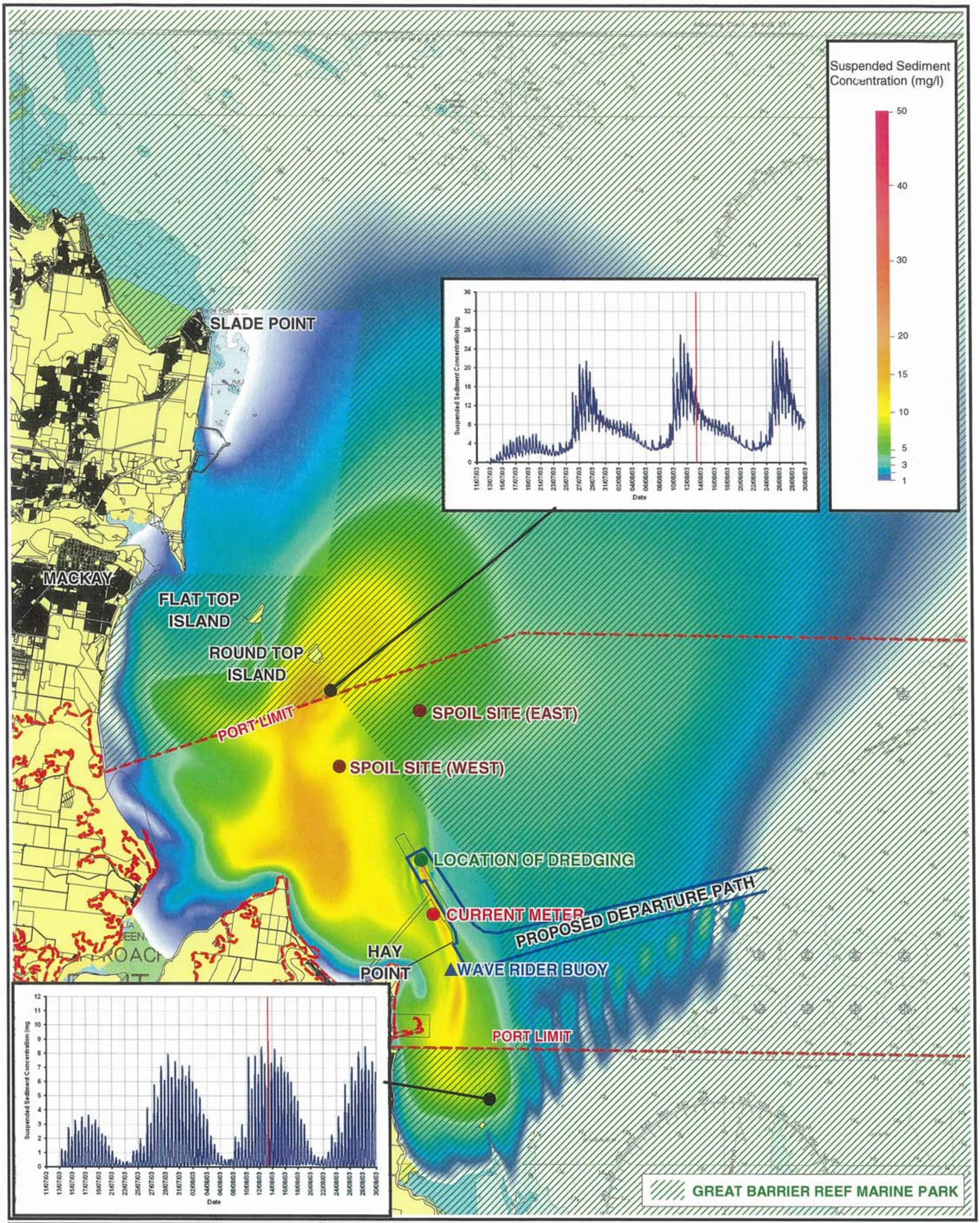

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Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

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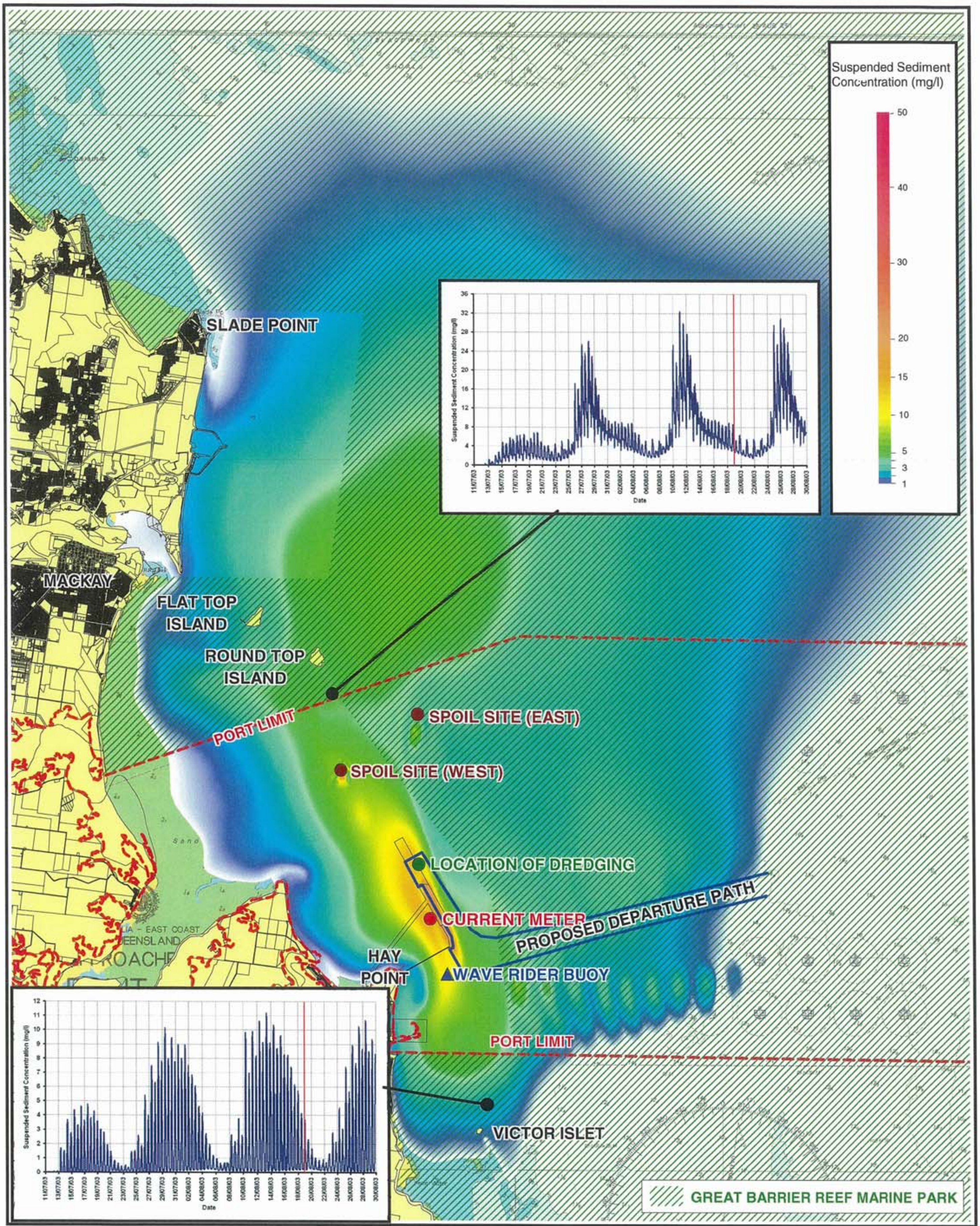
SEDIMENT PLUME AFTER 33 DAYS OF DREDGING WORST CONDITION FOR VICTOR ISLET DREDGING AT APRON & DUMPING AT SPOIL SITE (EAST & WEST) DURING SPRING TIDE CYCLE

FIGURE 6.11

Ports Corporation of Queensland



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Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

HAY POINT CAPITAL DREDGING EIS

SEDIMENT PLUME AFTER 39 DAYS OF DREDGING DREDGING AT APRON & DUMPING AT SPOIL SITE (EAST & WEST) DURING NEAP TIDE CYCLE

FIGURE 6.12

PCQ Ports Corporation of Queensland

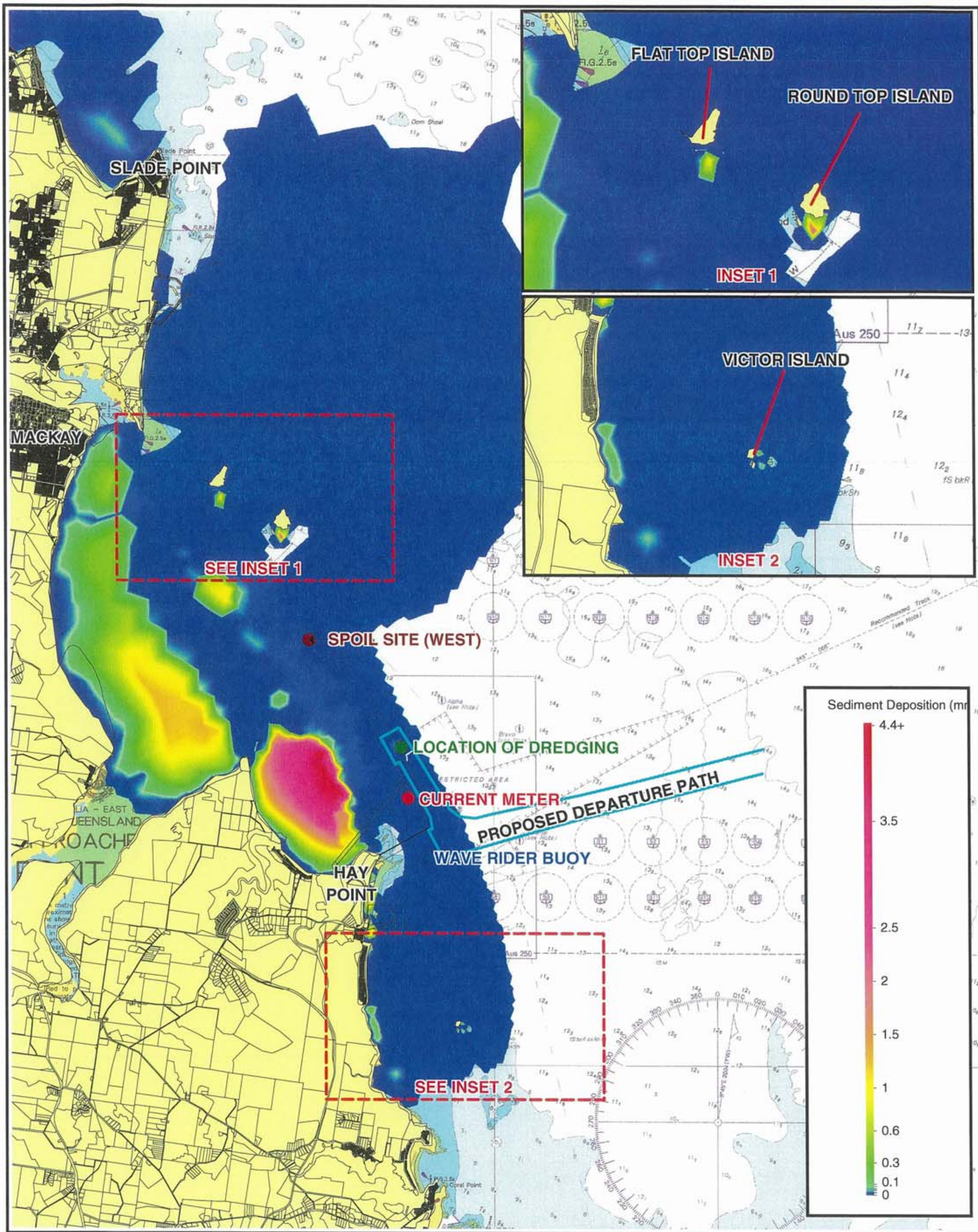
6.5.6 Sediment Deposition

The estimated sediment deposition at Hay Point after 50 days of dredging and disposal at the spoil ground are illustrated in Figure 6.13 for the first case (single dredge), and Figure 6.14 for the second case (two dredges).

Figure 6.13 shows small but detectable accretion occurring at Dalrymple Bay (4.4 mm) and around the tidal flats in Sandringham Bay (1.4 mm). Smaller accretions (0 to 1.5 mm) are shown south of the islands owing to the naturally occurring eddies at those locations. Elsewhere, deposition depths are less than 0.1 mm after 50 days of dredging and disposal activities.

Figure 6.14 exhibits a similar pattern of accretion and depths to Figure 6.13. The main difference is the more widespread accretion (< 0.1 mm) in deeper waters as result of dredging along the departure path.

The model predicts accretion around Sandringham Bay as a result of introducing suspended sediments into the water column. This prediction is consistent with the fact that this area is prone to naturally occurring build up of silt, and to the resuspension of sediments under various wave conditions.



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Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

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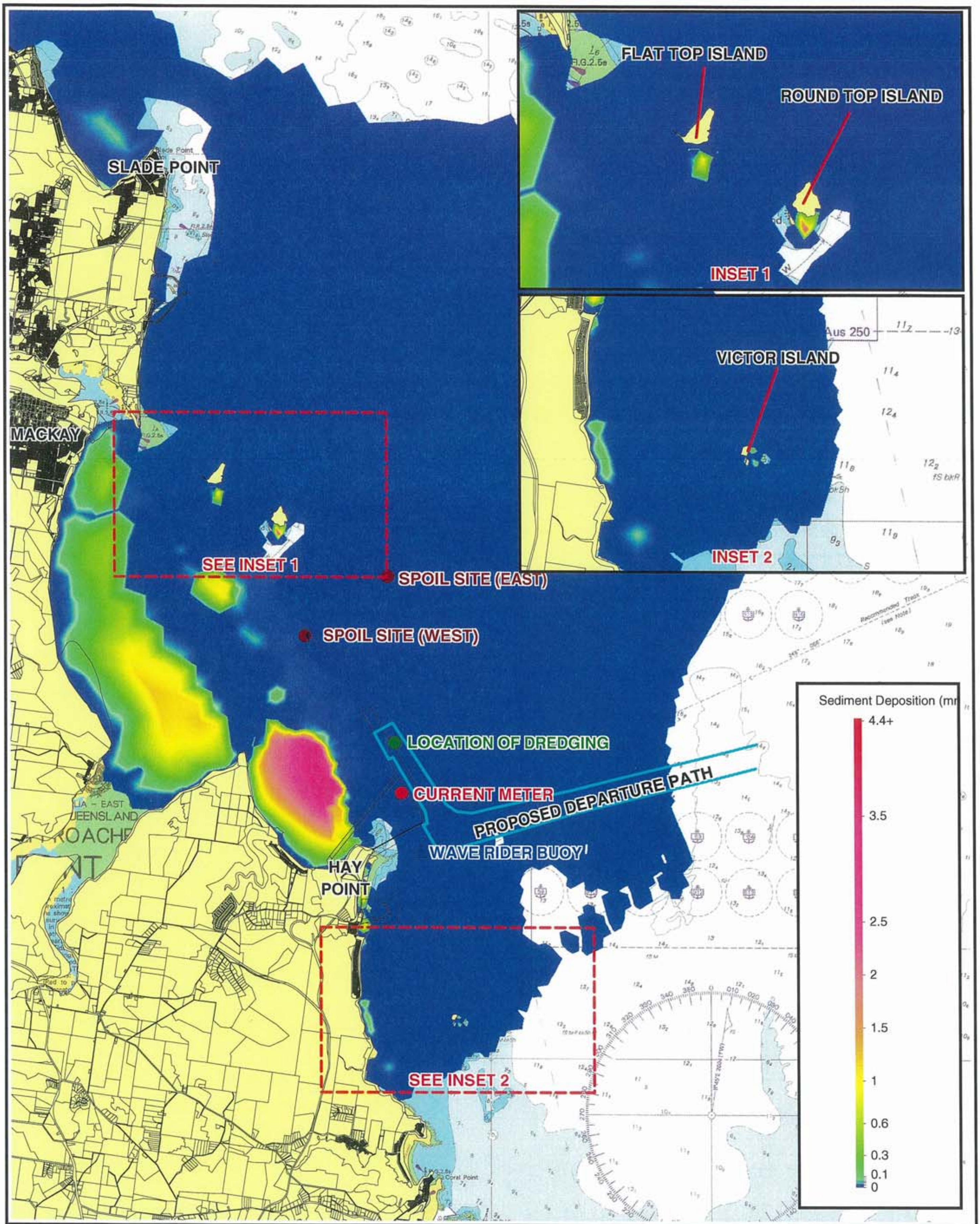
SEDIMENT DEPOSITION AFTER 50 DAYS OF DREDGING CASE 1 (SINGLE DREDGE)

FIGURE 6.13

Ports Corporation of Queensland



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Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

HAY POINT CAPITAL DREDGING EIS

SEDIMENT DEPOSITION AFTER 50 DAYS OF DREDGING CASE 2 (TWO DREDGES)

FIGURE 6.14

Ports Corporation of Queensland

6.5.7 Assessment of The Impact of Changes in The Bathymetry on Wave Transformation

Numerical modelling of wave transformation has been performed to predict the potential for adverse modification of waves resulting from the dredging operations, i.e., changes in bathymetry. Changes in bathymetry can cause energy focusing resulting in substantial alteration in sediment transport at the site of the dredging operations or along the shoreline landward of the site.

Changes in bathymetry associated with the dredging operations that have been modelled include a deepening of the proposed departure path to a depth of 14.9 m below LAT and the formation of a shoal (0.8 m above existing seabed) at the proposed future spoil ground as a result of placement of dredged material.

In relation to the latter, it has been assumed that the disposed material will undergo significant dynamic horizontal spreading and form a uniform layer at the surface of the seabed. Based on volumetric considerations it can be estimated that at the end of the placement operations the seabed will be at 0.82 m above the pre-dredge level.

To assess the rate of change in wave transformation patterns, three wave climates representative of the range of wave conditions observed at the site have been selected as illustrated by the three red triangles on Figure 6.15.

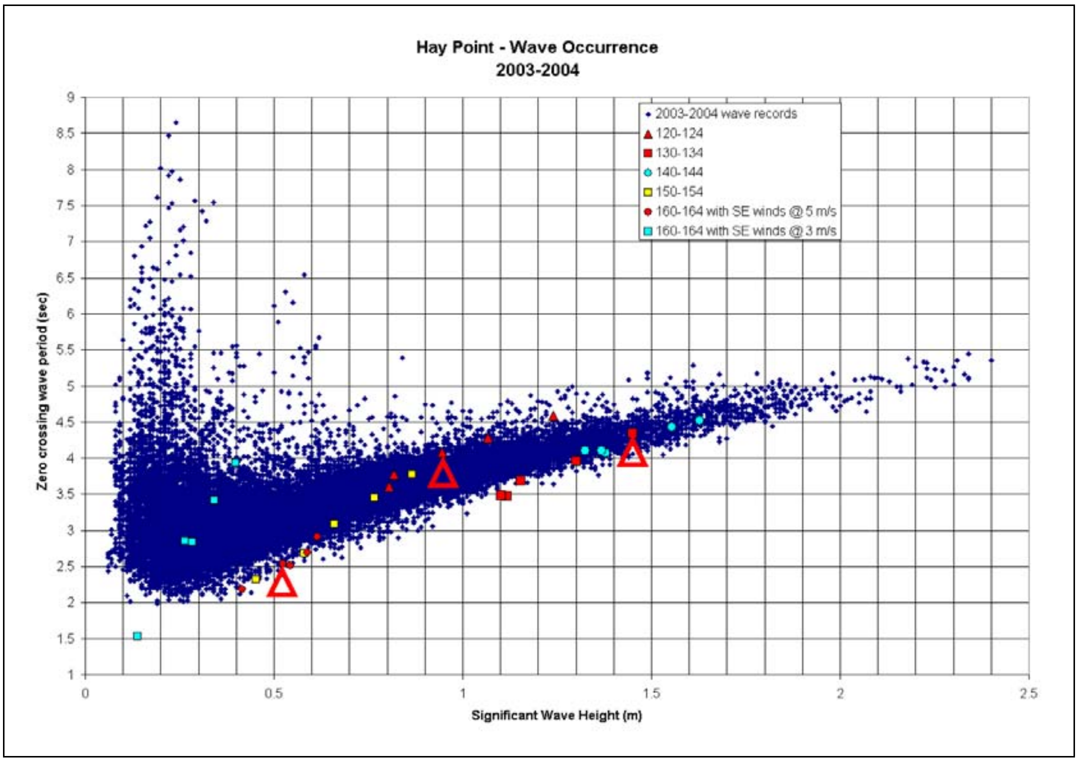


Figure 6.15 Selected wave climates (stroked red triangles) for assessment of the impact of changes in the bathymetry on wave transformation patterns

Table 6.5 lists the wave conditions adopted at the offshore boundary of the computational domain for each of the modelled scenarios.

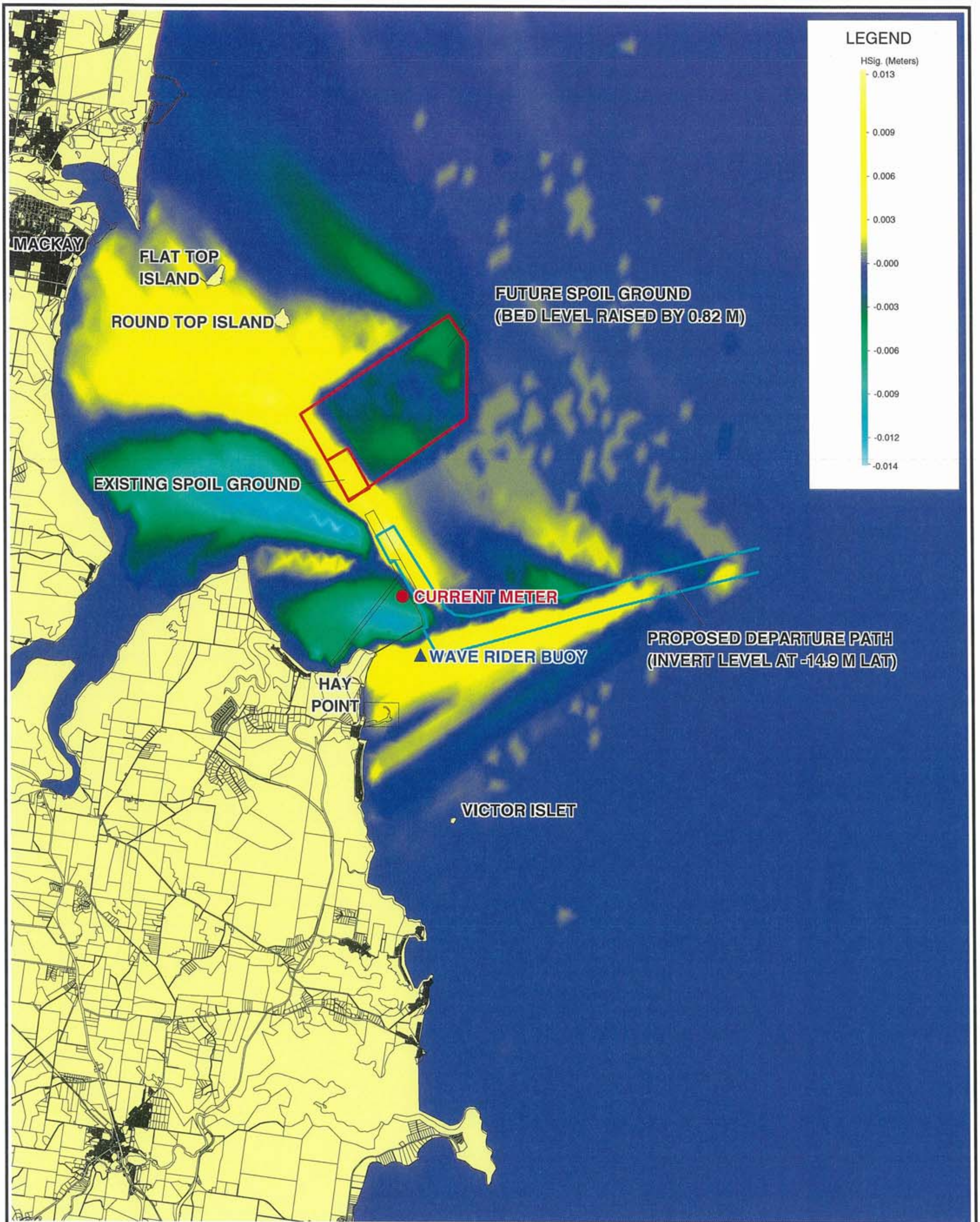
Table 6.5 Wave conditions used for the assessment of the impact of the changes in the bathymetry on wave climate

Scenario ID	Significant Wave Height (m)	Mean Wave Period (s)	Wave Direction (degrees nautical)	SE Wind (m/s)
122	1.25	5.0	120	5.0
130	1.80	6.0	120	8.0
163	0.30	5.0	120	5.0

Numerical comparisons of existing and post-dredging wave transformation patterns have been undertaken for each climate and difference maps produced as a means of documenting modifications to waves as they cross the proposed departure path and the proposed future spoil ground.

The difference maps include significant wave height, mean wave period and maximum amplitude of orbital velocity near the bottom. Figure 6.16 illustrates wave height differences for scenario #122. The differences have been obtained by subtracting post-dredging results from existing, pre-dredging results.

As illustrated by the figure, neither the excavation of the proposed departure path nor the elevation of the seabed at the proposed future spoil ground represent a substantial enough change to the bathymetry to effectively affect the wave transformation patterns. Changes in the wave transformation patterns are perceptible but insignificant. Maximum differences in significant wave height are less than 0.01 m. Similar trends were identified for the other two parameters (wave period and maximum amplitude of orbital velocity) included in the numerical comparisons.



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North

0 1500 3000 4500 6000
METRES

Source Information: PCQ and Chart AUS 249, Australia East-Coast Approaches to Hay Point to Mackay.

HAY POINT CAPITAL DREDGING EIS

DIFFERENCE IN SIGNIFICANT WAVE HEIGHT PRE-DREDGE VS. POST-DREDGE

FIGURE 6.16

Ports Corporation of Queensland

7. Conclusions

The key findings of the study are summarised below.

- The maximum suspended sediment concentrations during the spring cycles in the vicinity of Round Top Island were determined to be of the order of 40 % of the peak plume concentrations near the dredge. In the vicinity of Victor Islet the maximum suspended concentrations were determined to be approximately 15% of the peak plume concentrations near the dredge. These values should be treated as indicative, as the influence of wind, waves, or other influences may lead to changed conditions.
- Following the initial 10 days of dredging, a repeating trend of suspended sediment concentration (representing quasi-equilibrium) appears to be reached after 45 days.
- The overall extent of the plume is similar for spring and neap tide. However, at very low concentrations, high concentration bands (>10 mg/l) are shown to be significantly smaller during neap tide in comparison to spring. Therefore, the potential for adverse impacts on the identified environmentally sensitive areas during the neap cycles would be less than the potential for adverse impacts likely to be experienced at spring tides.
- Disposal at the western side of the spoil ground area produces a marginally worse condition for Round Top Island, as it brings the plume closer to the island.
- The highest turbidity due to dredging on the Apron for Round Top Island occurs during the ebb phase of the spring tide cycle.
- The highest turbidity due to dredging on the Apron for Victor Islet occurs during the flood phase of the spring tide.
- It is important to note that elevated suspended sediment concentrations oscillate with the tide, and hence marine flora and fauna communities are unlikely to be subjected to constant elevated turbidity levels.
- Mild re-suspension of sediments may occur around the tidal flats of Sandringham Bay during the ebb phase of the spring cycle.
- After 50 days of dredging using a single dredge at the apron, mild deposition (up to 4.4 mm) is shown to occur around Dalrymple Bay. Some accretion is also evident in Sandringham Bay (1.4 mm) and south of Round Top Island (2 mm).
- In the absence of significant wave or wind conditions, the two plumes generated by dredging along the departure path and by dredging at the apron will not mix or superimpose.
- The plume generated by dredging along the 9.5 km departure path is found to be of lower concentration (compared to plume generated from apron) as it is dispersed at a direction normal to the tidal currents in Hay Point.
- It was found that the plume generated from disposal of dredged material at the eastern spoil site did not impact on Round Top Island. The plume moves in a

northeast direction (away from Round Top Island) during ebb tide before settling to the seabed.

- For most of the area, only a small amount of accretion (<0.1 mm) is evident after 50 days.
- The model predicts accretion around Sandringham Bay as a result of introducing suspended sediments into the water column. This prediction is consistent with the fact that this area is prone to naturally occurring build up of silt.
- The effect of the post-dredge bathymetry to the coastal processes in Hay Point are minimal (change in velocity < 0.06 m/s and direction typically < 6 degrees over the area of interest), and are constrained in the vicinity of the departure path and spoil ground.
- There is minor energy dissipation as waves advance toward the shoreline, i.e., there is little variation of wave height, mean wave period and maximum amplitude of orbital velocity along the monitored transects;
- Neither the excavation of the proposed departure path nor the elevation of the seabed at the proposed future spoil ground represent a substantial enough change to the bathymetry to effectively affect the wave transformation patterns. Changes in the wave transformation patterns are perceptible but insignificant. Maximum differences in significant wave height are less than 0.01 m. Similar trends were identified for the other two parameters (wave period and maximum amplitude of orbital velocity) included in the numerical comparison.

8. Recommendations

The following recommendations arise from this study.

- It is recommended that near-dredge field suspended sediment concentrations should be determined during the dredging campaign and for the sediment model to be validated to these measurements;
- Sensitivity analysis with respect to the settling velocity should be considered, in order to assess its impact on plume concentrations and extent.
- Should dredging coincide with high energy wave conditions, further modelling may be required to assess the potential for sediment re-suspension, change in plume extent and impact on potential deposition rates.

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Appendix A

Wave Data Recording Program

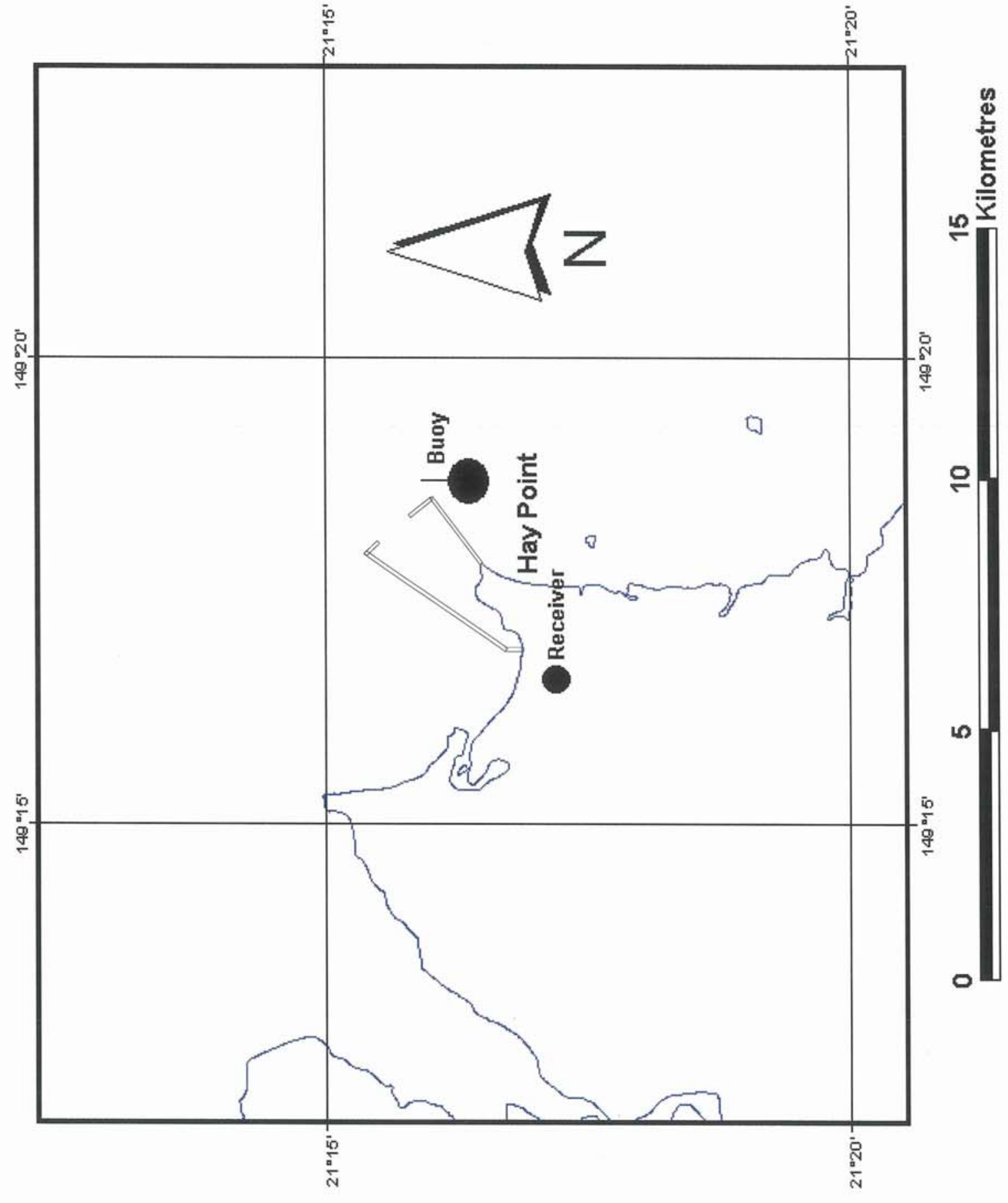
Hay Point

Wave recording station

Details of wave recorder station

Maximum Possible Analysis Days (Last record–First record)	=	365.000
Total Days Used in Analysis	=	364.667
Gaps in Data from Selected Dates (Days)	=	0.333
Gaps in Data from Analysed Records (Days)	=	0.333
Gaps in Data from Duration Analysis (Days)	=	0.333
Number of Records Used in Analysis	=	17397

HAT at nearest standard port: Hay Point, 7.14m



Latitude	Longitude	Depth (m) LAT	Deployment date	Removal date
21° 16.14'	149° 18.83'	11.0	17/05/2002	15/05/2003
21° 16.41'	149° 18.73'	11.5	15/05/2003	25/11/2003

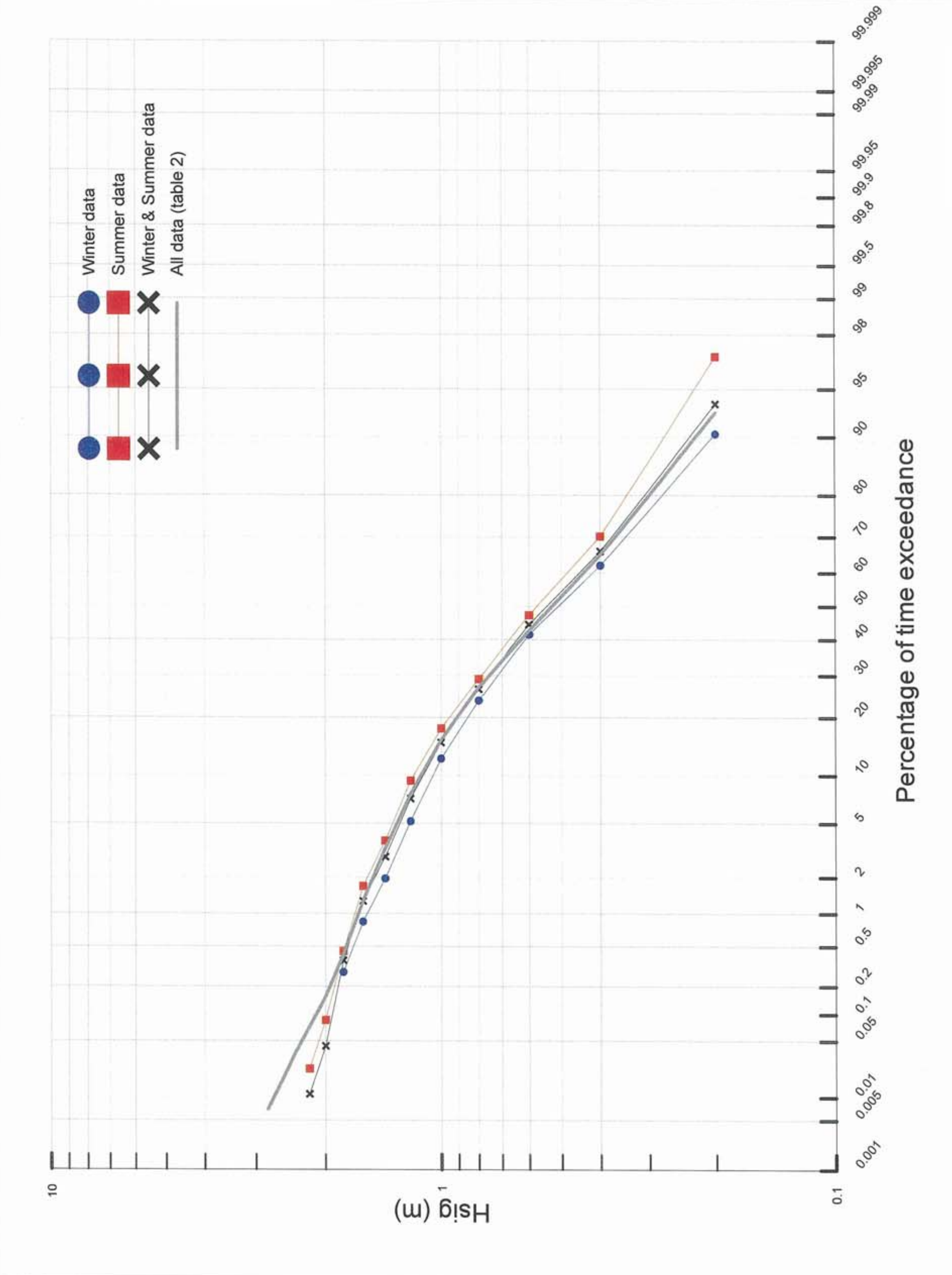
Hay Point region—Locality plan

Queensland Government Environmental Protection Agency

Wave data recording program
Annual summary for season 2002-03

Figure 7.1

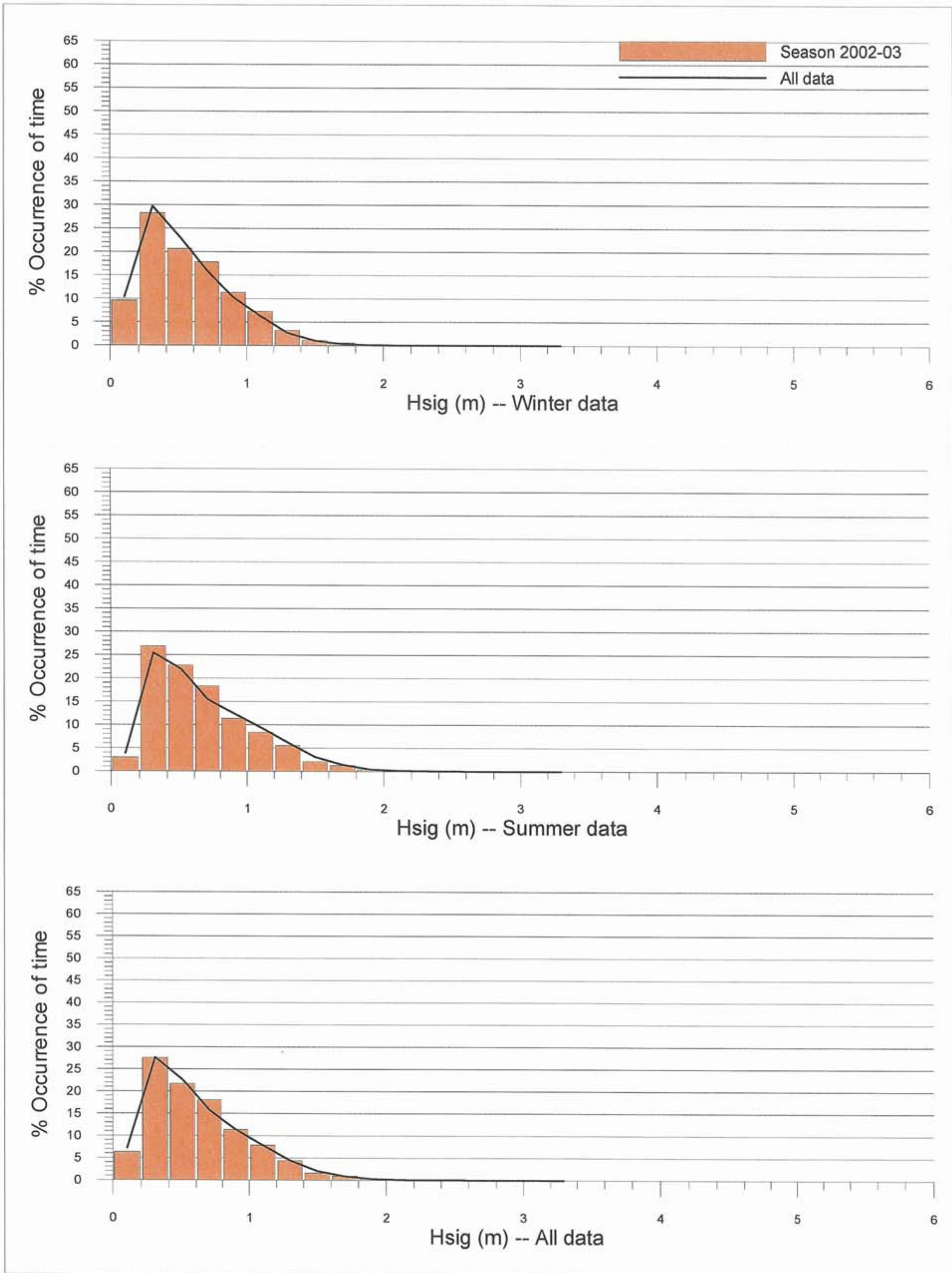
ISSN 1449–7611



Hay Point region—Percentage (of time) exceedance of wave heights (Hsig) for all wave periods (Tp)

Queensland Government Environmental Protection Agency	Wave data recording program Annual summary for season 2002-03	Figure 7.2

ISSN 1449–7611



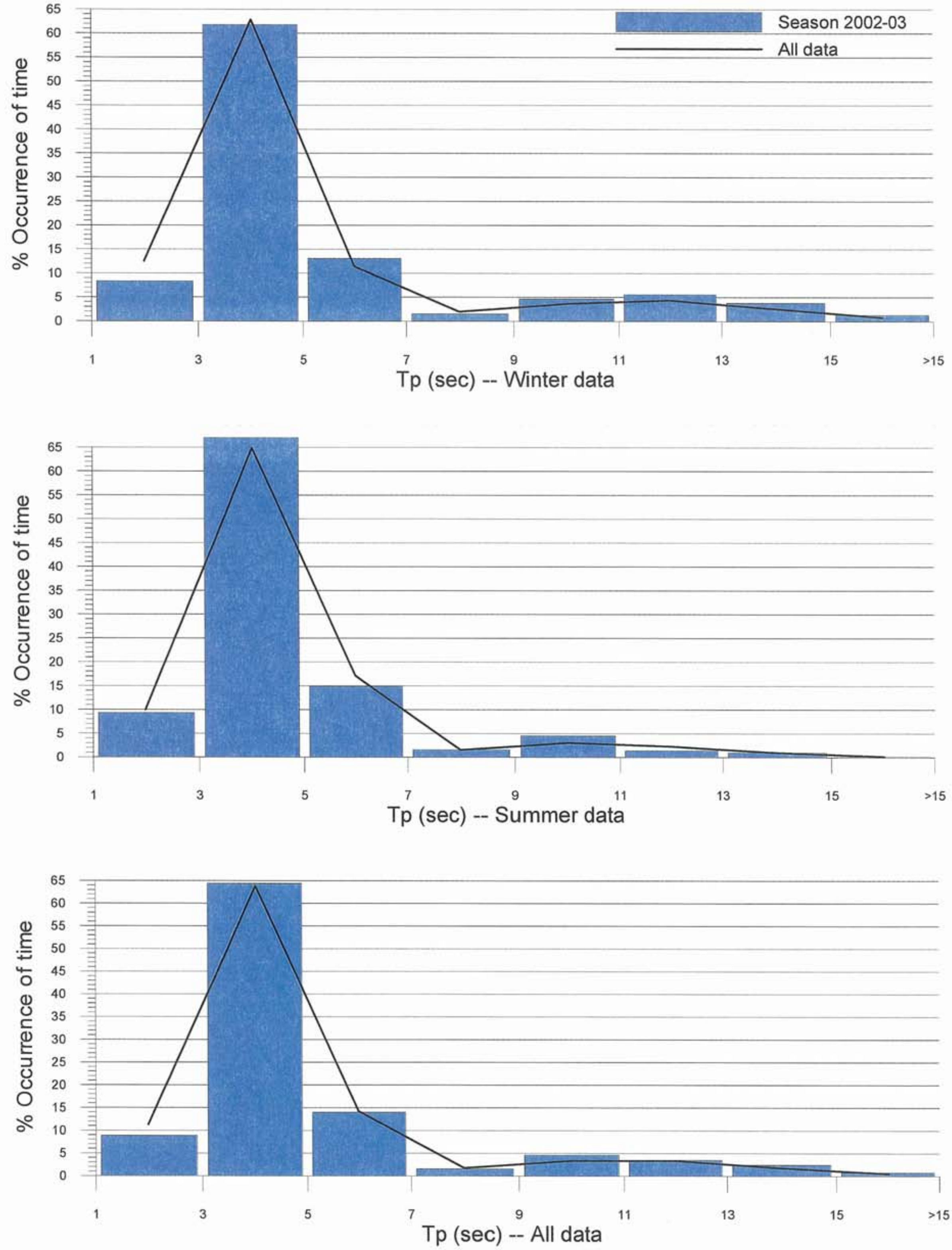
Hay Point region—Histogram percentage (of time) occurrence of wave heights (Hsig) for all wave periods (Tp)

Queensland Government Environmental Protection Agency

Wave data recording program
Annual summary for season 2002-03

Figure 7.3

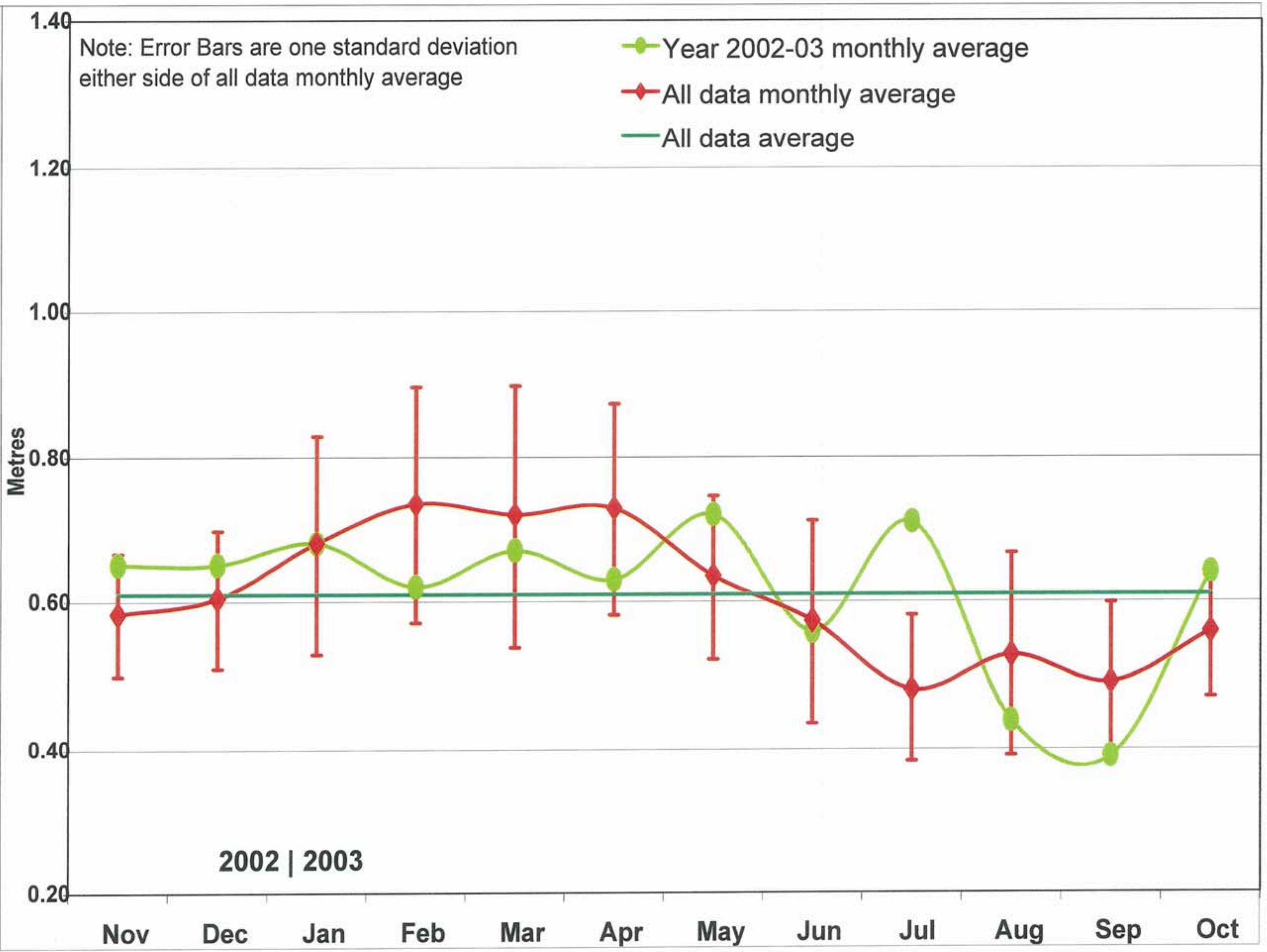
ISSN 1449–7611



Hay Point region—Histogram percentage (of time) occurrence of wave periods (Tp) for all wave heights (Hsig)

Queensland Government Environmental Protection Agency	Wave data recording program Annual summary for season 2002-03	Figure 7.4

ISSN 1449–7611



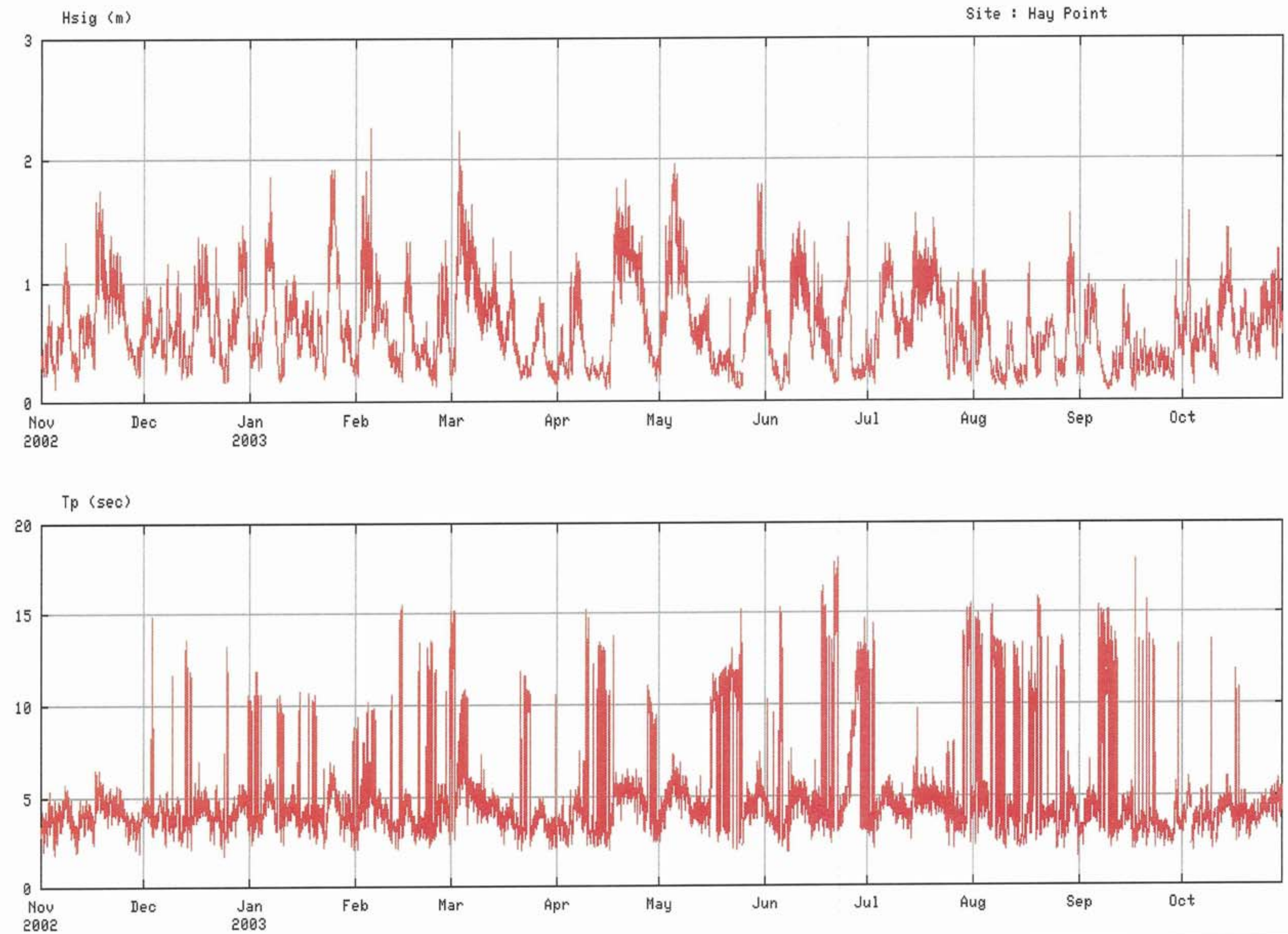
Hay Point region—Plot of monthly averages for seasonal year and for all data, for wave height (Hsig)

Queensland Government
Environmental Protection Agency

Wave data recording program
Annual summary for season 2002-03

Figure 7.5

ISSN 1449–7611



Hay Point region—Daily wave recordings

Queensland Government Environmental Protection Agency

Wave data recording program
Annual summary for season 2002-03

Figure 7.6

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