Cairns Shipping Development Project

Ports North

VOLUME 2

Draft : Environmental Impact Statement

Chapter B3 Coastal Processes

B3.1 Introduction

This chapter addresses the physical hydrodynamic and sedimentation processes as set out in Section 5.3 of the Cairns Shipping Development Project (CSDP) Terms of Reference (TOR)for an environmental impact statement, November 2012 (Terms of Reference), issued by the Queensland Coordinator-General. It also meets the requirements of the guideline for an Environmental Impact Statement for the CDSP, Queensland (EIS Guidelines), issued by the Australian Government Department of Sustainability, Environment, Water, Population and Communities and the Great Barrier Reef Marine Park Authority (GBRMPA). Consistent with this, the coastal processes as described herein include the hydrodynamic factors, particularly waves and currents, sediment transport forced by those factors and the resulting seabed and coastal morphology within the littoral and marine zone of Trinity Bay and Inlet, at and adjacent to the project area.

Chemical properties of the marine sediments and water quality aspects are addressed separately in **Chapter B4, Marine Sediment Quality** and **Chapter B5, Marine Water Quality** of this EIS.

As such, this chapter provides:

- A description of the key existing coastal processes in the broader study area that potentially may be affected directly or indirectly by the (the project)
- An assessment of the impacts on these coastal processes that may result from the project. This specifically takes in account the construction and operation of the proposed channel widening/deepening and new port infrastructure.
- Any required measures proposed to manage and mitigate potential impacts to coastal processes.

B3.2 Policy and Legislation

Prospective changes to coastal processes from the proposal are a relevant consideration in the context of impacts on matters of National Environmental Significance (NES) under the ***Environment Protection and Biodiversity Conservation Act 1999*** and also the ***Great Barrier Reef Marine Park Act 1975***, if such changes materially affect the declared marine park or its values.

From a Queensland Government perspective, the matters outlined in this chapter deal with aspects of the project that require assessment under the provisions of the ***Sustainable Planning Act 2009*** and the ***Coastal Protection and Management Act 1995*** (Coastal Act), specifically the project's consistency with the relevant policies of the ***Coastal Protection State Planning Regulatory Provisions 2013*** (SPRP) and the ***Draft Coastal Plan 2013***.

B3.3 Methodology

B3.3.1 Impact Assessment Approach

The TOR and EIS guidelines have been followed in assessing the impacts on coastal processes by:

- Determining the nature and behaviour of the existing conditions and processes occurring
- Assessing the potential changes to processes affecting the existing conditions that may be caused by the proposed project.

A review of available relevant literature and existing data was undertaken in order to:

- Characterise existing coastal processes that affect the stability and integrity of the physical marine and coastal environment (coastal landforms) in and around the study area
- Identify potential issues that are of key relevance to the impact assessment process
- Identify gaps in existing knowledge to be investigated in this study.

Key sources utilised during the review of existing literature are set out in the Reference section of this chapter. Review of available existing information as published in reports and other sources has been augmented by additional investigations undertaken as part of the EIS preparation.

Coastal processes have been considered in two broad categories, based on their morphological nature and the predominant sediment transport mechanisms, namely:

- Trinity Bay and Inlet marine hydrodynamic and sedimentation processes, including siltation in dredged areas and effects of dredged material placement
- Cairns littoral and beach system processes.

Each of these systems has been investigated and assessed using a combination of historical records, continuous datasets obtained specifically for this EIS and numerical modelling tools.

B3.3.2 Data Sources

Data and information have been sourced for this EIS from existing publications and databases as referenced and from field measurements undertaken by the proponent specifically in support of the investigations. These are discussed in the below sections.

B3.3.2.1 Hydrographic Survey

Hydrographic (bathymetric) data were sourced from the following:

- Hydrographic surveys of the Port of Cairns, Cairns shipping channel and Dredge Material Placement Area (DMPA) provided by Ports North
- Australian Hydrographic Service Navigation Chart AUS264 (Cairns Southern Sheet)
- Australian Hydrographic Service Navigation Chart AUS263 (Cairns Northern Sheet)
- Australian Hydrographic Service Navigation Chart AUS262 (Approaches to Cairns)
- James Cook University Project 3DGBR (Beaman, 2010).

All the elevation data were converted to metres above Australian Height Datum (mAHD).

B3.3.2.2 Wind and Meteorological Data

Wind data was sourced from regional Commonwealth Bureau of Meteorology and Australian Institute of Marine Science stations, and weather station instrumentation temporarily installed on Beacons C2, C11 and C20.

Spatially and temporally variable wind fields were constructed by interpolation between stations. The detailed list of the meteorological stations and the interpolation procedure is provided in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**. The interpolated wind fields were used as a boundary condition input for the numerical wave, hydrodynamic and sediment transport models.

Other meteorological datasets required for numerical model boundary conditions were obtained from the NCEP/NCAR Reanalysis 2 global assimilative model output. The following parameters were extracted from this dataset as spatially varying fields:

- Air temperature
- Relative humidity
- Downward short wave radiation
- Downward long wave radiation.

B3.3.2.3 Water Level, Salinity and Temperature Data

The 3D hydrodynamic model extents are such that transverse tidal phase variations are evident across the boundaries. As such, careful attention was paid to constructing these boundaries. A calibrated regional tide model developed by BMT WBM was used for this purpose (refer **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**).

Tide level data from regional tide gauges were obtained from Maritime Safety Queensland (MSQ) and was used for the purpose of tide model calibration/validation.

Pressure, conductivity and temperature measurements were collected at six locations as described in **Table B3.3.2.7a**. The purpose of these measurements was to aid in calibrating and validating the 3D numerical hydrodynamic model within Trinity Bay.

The pressure measurements were converted to water level time series reduced to the Australian Height Datum. The conductivity measurements were converted to Practical Salinity Units (PSU) and were intended to identify any influence from freshwater plumes discharged by the Barron River into Trinity Bay. Near-surface and bed-mounted instruments were deployed at Beacons C7 and C11 in order to identify potential vertical salinity gradients due to Barron River plumes. Temperature measurements were used to validate the numerical models representation of atmospheric heat exchange.

B3.3.2.4 Current and Wave Data

Current and wave data were collected specifically for the purpose of supporting the development and validation of numerical models as part of the project EIS. **Table B3.3.2.7a** summarises the bed-mounted ADCP deployments for the purpose of collecting continuous current and wave datasets at locations within the study area. Between six and 12 months of current and wave data were collected at four locations; the existing DMPA, a potential alternative DMPA site, and at Beacons C7 and C11 adjacent to the outer channel (**Figure B3.3.2.7a**).

The bed-mounted ADCPs were deployed in depths ranging from approximately 11m at the DMPA site to 4m at beacon C11 and collected vertical profile data using a 0.5m bin size. The current data was used to calibrate and subsequently validate the 3D hydrodynamic model as described in detail in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**.

Wave measurement bursts were performed hourly for the AWAC instruments, and once every three hours for the RDI instrument and were used to derive the time history of directional wave spectra. The directional spectra were processed to derive time series of wave parameters, such as significant wave height, peak wave direction and peak wave period. Analysis was also undertaken to decompose the directional spectra into sea and swell components.

In addition to the bed-mounted ADCP measurements, transects were undertaken with a vessel-mounted ADCP in order to provide some spatial representation of currents. Transect measurements were performed on two occasions during spring tidal conditions as detailed in **Table B3.3.2.7b**. These datasets were used for the purpose of 3D hydrodynamic model validation as described in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**.

B3.3.2.5 Turbidity and Total Suspended Solids (TSS) Data

Nephelometer instruments were collocated with the bed-mounted ADCP deployments to provide continuous datasets of turbidity at the four locations described in **Table B3.3.2.7a**. These measurements were collected in order to calibrate and validate the numerical sediment transport model developed for this study as described in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**.

Turbidity depth-profiling was also performed at the bed-mounted deployment sites during instrument maintenance and retrieval operations and whilst undertaking ADCP transect measurements. Water samples were collected during selected profiles and subsequently analysed for TSS content and in some cases for Particle Size Distribution (PSD). The frequency of sampling is outlined in **Table B3.3.2.7a**. Correlation of collocated TSS and turbidity measurements was undertaken in order to derive a regression relationship between these parameters.

Additional nephelometer instruments were deployed for the specific purpose of obtaining baseline water quality data adjacent to sensitive ecological receptor sites. These deployments are described in **Chapter B5, Marine Water Quality**.

A monitoring campaign was commissioned by Ports North during maintenance dredging operations in August 2011 (BMT WBM, 2011). This data has been used for the purpose of 3D dredge plume modelling validation as described in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**.

B3.3.2.6 Sediment Data

Grab samples of surface sediments were collected and were subjected to PSD analysis. Acoustic surveying of benthic habitat was also undertaken and used to derive interpolated maps of benthic habitats. These datasets, described in **Chapter B7, Marine Ecology**, were used to parameterise the surface sediment fractions of the numerical sediment transport model.

Additional information for the underlying sediments has also been provided by Ports North and interpreted by the project's dredging consultant to characterise the nature of the material that is proposed to be dredged based on both historical and recent geotechnical surveys of the channel.

B3.3.2.7 Barron River Discharge Data

Freshwater flows in the Barron River were obtained from Department of Natural Resources and Mines (DNRM) via the online "Watershed" data delivery service (http://watermonitoring.derm.qld.gov.au/host.htm). Barron River hydrology and annual sediment load data was also supplied by the Reef and Rainforest Research Centre.

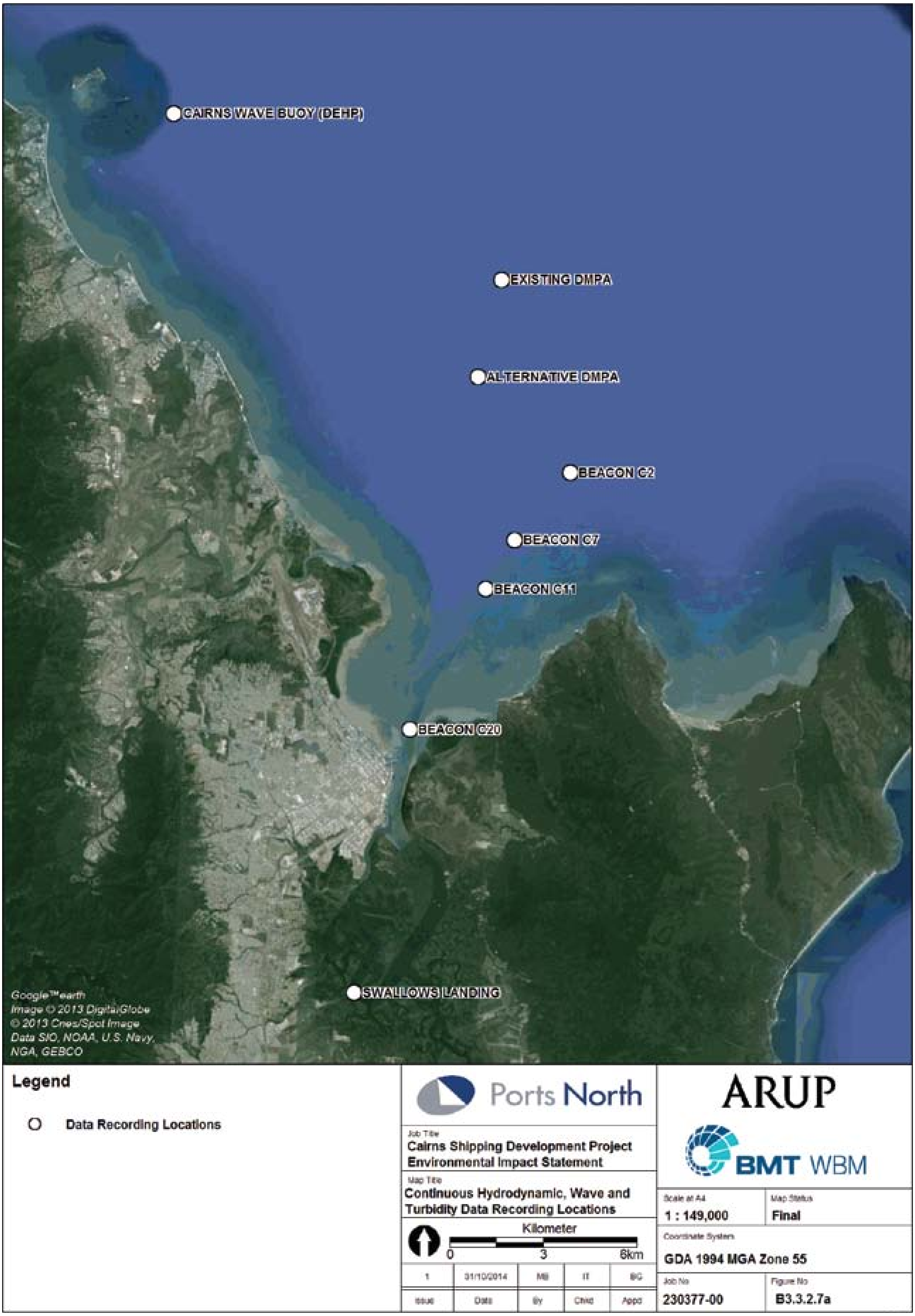
Table B3.3.2.7a Fixed Data Collection Sites and Instruments

Location	Coordinates	Deployment Period/s	Tide Recorder	ADCP Currents	Waves	Nephelometer	CTD
DMPA	145.8104, 16.7804	15/2/2013-15/4/2014	Yes	600 kHz AWAC	Directional	Near bed	Near bed
Alternative DMPA	145.8040, -16.8089	15/2/2013-22/08/2013	Yes	600 kHz AWAC	Directional	Near bed	Near bed
Outer channel Beacon C2	145.8326, -16.8361	20/2/2013-22/8/2013	Yes		Non-Directional (from CTD)		Near bed
Outer channel Beacon C7	145.8162, -16.8561	20/2/2013-15/4/2014	Yes	600 kHz AWAC.	Directional		Near-bed Near-surface
Outer channel Beacon C11	145.8078, -16.8706	20/2/2013-24/8/2013	Yes	1200 kHz RDI Workhorse	Directional	Near bed	Near-bed Near-surface

Table B3.3.2.7b Vessel Measurement Locations and Timings

Location	Timing	Data Campaign
Port Area Navy swing basin between Berth 10 - 11	three occasions (April, June and August 2013) spring tides – cross channel	Vessel mounted ADCP transects with TSS and CTD profiles - TSS samples at profiler locations.
Port Area Confluence of Smith's Creek and Trinity Inlet	two occasions (April and June 2013) – cross channel	Vessel mounted ADCP transects.
Outer channel Beacon C20 to Beacon C15	three occasions (April, June and August 2013) spring tides – along channel and cross channel	Vessel mounted ADCP transects with TSS and CTD profiles - TSS samples at profiler locations.
Outer channel Beacon C15 to Beacon C5	three occasions (May and June 2013) spring tides – along channel and cross channel	Vessel mounted ADCP transects with TSS and CTD profiles - TSS samples at profiler locations.
Trinity Bay, inner and outer channel, port area	four occasions (February, May, June and August 2013)	CTD and Turbidity profiles, water samples for TSS and particle size analysis.

Figure B3.3.2.7a Continuous Hydrodynamic, Wave and Turbidity Data Recording Locations



B3.3.3 Modelling

The measured data describing the hydrodynamics of the marine environment within Trinity Bay and Inlet have been supported and enhanced using validated numerical models. These models facilitate description of complex interactions of processes, including those not able to be measured directly for practical and logistical reasons, and were used as the key method for assessment of the project impacts.

These models have been shown in previous studies to simulate the hydrodynamic processes reliably and accurately and are capable of reproducing the dominant wave-current driven sedimentation processes in a manner suitable for impact assessment purposes.

The methodology for evaluation of hydrodynamic (HD), advection-dispersion (AD) and sediment transport (ST) processes within Trinity Bay was based on coupled three-dimensional modelling using TUFLOW FV (http://www.tuflow.com). This is a finite volume numerical model that handles HD, AD and ST components within an unstructured (flexible) mesh computational scheme. A key advantage of employing the flexible mesh model framework was its ability to adjust the spatial resolution of the computational network and, in particular, to increase resolution in areas of specific interest to the study. In the current study, these areas include the proposed dredge footprint and DMPA. The hydrodynamic model was constructed to accurately resolve these important features, with resolution also being commensurately reduced in far-field areas where impacts associated with the project are not expected and/or the hydrodynamics vary more gradually under normal conditions (i.e. deep water offshore).

The hydrodynamic model is three-dimensional with a horizontal resolution of ~30m and a vertical resolution of ~1m within Trinity Bay. The TUFLOW FV model mesh and extent is shown in **Figure B3.3.3a**. Model mesh detail within the inner harbour area is shown in **Figure B3.3.3b**. The model was configured in order to resolve the following processes, which are relevant to the circulation of water within the Great Barrier Reef Lagoon (Wolanski, 1994):

- Tidal water levels and currents
- Wind driven currents
- Large scale ocean circulations e.g East Australia Current
- Influence of density structure on vertical mixing i.e. stratification
- Salinity from mixing of freshwater inputs, including influence on water density
- Water temperature, including influence on density
- Surface heat fluxes due to solar radiation and atmospheric exchange.

Spectral wave modelling based on the industry standard SWAN software system (Delft University of Technology, 2012) was used to describe the wave climate and wave propagation. The wave model was configured to resolve the combined influence of ocean swells entering the GBR lagoon and locally generated wind waves within the GBR lagoon and Trinity Bay.

A detailed description of the SWAN model and its validation is presented in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**. SWAN has been applied to simulate both propagation of ocean swell and the generation and propagation of waves generated by winds within the model domain, providing for dissipation by white-capping, depth-induced wave breaking, bottom friction and wave-wave interactions in both deep and shallow water. SWAN simulates wave propagation in two-dimensions, including shoaling and refraction due to spatial variations in bathymetry and currents.

A regional model covering a large section of the Great Barrier Reef lagoon and Coral Sea was established to identify and simulate both deep ocean waves and more locally generated wind waves (~500m grid resolution). Finer resolution simulation of wave propagation within the study area has been achieved by establishing a nested grid (~100m resolution) local model within the larger regional domain. For assessing impacts to wave propagation and channel siltation associated with the CSDP, an additional nested grid (~25m resolution) sub-model was also applied in the vicinity of the shipping channel. The regional (~500m resolution) and local (~100m resolution) SWAN model domains are shown in **Figure B3.3.3c**.

Validation of the modelled wave propagation within Trinity Bay has been undertaken by correlation with data recorded at the Cairns Offshore waverider buoy and from bottom-mounted ADCP measurements at four separate locations summarised in **Table B3.3.2.7a** and indicated in **Figure B3.3.2.7a**.

The SWAN wave model output was linked to the TUFLOW FV ST model in order to cater for the interaction of wave, water level and current processes and their effects on sediment re-suspension, transport and deposition across Trinity Bay. The sediment transport model was configured to resolve four sediment fractions, comprising:

- Clay sized particles
- Silt sized particles
- Terrigenous sand particles
- Carbonaceous sand particles.

The TUFLOW FV ST model was used for the purpose of understanding baseline sediment transport dynamics and the related impact of the proposed channel development works. The ST model also underpinned the assessment of water quality impacts associated with the dredging works, as outlined in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report** and **Chapter B5, Marine Water Quality**.

Formal calibration and validation of the TUFLOW FV and SWAN numerical models was undertaken as part of the EIS study, described in more detail in The Cairns Shipping Development Project Model Development and Calibration Report provided in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**.

Figure B3.3.3a Hydrodynamic Model Mesh and Extent

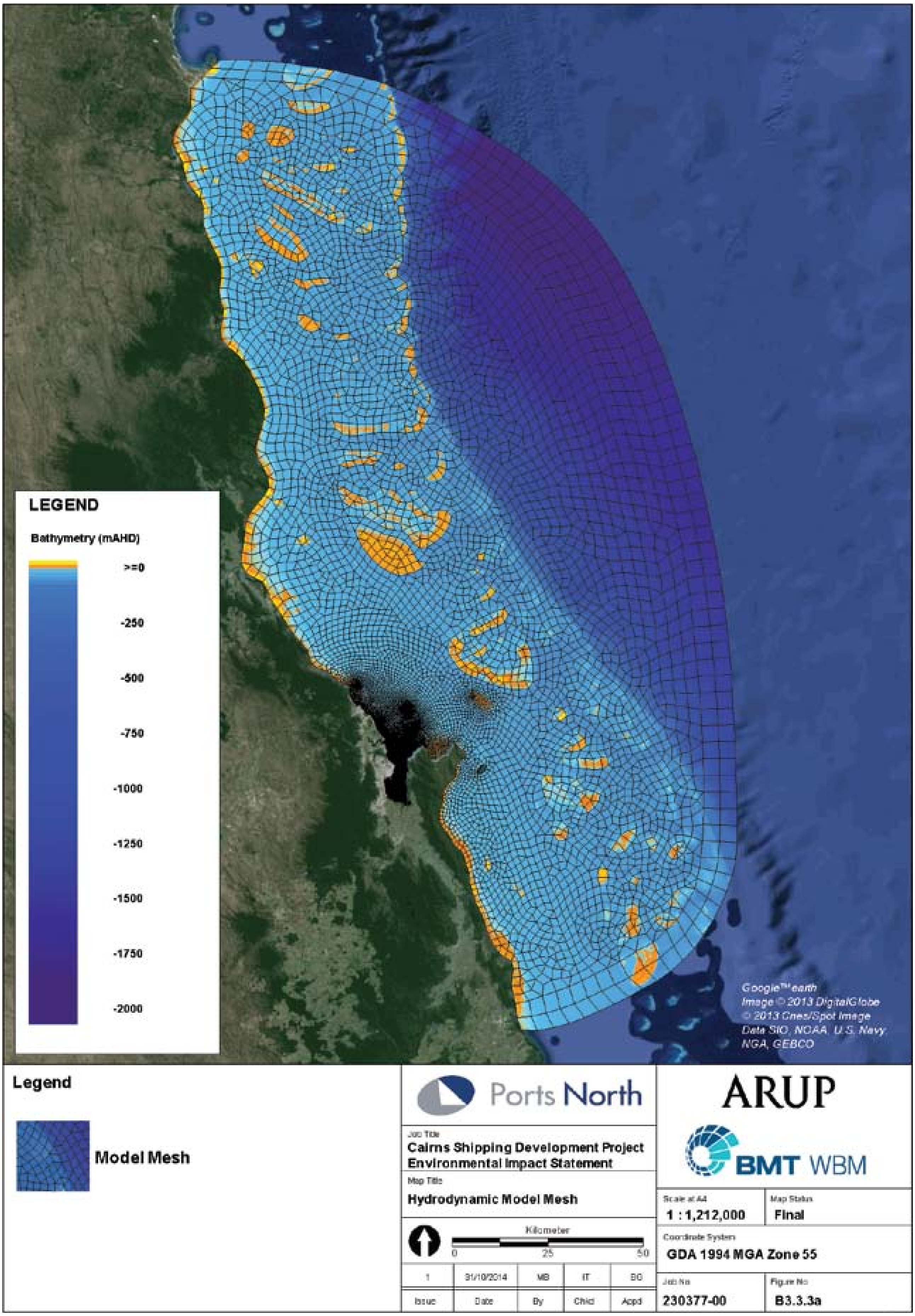


Figure B3.3.3b Hydrodynamic Model Mesh Detail

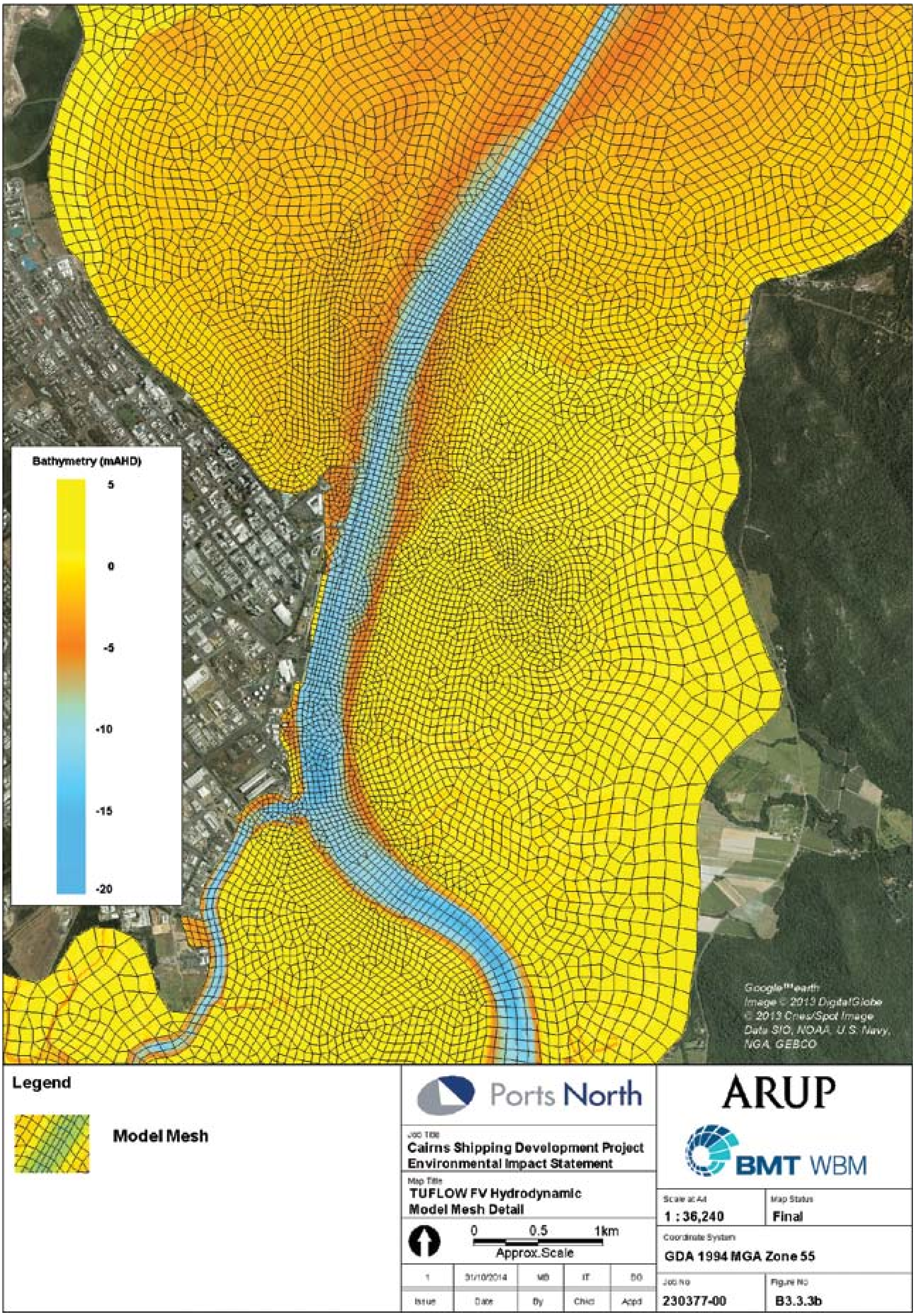
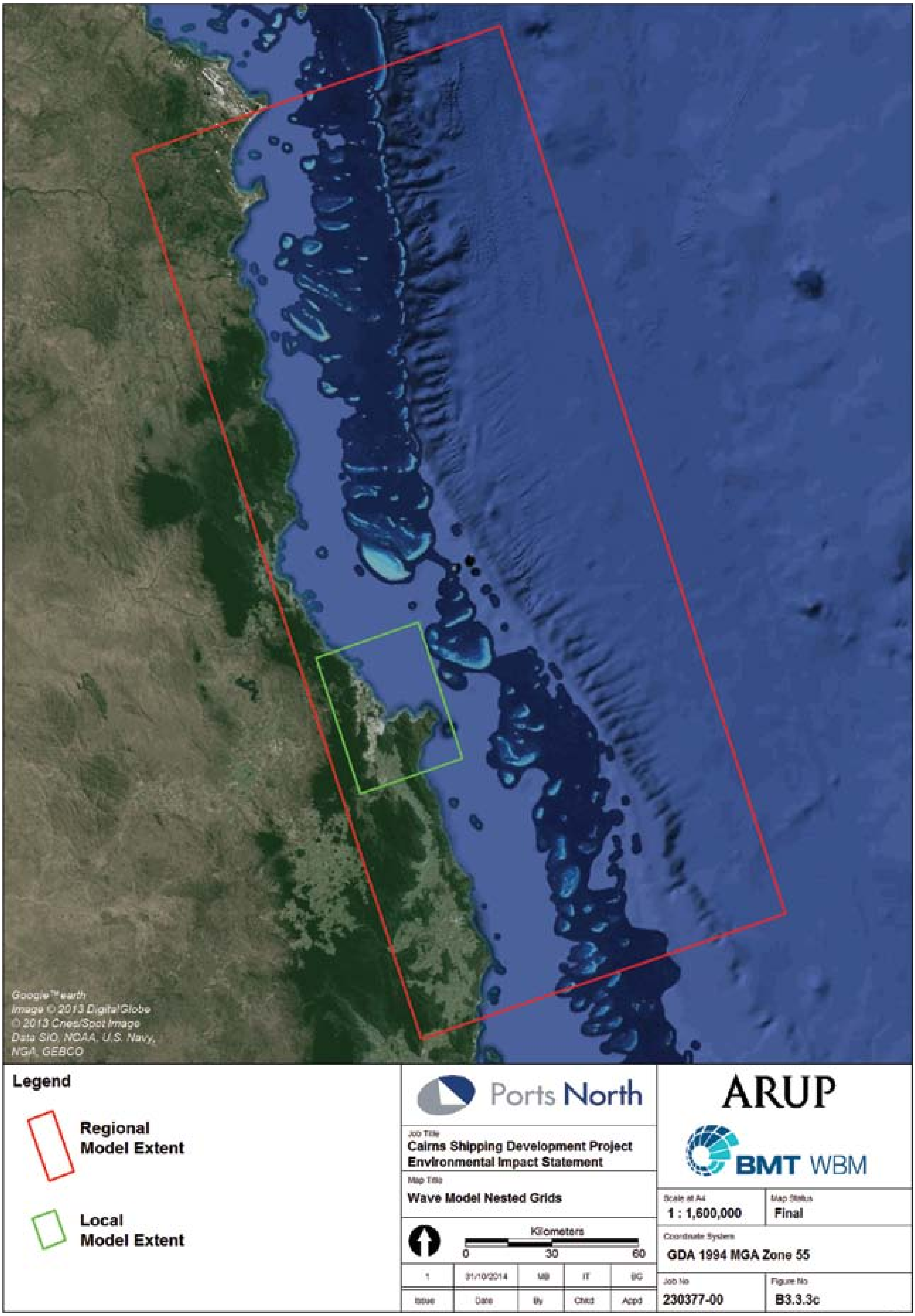


Figure B3.3.3c Wave Model Nested Grids



B3.4 Existing Environment

B3.4.1 Study Area

The Study Area (**Figure B3.4.1a**) extends to the area that may potentially be affected by the CSDP either directly or indirectly, as well as additional surrounding areas required to facilitate comprehensive modelling and analysis.

For the purpose of this report the following terminology has been adopted:

- The term ***study area*** refers to all waters within Trinity Bay, Trinity Inlet, and adjacent Great Barrier Reef lagoon waters between Double Island and Cape Grafton
- The ***project areas*** include:
  - *Terminal site* – refers to the proposed construction footprint and immediate surrounds for the Project, including existing cruise shipping wharves 1-5 and the construction footprint for associated ship services, including fuel supply, potable water and fire-fighting services
  - *Existing offshore dredged material placement area* (DMPA), refers to the existing offshore disposal site
  - Preferred offshore DMPA for CSDP capital placement.
- ***Dredge areas*** refers to the navigation channels, swing basins and berth pockets that will be subject to capital dredging as part of this project
- The ***surrounding area*** refers to the intertidal and subtidal waters within approximately 30 km of the study area. This wider area is shown in **Figure B3.4.1b**.

Figure B3.4.1a Study area

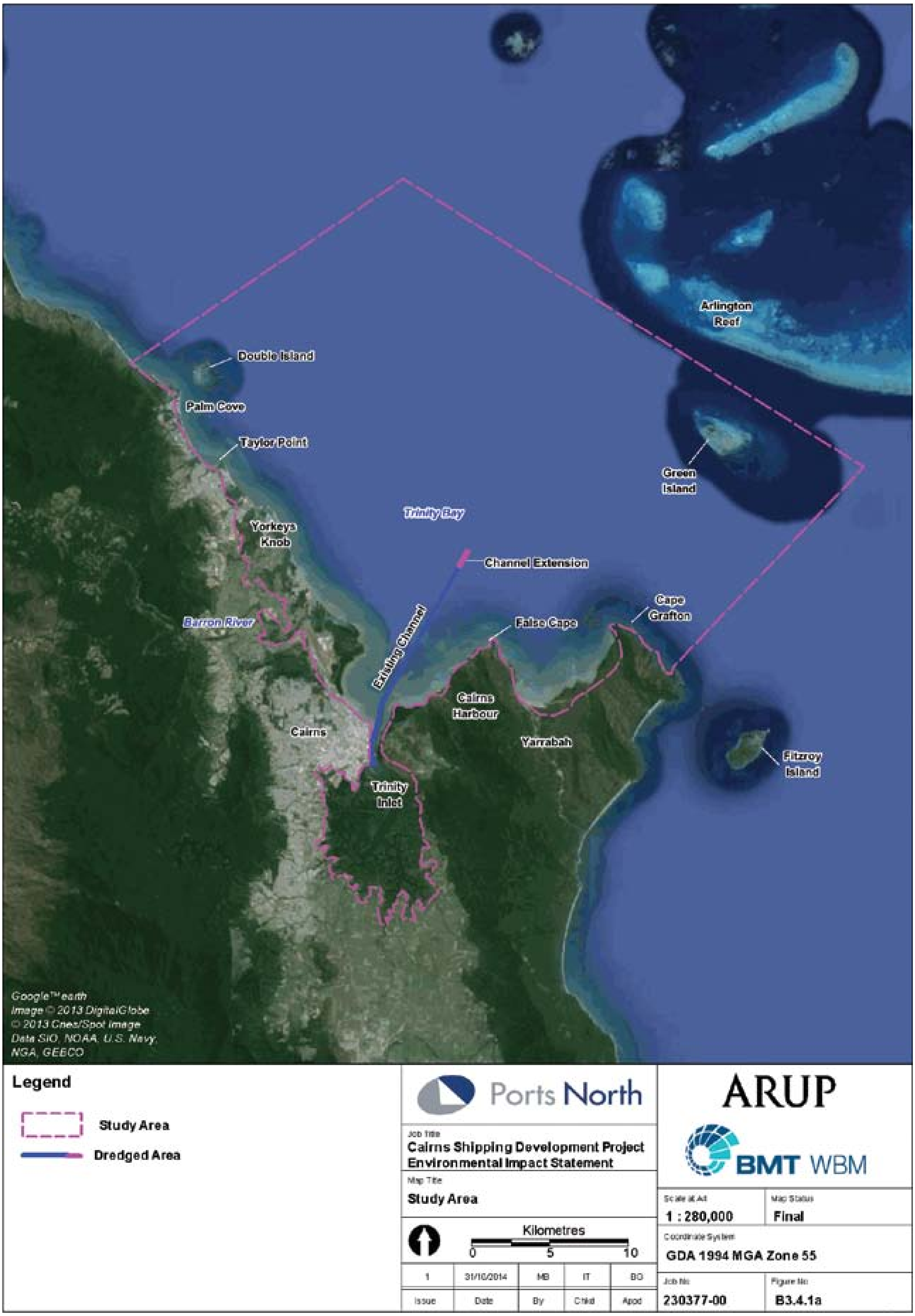
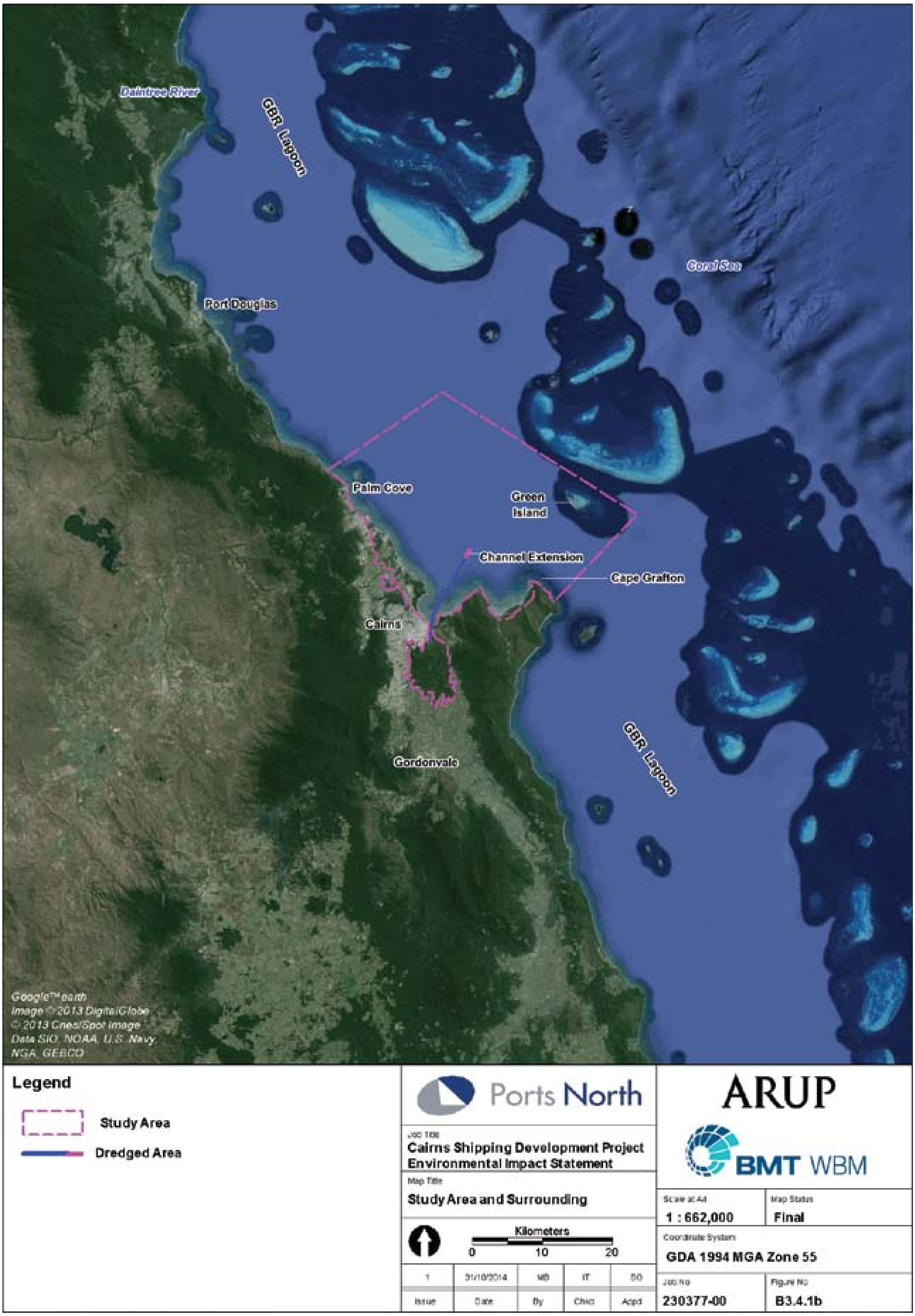


Figure B3.4.1b Study Area and Surrounding



B3.4.2 Conceptual Description of Coastal Processes

Figure B3.4.2a illustrates conceptually the broad coastal processes of Trinity Bay and Inlet, of relevance to this EIS. These processes and the marine and coastal landform morphology are described herein, together with assessment of potential impacts of the proposed CSDP. They include:

Hydrodynamics

- Water levels relating to tides and storm surges
- The wave climate, which comprises:
  - *Coral Sea (ocean) waves propagating into the GBR Lagoon through passages in the outer reef, during which their energy is significantly attenuated*
  - *Wind waves generated within the GBR Lagoon, which may refract into Trinity Bay*
  - *Short period wind waves generated within Trinity Bay.*
- Currents within the Bay, generated predominantly by tidal and wind forcing
- Freshwater inflows from the Barron River and Trinity Inlet
- Tidal flows at the Barron River and Trinity Inlet
- Key influencing factors of cyclones and other severe weather events.

Marine sedimentation processes

- Fluvial sediment supply from the rivers and streams, which may be fine wash load that extends out into the Bay before settling to the seabed or coarser sand that deposits near the stream mouths and may be re-distributed along the coast by wave/currents action
- Trinity Bay seabed sediment re-suspension, transport and deposition, potentially changing the seabed morphology or sediment composition and/or infilling dredged areas.

Shoreline sedimentation processes

- Alongshore sand transport at the beach shorelines, driven by wave breaking
- Beach erosion and accretion along the adjacent beach system, including the northern beaches
- Factors affecting and required for beach stability.

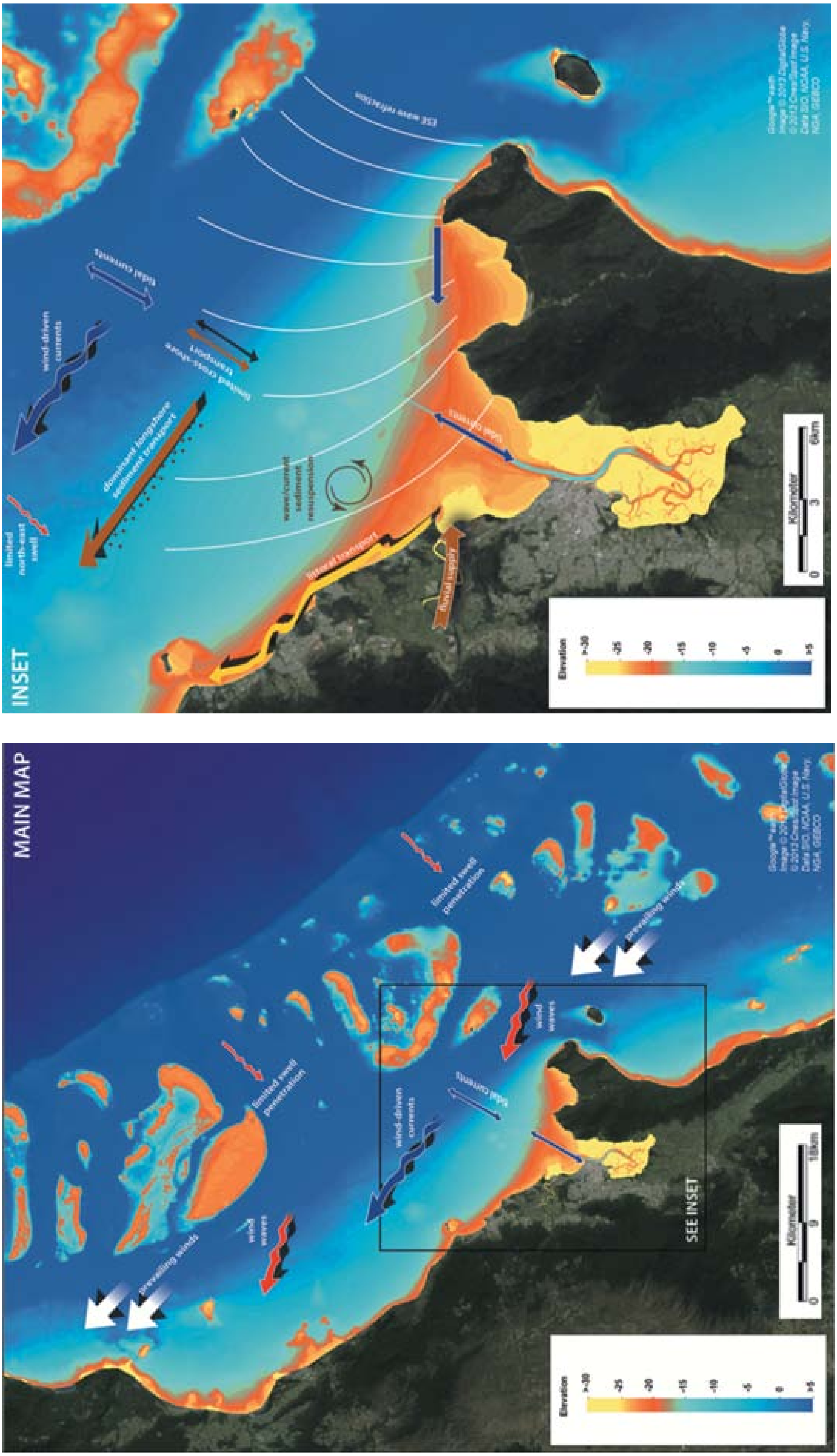


Figure B3.4.2a Conceptual Model of Coastal Processes

B3.4.3 Geological and Geomorphological Setting

A comprehensive description of the Quaternary geology and coastal evolution of the Cairns region is given in the report "Mulgrave Shire Northern Beaches" by the (then) Beach Protection Authority (BPA, 1984). Much of the information below is derived from that report, with the key aspects acknowledged by direct reference. Other sources of information include the more recent comprehensive investigation over five years by James Cook University in collaboration with Cairns Port Authority (Carter et al. 2002) and other studies including Environment North (2005) and Worley Parsons (2010).

The bedrock structures of the Cairns region provide controls for evolution of the coastline and river systems and, importantly, yield the sediments that form the onshore and offshore coastal landform and seabed of Trinity Inlet and the northern beaches. These consist of the Barron River Metamorphics between Cairns and Buchan Point and the Mareeba Granite east of Cairns forming the Murray Prior Range and the Grant Hill and Cape Grafton massifs.

The Barron River is the major source of sediment input to Trinity Bay, determining the characteristics of most of the coastal and Trinity Inlet sediments. The mineral composition of the material that resists abrasion during fluvial transport to the coast includes quartz, feldspar and mica, which occur in substantial proportions within the sand fraction (mean particle diameters 0.063-2.0mm) of the Barron River sediment load (BPA, 1984). There is a high discharge of fine (muddy) wash load from the catchment to the sea where it forms a substantial proportion of the seabed sediment material.

The onshore geology of the region is illustrated in **Figure B3.4.3a** (from BPA, 1984), showing the surficial sediment units that have developed during the Quaternary period, most particularly the Holocene deposits that form the present coastal landforms seaward of older Pleistocene material and the bedrock. Four phases of accretion are identified within Trinity Inlet, corresponding to the areas labelled Qh1, Qh2, Qh3 and Qh4. These are quite distinct in terms of their chenier and beach ridge landforms and sediments on the western side of the inlet while they form a fairly continuous chenier plain to the east.

The chenier plain extends across the inlet, seaward of an accumulation of estuarine back-barrier sandy muds. The cheniers are long narrow sandy ridges about 1-2m high roughly parallel to the present shoreline, flanked by and overlying mud deposits, as illustrated conceptually in **Figure B3.4.3b** (BPA, 1984). They are distinguished from beach ridge barriers by not having a continuous base of sand between the successive ridges and form by the shoreward migration of the sand component from the predominantly muddy nearshore inter-tidal zone during high wave events, with the mud dispersed seawards. At lower wave energy periods with fluvial and adjacent seabed supply, the inter-tidal zone builds seawards again, typically accompanied by mangrove forest progradation.

While the chenier plains Qh1 and Qh2 gave way to the sand beach ridge development of Qh3 on the western side of Trinity Inlet where wave energy and sand supply were stronger, Qh3 and then Qh4 on the eastern side both exhibit weak chenier development because wave energy and sand supply there are relatively weak. During the Holocene, the inlet channel has been an effective barrier separating the eastern and western sides. The ridges on the eastern side may have been supplied with sand at least in part from alongshore further east, although this would have been minor, and the sediment supply to the eastern side appears substantially less than to the western area throughout the Holocene accretionary period.

Figure B3.4.3c illustrates the chenier ridges of the Cairns coastal plain on which the city is located (from Carter ***et al***, 2002). The beach ridges typically consist of quartzose fine to medium sand with coarse sand at their base overlying sticky mud containing shells and wood fragments. The Qh3 beach ridge barrier along the north-west margin of Trinity Inlet is separated from the earlier units by a wide inter-barrier swamp. The inner margin is lobate in outline extending into the swamp, suggesting wave washover events during formation. Near the Barron River mouth, the history of delta evolution is evident in the series of sandy beach ridges, back-barrier deposits and a pattern of extensive channel switching. The most recent major mouth channel movement occurred in 1939 when it switched from Ellie Point to near its present position between casuarina Point and Machans Beach (BPA, 1984).

Figure B3.4.3a Onshore Quaternary Geology of Cairns Region (from BPA, 1984)

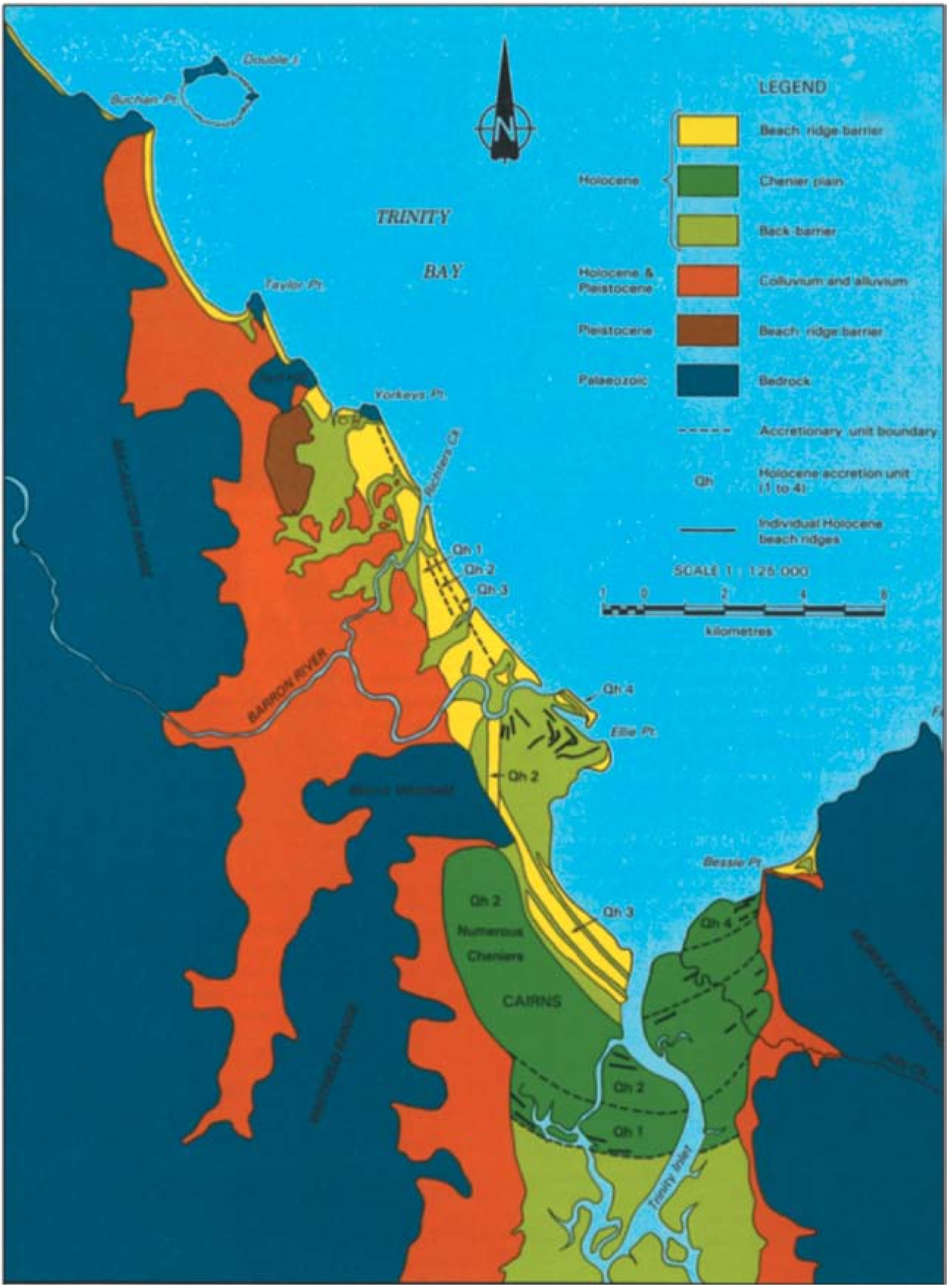


Figure B3.4.3b Conceptual Chenier Plain Cross-Section (from BPA, 1984)

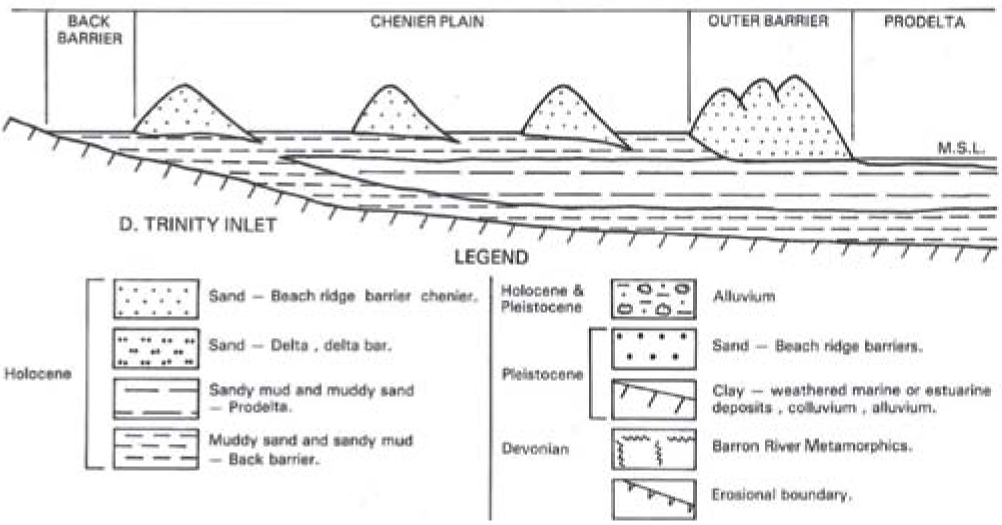
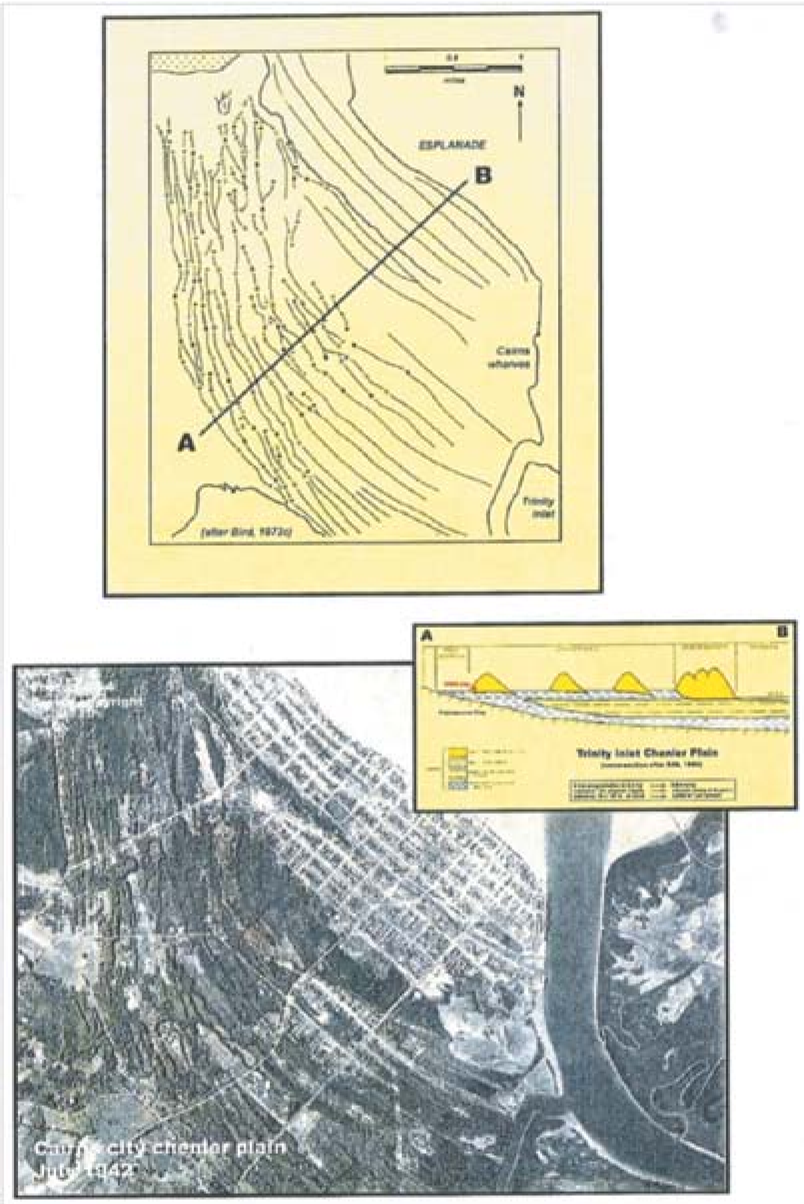


Figure B3.4.3c Cairns Coastal Plain of Chenier Ridges (from Carter *et al*, 2002)



B3.4.4 Trinity Bay Bathymetry

A bathymetric Digital Elevation Model (DEM) was constructed from the datasets described in **Section B3.3.2** and is shown in **Figure B3.4.4a**.

Bathymetric features of note within the study area include:

- Barron River delta
- Trinity Inlet, Smith's Creek and surrounding intertidal mangrove flats
- Cairns Port Shipping Channel
- Cairn's Port Dredge Material Placement Area (DMPA)
- Previously used DMPA abandoned in 1991 (approximately 2km south-west of current site).

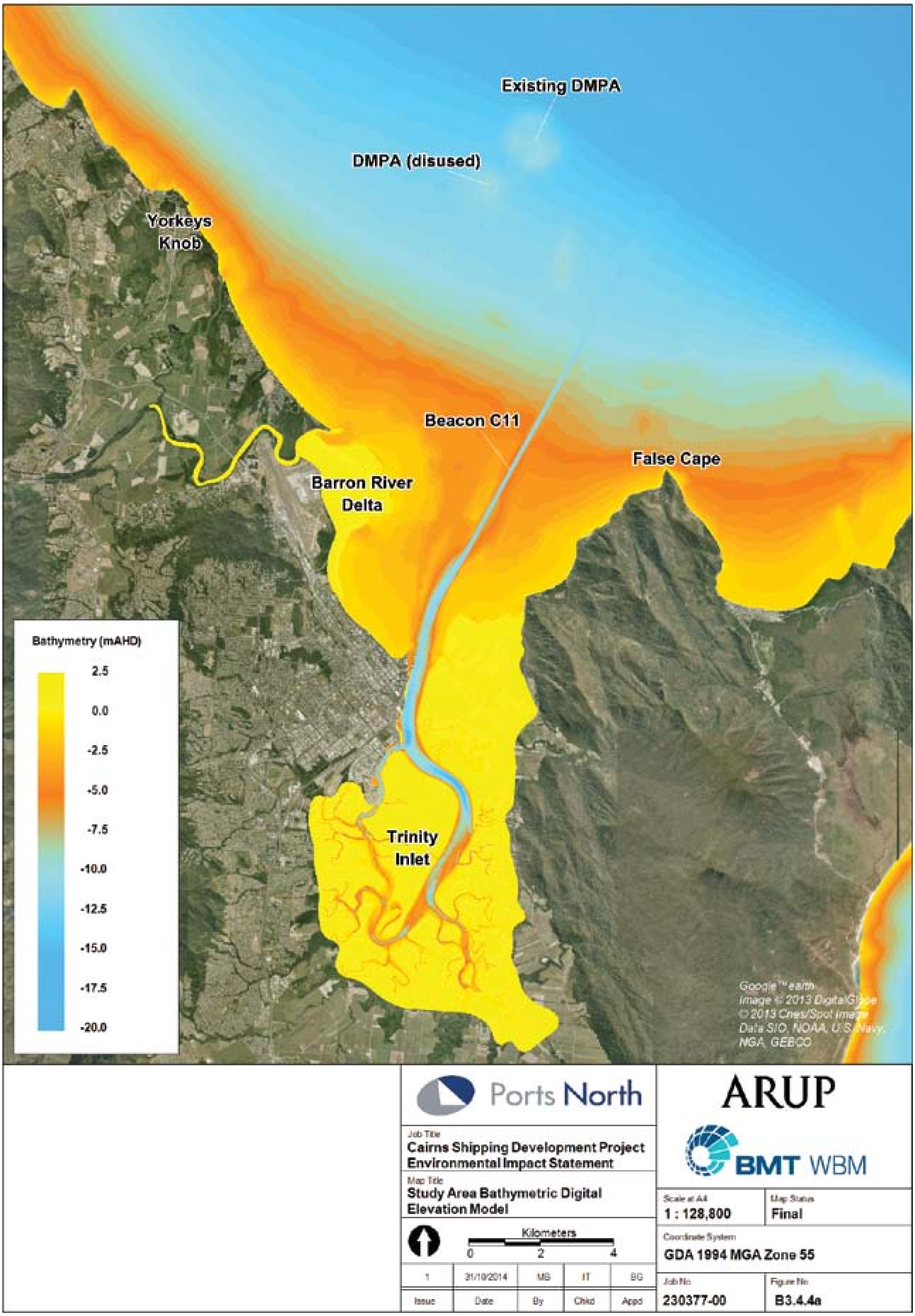
The current design depth of the shipping channel is -8.3m LAT (-9.9m AHD) with an additional overdredge allowance that varies along the channel depending on the amount of siltation experienced.

Bed Elevations outside the shipping channel are very shallow for the 8km length inshore of Beacon C11, generally ranging between -2m AHD and -5m AHD. Between Beacon C11 and the offshore channel extent the natural bed elevations gradually slope away at around 1 in 600.

The raised bathymetry within the current and former DMPAs indicates that they are significantly retentive of placed dredge material in the short and long term. The former DMPA is located in the vicinity of the surrounding -12m AHD contour and rises locally to around -9m AHD, while the existing DMPA is centred around the surrounding -13.5m AHD contour and rises to around -10.0m AHD along its inshore extent.

Bed elevations within Trinity Inlet vary significantly between the relatively deep natural channels and surrounding intertidal flats with elevations close to mean sea level. Elevations also vary substantially along the main channel thalweg, with some localised deeper sections below -15m AHD at channel bends and tributary confluences.

Figure B3.4.4a Study Area Bathymetric Digital Elevation Model



B3.4.5 Meteorology

The study area experiences a wet tropical climate. Cairns mean annual rainfall is 2013 mm, with the vast majority of rainfall occurring during the north-west monsoon influenced "wet season" months from November to April. The "dry season" period typically occurs from May to October where the synoptic meteorological pattern is strongly influenced by the Coral Sea trade winds.

Dry season wind roses for the BOM Cairns Aero and Arlington Reef stations are shown in **Figure B3.4.5a** and demonstrate the predominance of trade winds from the South to East-South-East sectors. There are significant orographic influences within the study area and inshore measurements such as Cairns Aero station are not necessarily representative of conditions within Trinity Bay and the GBR lagoon. A subtle land breeze/sea breeze cycle is also present along the coastal margin of the study area. Trade wind speeds can occasionally exceed 25knots within the open waters of the GBR lagoon.

During the wet season, North Queensland can experience a mixture of trade wind conditions and periods influenced by the north-west monsoon trough. Tropical cyclones are an intermittently occurring synoptic feature during the wet season and systems influencing Cairns can have their genesis both in the Coral Sea and in the Gulf of Carpentaria waters. On average since 1959, 1.38 tropical cyclones per year have entered a Cairns region "Zone of Influence" with approximately 70% of these crossing the coastline (BMT WBM, 2013). Extreme wind speeds in the Cairns region are generally associated with tropical cyclone systems. The 1% AEP (100 year ARI) 10-minute average wind speed for Cairns is approximately 40m/s (BMT WBM, 2013).

Wet season wind roses for the BOM Cairns Aero and Arlington Reef stations are shown in **Figure B3.4.5b**. Prevailing winds are still from South to East-South-East sectors, however there is generally greater variability and slightly lower wind speeds prevalent during this period.

Figure B3.4.5a Dry Season Wind Roses for Cairns Aero and Arlington Reef

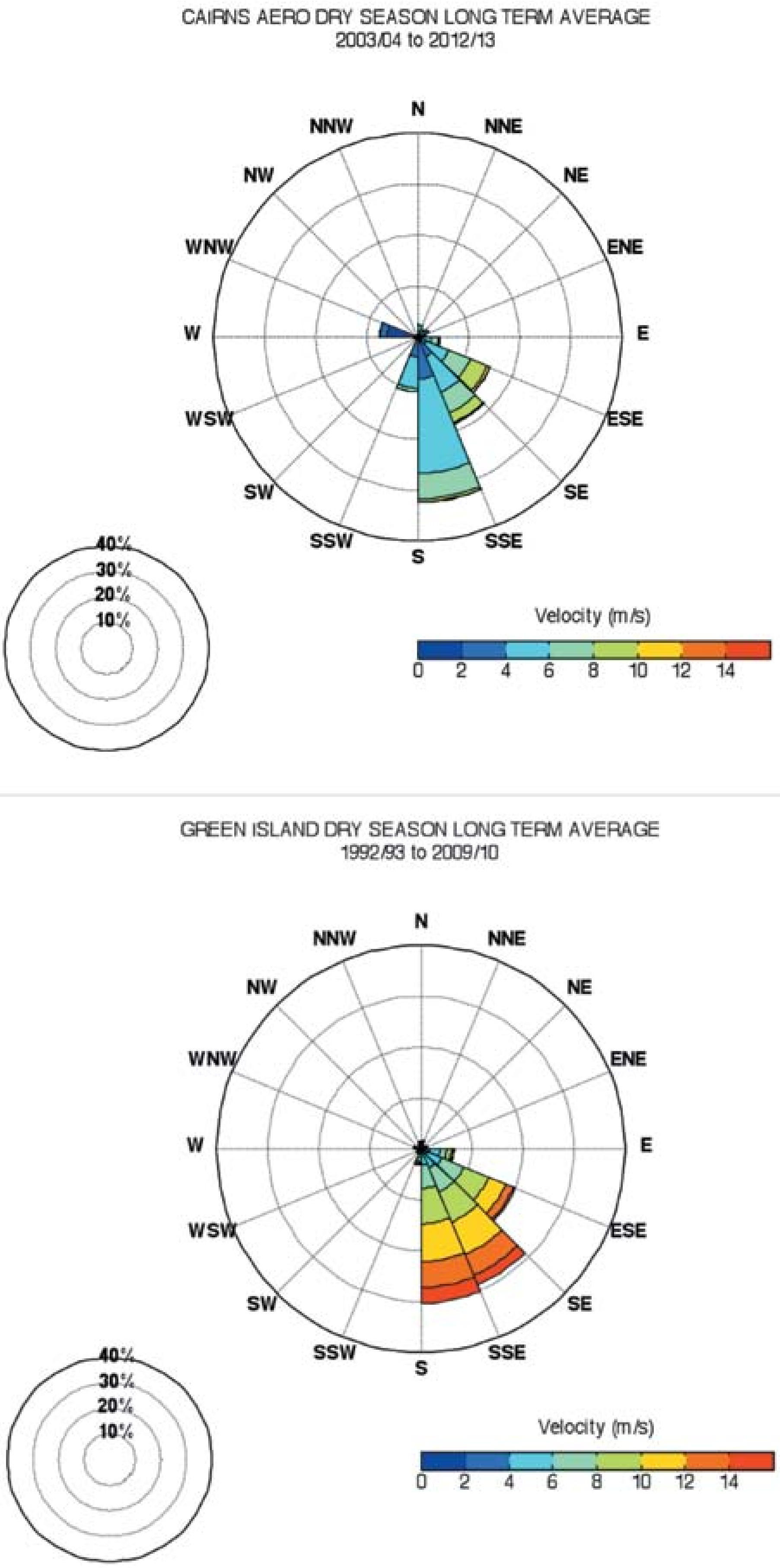
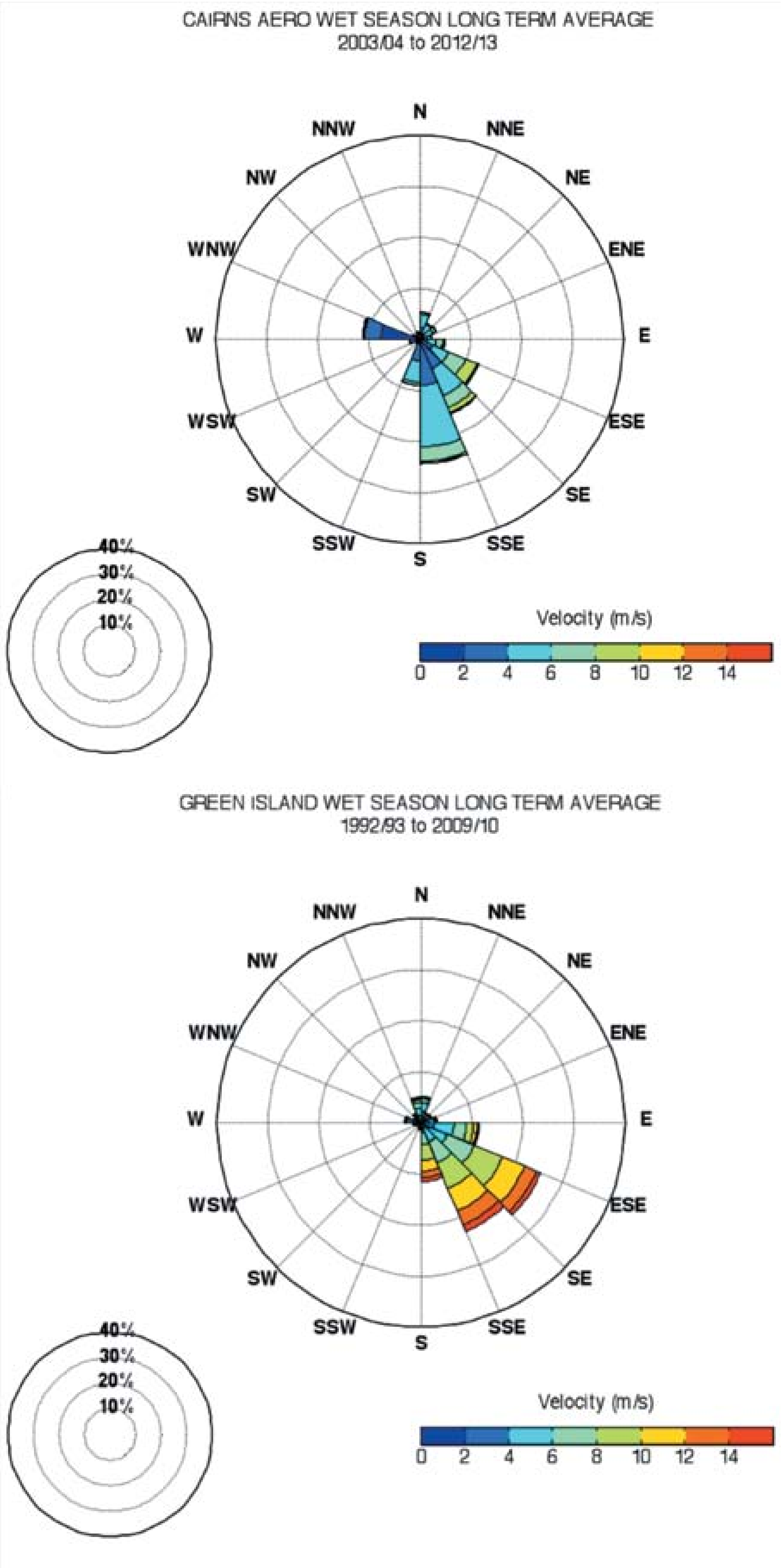


Figure B3.4.5b Wet Season Wind Roses for Cairns Aero and Arlington Reef stations



B3.4.6 Catchments

The study area is located within the Wet Tropics region of North Queensland. Within this region seven major river catchments flow into the GBR lagoon, of which the Barron River catchment (2,100km2) discharges directly into Trinity Bay. The wet tropics catchments are primarily characterised by frequent flooding (approximately annually) associated with high wet season rainfall and in particular monsoon trough and/or tropical cyclone influences.

Catchment loads of sediment, nutrients and other elements into the GBR Lagoon have increased manyfold over the last 150 years as a result of human activities (Furnas, 2003). Devlin (2005) undertook research on the spatial and temporal patterns of flood plumes in the Great Barrier Reef and concluded that the region including and adjacent to Trinity Bay was the most frequently exposed to river plumes within the entire GBR lagoon. The mid-shelf reefs on the outer eastern edge of the study area (such as Green Island) are infrequently exposed to river plumes, both from Barron River floods but also from major catchments further to the south.

Modelling of Barron River flood plumes is described in **Section B3.4.11** and with more detail provided in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**.

B3.4.7 Water Levels

Water level variations in Trinity Bay and Inlet predominantly result from the combined effects of:

- Astronomical tide
- Tidal anomalies due to regional scale meteorological and ocean circulation influences
- Periodic storm surges associated with cyclones and severe weather systems in the region.

The astronomical tide is predominantly semi-diurnal with the dominant tidal planes as specified in the Maritime Safety Queensland (MSQ) Tide Tables (2014) given in **Table B3.4.7a**. Typical variation in the tides throughout the year is illustrated in **Figure B3.4.7a** for 2009, showing in particular the significant fortnightly variation associated with the neap-spring cycle. The tidal anomaly is also shown and regularly attains amplitudes of ±0.2m. Tidal anomaly values of 0.5m are typically only exceeded during tropical cyclone storm surge events. An example seven day tidal record from April 2013, showing a transition from a spring tide to neap tide range is shown in **Figure B3.4.7b**. Modelled water levels are also shown and demonstrate a good level of predictive skill with respect to tidal variations. Further hydrodynamic model validation is provided in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**.

Table B3.4.7a Tidal Planes at Cairns Port

Tidal Plane	Level to Local Chart Datum (m LAT)	Level to Australian Height Datum (m AHD)
HAT	3.50	1.86
MHWS	2.62	0.98
MHWN	1.94	0.30
MSL	1.70	0.06
MLWN	1.46	-0.18
MLWS	0.78	-0.86

Extreme water levels well in excess of HAT can be generated during tropical cyclone storm events. The storm tide is the total water level resulting as the combination of tide and surge during a storm event. The largest recorded storm surge in the last 20 years at Cairns was 1.03m above the astronomic tide level at the time and occurred as Tropical Cyclone Steve (980hPa) crossed the coast at Yorkeys Knob on 27/02/2000 (Queensland Government, 2001). As shown in **Figure B3.4.7c** the peak surge during this event occurred coincident with low tide and therefore the combined storm tide level remained well below HAT. **Table B3.4.7b** lists the five highest water levels recorded in the last twenty years at Cairns Storm tide gauge. Only two of the highest water levels in this table occurred in relation to a Tropical Cyclone, while the remaining three were associated with non-cyclonic monsoon trough activity coinciding with large spring tides.

Table B3.4.7b Highest Recorded Water Levels at Cairns (since 1993)

Rank	Date	Water Level (m AHD)	Tropical Cyclone Name (if applicable)
1	30/01/2014	2.19	Monsoon trough
2	12/01/2009	2.02	TC Charlotte
3	8/2/2001	1.97	Monsoon trough
4	9/3/1997	1.94	TC Justin
5	8/2/2009	1.92	Monsoon trough

Storm surges and storm tide levels in Trinity Bay have most recently been investigated by BMT WBM (2009 & 2013) as part of a study for the entire Cairns Regional Council coastline. In these studies design storm surge and storm tide levels were determined on a probabilistic basis utilising hydrodynamic modelling, as the data record of historical storm tide levels is insufficient for that purpose. **Table B3.4.7c** sets out the tropical cyclone-generated storm tide probabilities in terms of average return intervals (ARI).

Table B3.4.7c Design Tropical Cyclone Storm Tide Levels at Cairns

Average Recurrence Interval (years)	Storm tide level (m AHD)
100	1.99
200	2.24
500	2.65
1000	3.02

Figure B3.4.7a Measured Water Level and Tidal Anomaly Variations during 2009 at Cairns Port

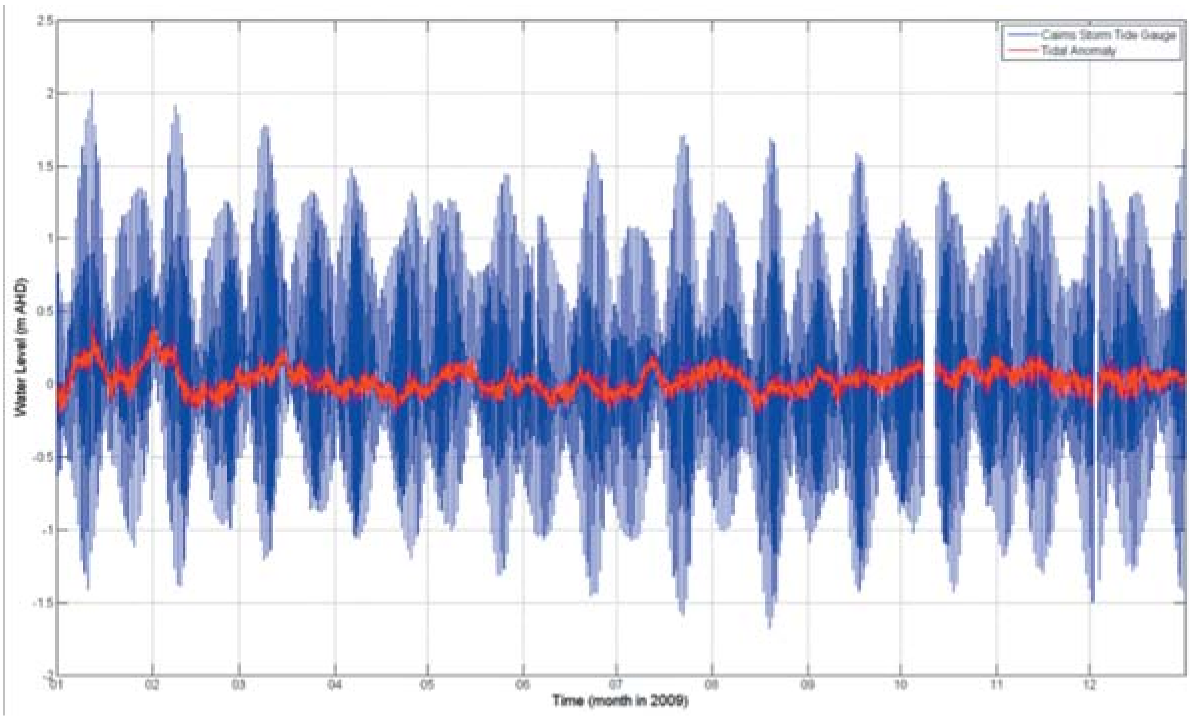


Figure B3.4.7b Measured and Modelled Water Levels at Beacon C11

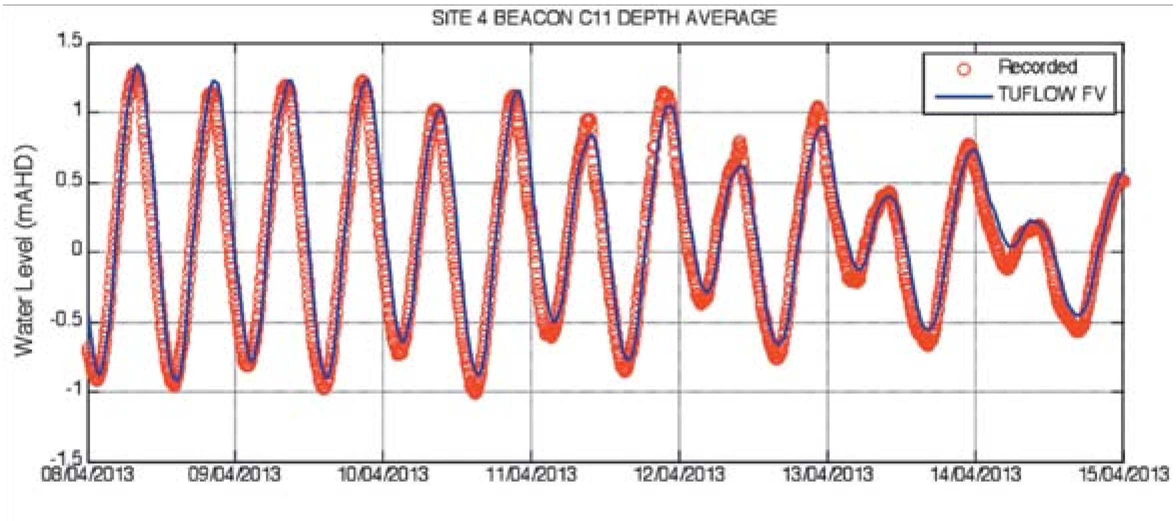
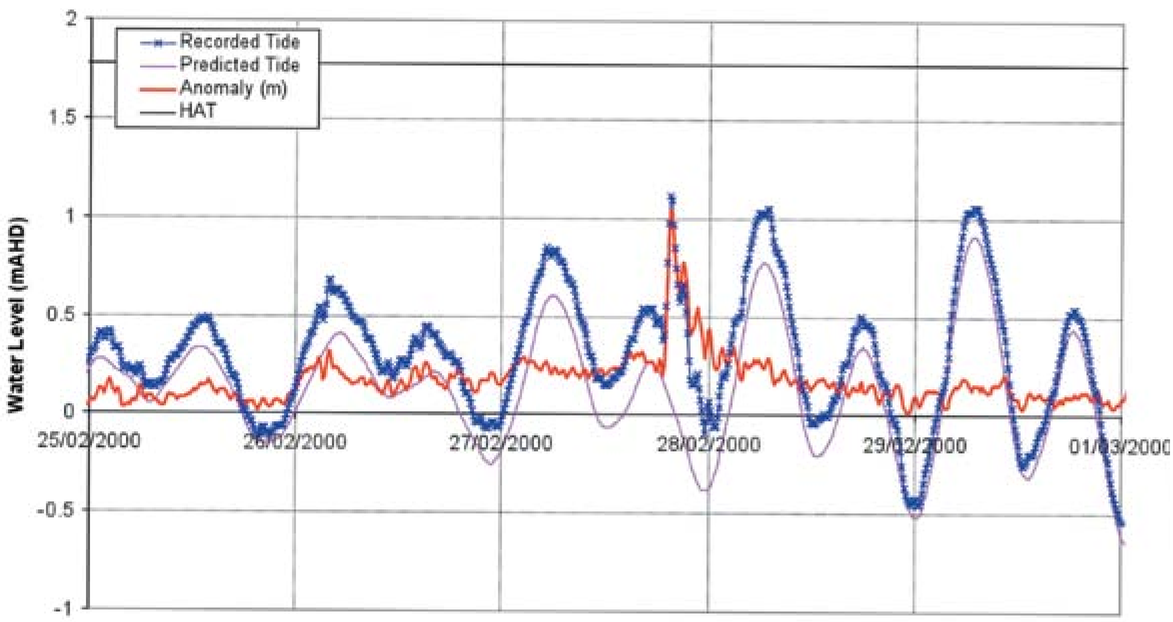


Figure B3.4.7c Measured and Predicted Water Levels during TC Steve at Cairns Port. The red line is the storm surge (tidal anomaly) signal



B3.4.8 Salinity and Temperature

Salinity within Trinity Bay is driven by the balance between evaporation and the wet season freshwater inflows from local catchments such as Barron River and Trinity Inlet and from the major regional sources located to the south. Slightly hypersaline conditions are typically experienced in the western GBR lagoon during the winter dry season and lower salinities in the range 20-30psu have been measured in Trinity Bay during certain summer wet seasons (RRRC – Pers. Comm.).

Data collected at the nearby Green Island indicates that water temperatures within Trinity Bay typically range from a July minimum of around 22°c to a January maximum of around 30°c (Wolanski & Pickard, 1985).

In general it is expected that the vertical structure would be generally well-mixed during the winter and weakly stratified due to vertical salinity and temperature gradients during the wet season (Wolanski, 1994).

B3.4.9 Currents

Currents within Trinity Bay are predominantly driven by a combination of:

- Tide
- Wind, acting at both regional and local scales
- Non-tidal water levels and currents in the adjacent Coral Sea.

Within the study area the tide and locally acting wind are generally the most significant drivers of both regional and local scale currents.

B3.4.9.1 Regional Currents

On a regional scale the GBR lagoon exists at the western boundary of the Coral Sea, where the south-equatorial surface current bifurcates as a western boundary current along the Australian continental shelf margin (**Figure B3.4.9.1a**). The southward flowing arm is referred to as the East Australia Current (EAC) and is a highly dynamic large-scale ocean circulation feature, which is known to oscillate strongly in terms of position and intensity. The influence of the EAC on the circulation of water within the GBR lagoon has been postulated and studied numerically by King and Wolanski (1992) and Andutta (2012).

Measurements from an ADCP deployed at the Cairns DMPA as part of this study, indicate some intermittent substantive influence by the EAC within the study area, and this was confirmed with the inclusion of ocean current forcing in the numerical modelling assessment (refer **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**). The left-hand panel in **Figure B3.4.9.1b** shows an example snapshot of the modelled surface currents during a period where the EAC is flowing strongly southward along the continental shelf margin to the east of the GBR lagoon.

While the ocean current forcing can occasionally be a significant driver of currents within the study area located in the western GBR lagoon, and has been included in the modelled assessments, it is predominantly secondary to both the tidal and wind driven current forcing. The right-hand panel in **Figure B3.4.9.1b** shows a current snapshot from a period where the south-easterly trade winds are the dominant force driving regional scale currents.

Figure B3.4.9.1a Australian Region Ocean Surface Currents

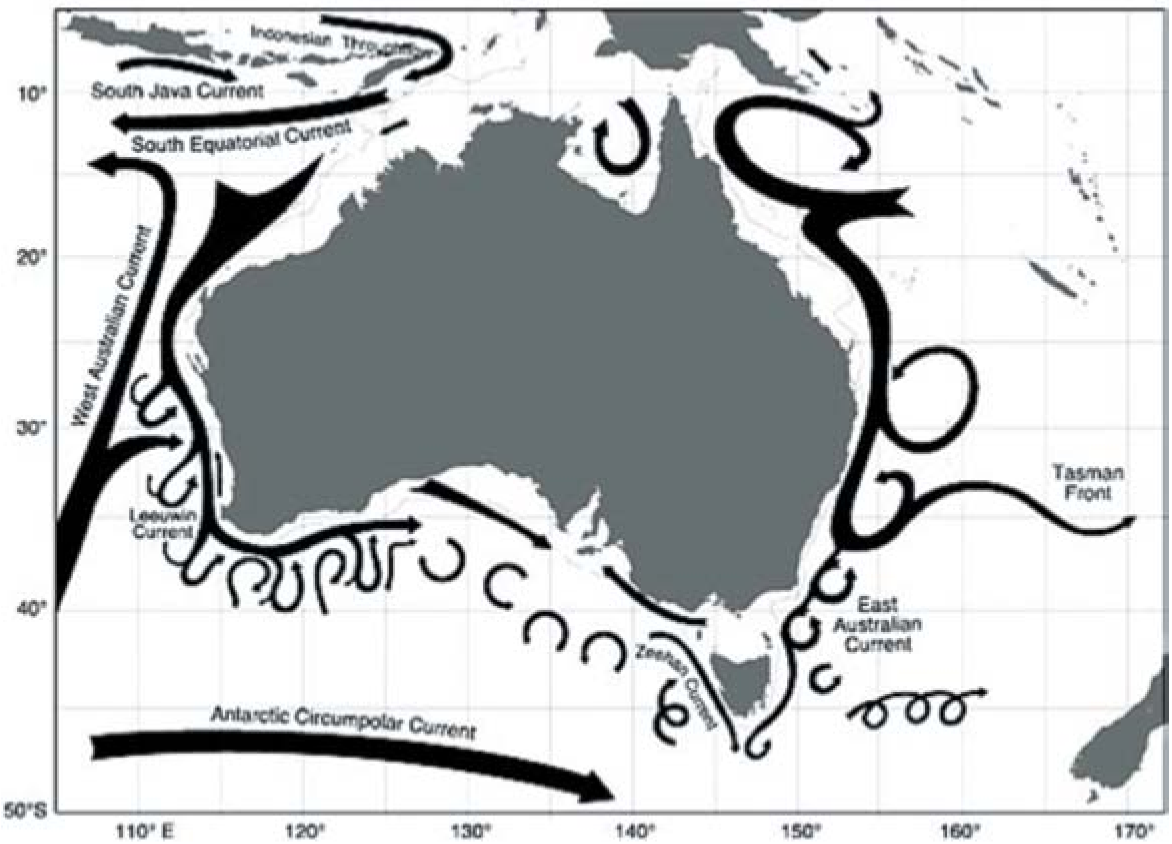
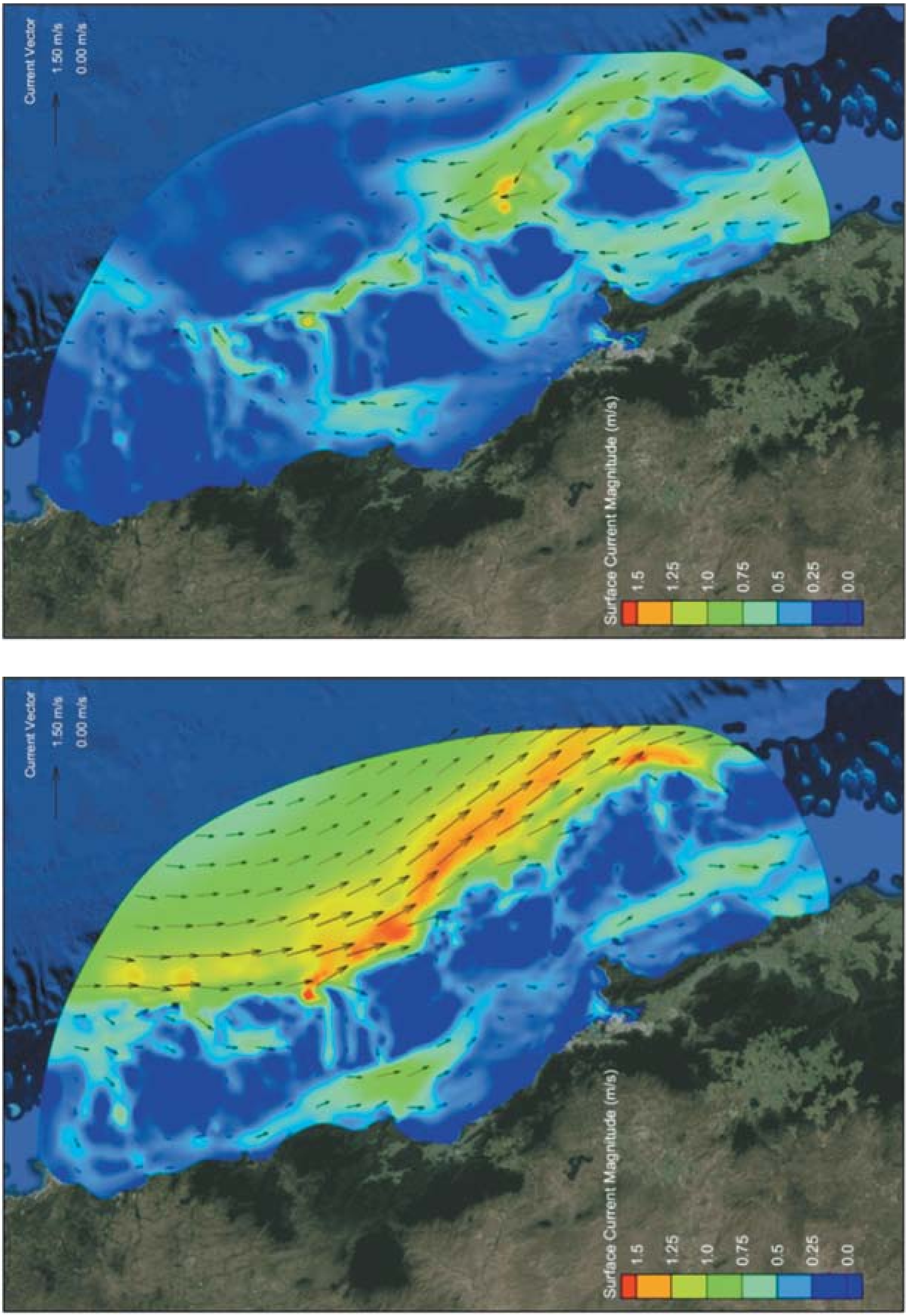


Figure B3.4.9.1b An Example of Modelled Offshore Currents: Strong Southward Flowing EAC *(left)* and Northward Flowing Trade Wind-Driven Current *(right)*



B3.4.9.2 Trinity Bay Currents

Within the western GBR lagoon, including Trinity Bay, currents are predominantly driven by tidal flows and wind stresses. **Figure B3.4.9.2a** illustrates the spatial pattern of ebb and flood spring tide flows, in the absence of wind forcing. Within Trinity Bay these tidal currents tend to flow inshore/offshore roughly perpendicular to the bathymetric contours and along the channel alignment. Tidal currents within the shipping channel are generally higher than the relatively shallow surrounds and are found to reach higher peak speeds during the ebb.

Figure B3.4.9.2b illustrates the typical influence of the predominant east-southeast trade wind on the currents. The wind generates a persistent north-west drift in the GBR lagoon waters and along the open coastline of the study area. The flood tide flows around Cape Grafton and False Cape are reinforced by the wind driven currents, while the corresponding ebb tide flows are opposed. Within Cairns Harbour and Trinity Inlet the tidal flow component remains dominant over the wind driven currents. The wind induces a slight cross-channel component to the currents, which is significant for channel siltation processes.

Further offshore the wind driven currents are generally dominant over the tidal currents whenever sufficiently strong winds prevail. Time series plots of current speed and direction for the existing DMPA are shown in **Figure B3.4.9.2c**, covering a range of tidal and wind conditions, and includes both measured and modelled currents utilised as part of the model validation process (refer **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**). It can be seen that the current signal is not strongly tidal due to the dominant influence of wind at this location. During periods of weak tidal forcing (and weak current magnitude) the current direction data shows significant scatter. Current speeds can range up to about 0.5 m/s at the existing DMPA during strong wind events.

Time series plots of current speeds and direction at Beacon C11 are shown in **Figure B3.4.9.2d**. It can be seen that at this most inshore location the current signal is dominated by the tidal exchange with Trinity Inlet. At this particular location adjacent to the shipping channel a significant ebb tide dominant asymmetry is apparent during certain spring tides, with flood tide current speeds reaching a maximum of around 0.5m/s while the ebb tide current speeds peak at around 0.75m/s.

The vertical current structure measured during the period from March to June 2013 does not indicate any significant degree of water column stratification. At most instances in time during this period both near-surface and near-bed currents typically exhibit similar directions with relatively lower current magnitudes near the bed. This trend can be seen in the **Figure B3.4.9.2c** and **Figure B3.4.9.2d** timeseries, which are split into comparisons for the top and bottom 50% of the water column. The broadly similar directional properties of near-surface and near-bed currents can also be seen in scatter plots of both measured data and model currents at the DMPA shown in **Figure B3.4.9.2e**. While not seen in the 2013 field measurements, which were undertaken during a relatively low rainfall season, the water column would be expected to exhibit some vertical stratification following significant runoff events as considered in **Section B3.4.11**.

The net current (often referred to as the “residual” current) for the period from 4 March to 17 June (equal sampling of spring/neap conditions) is presented in **Figure B3.4.9.2f** and shows the dominant influence of the prevailing south-easterly trade winds in driving a north-west drift through the GBR lagoon.

Figure B3.4.9.2a Modelled Tidal Currents (no wind). Flood Tide *(top)* and Ebb Tide *(bottom)*

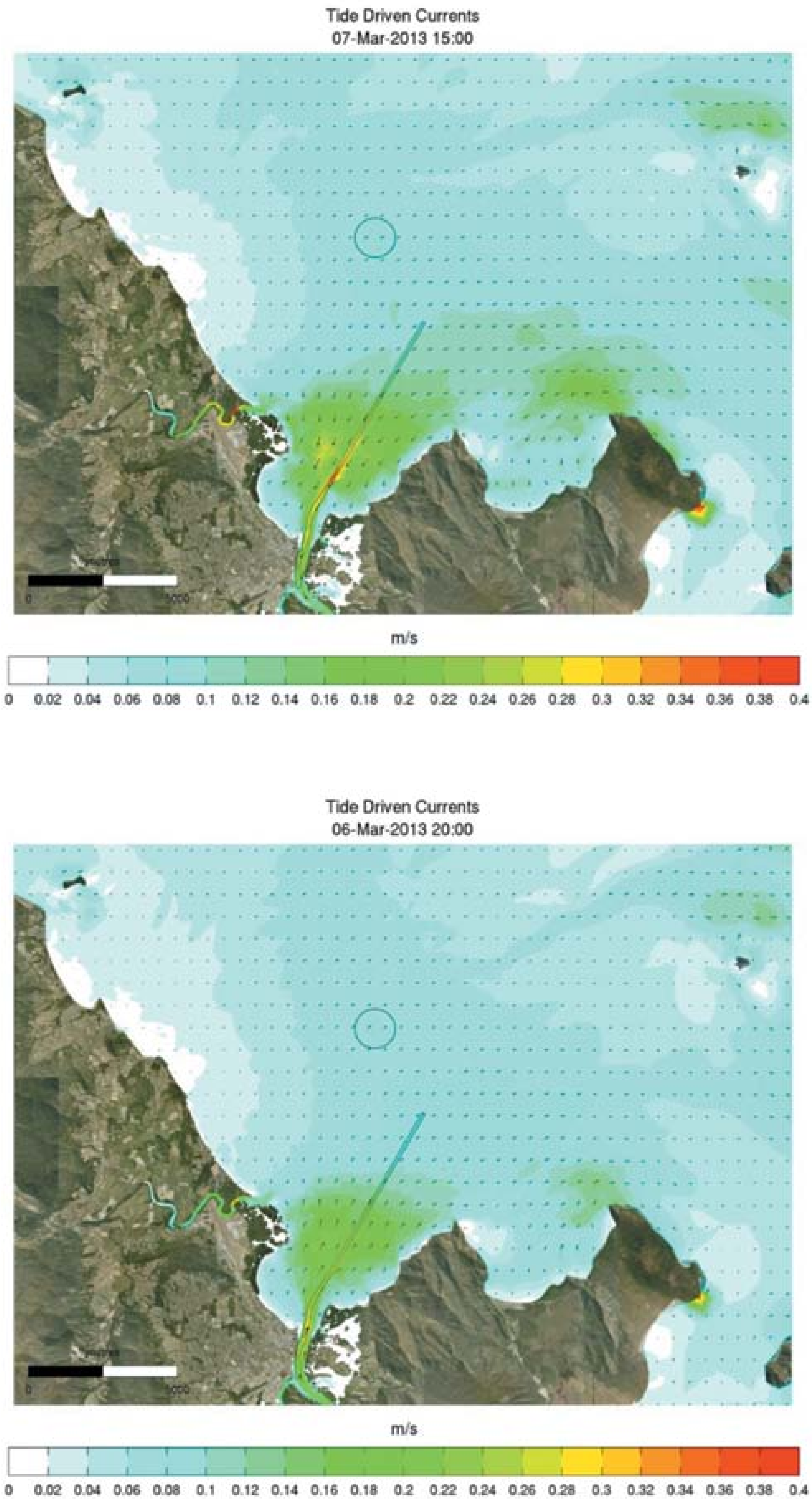


Figure B3.4.9.2b Modelled Currents During a 20knot Trade Wind. Flood Tide *(top)* and Ebb Tide *(bottom)*

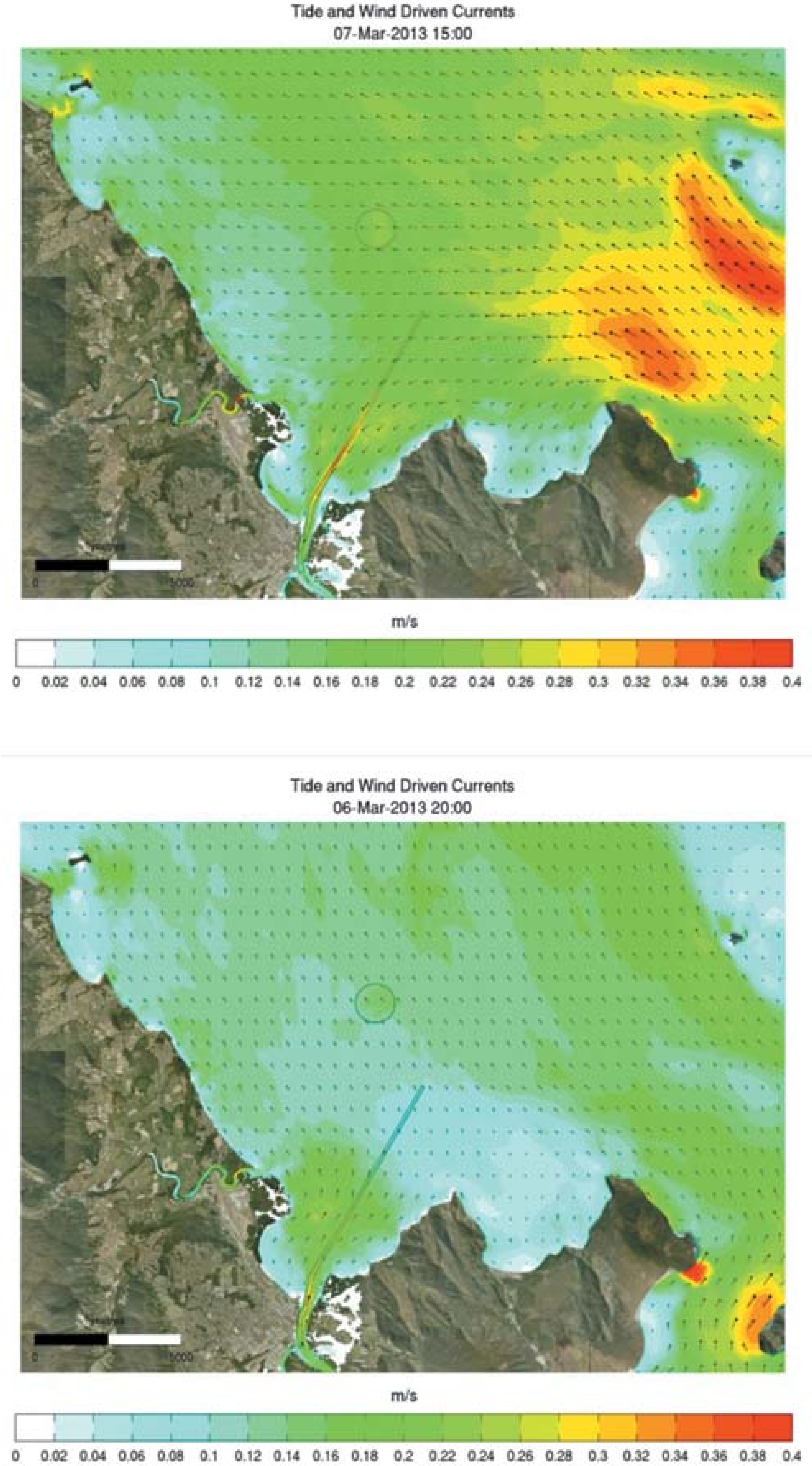


Figure B3.4.9.2c Measured and Modelled Current Speeds and Directions at the existing DMPA

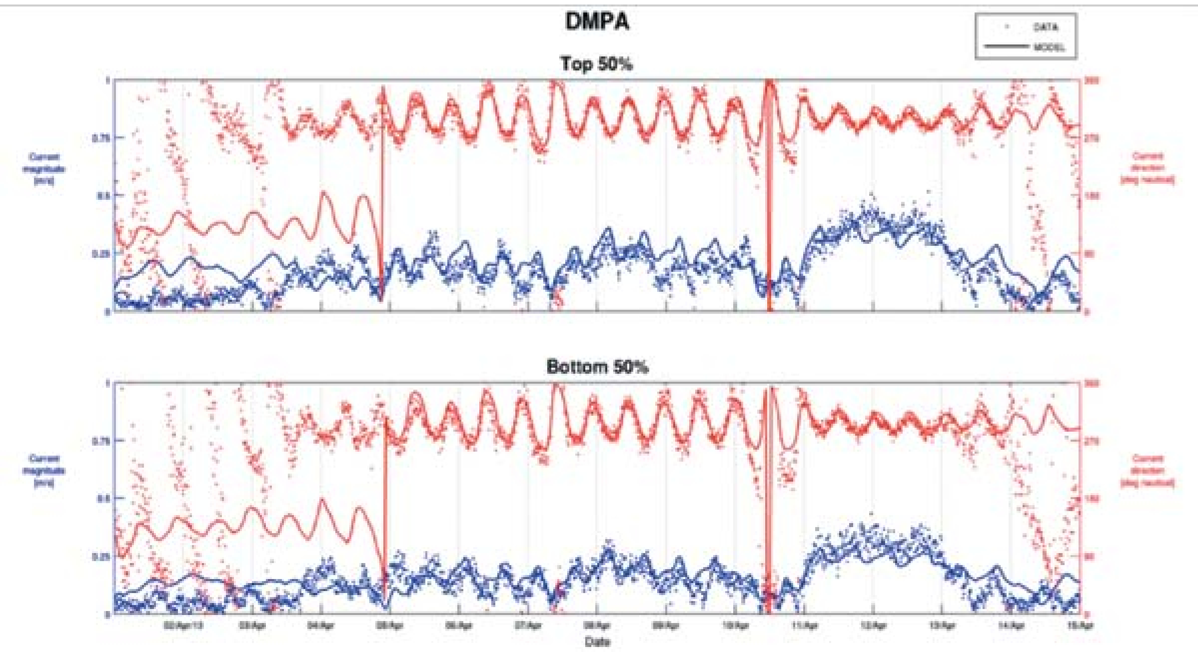


Figure B3.4.9.2D Measured and Modelled Current Speeds and Directions at Beacon C11

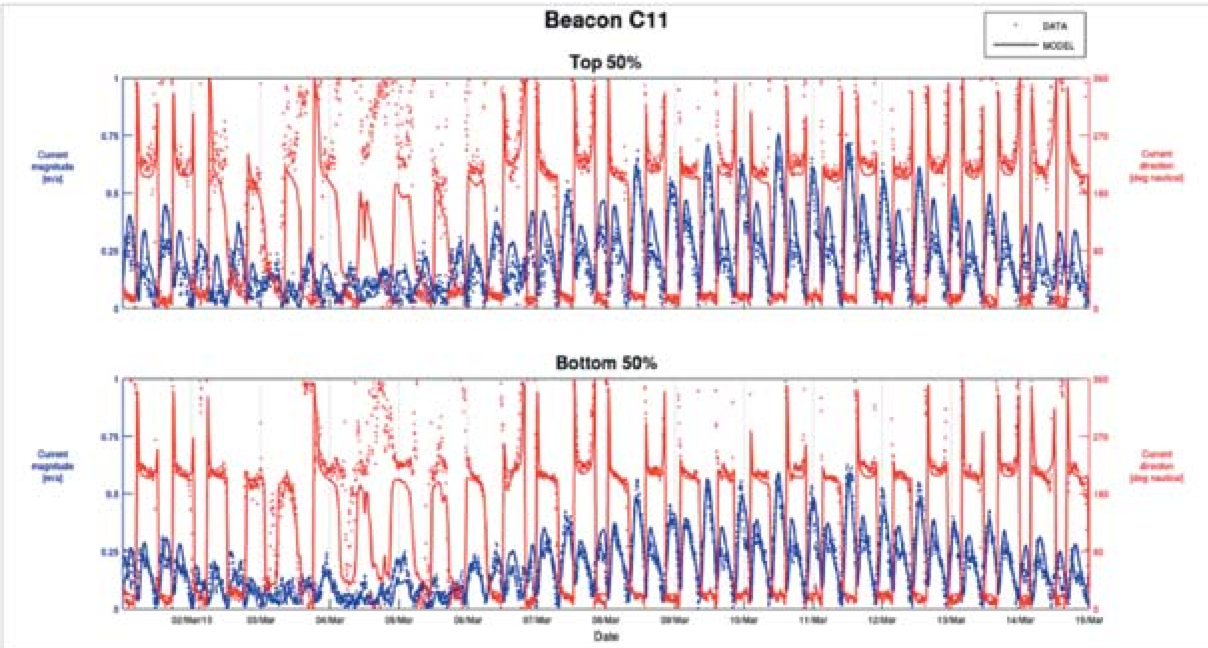


Figure B3.4.9.2e Near-Surface *(left)* and Near-Bottom *(right)* current scatter plots at the DMPA

Both modelled (top) and recorded (bottom) data are shown

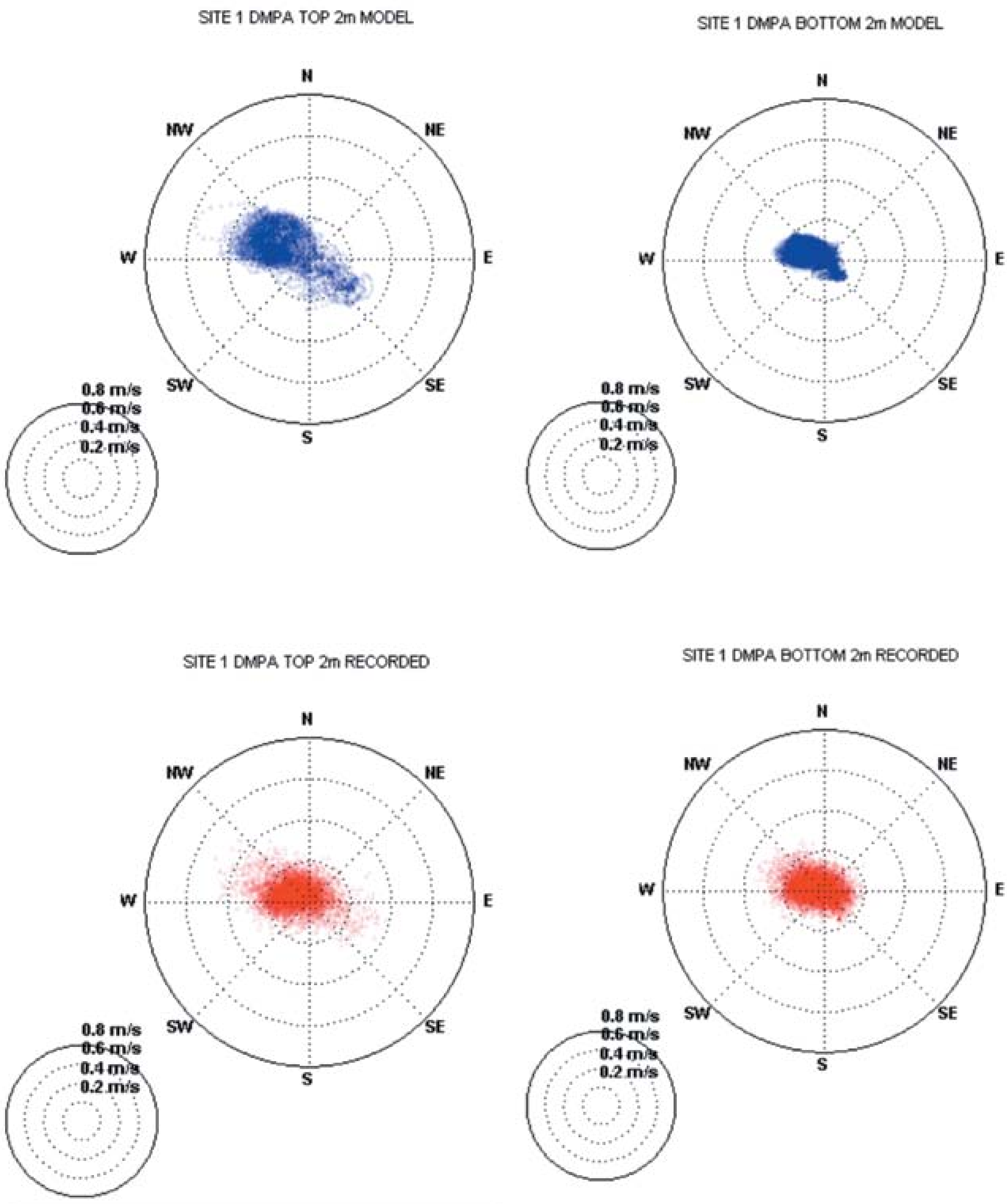
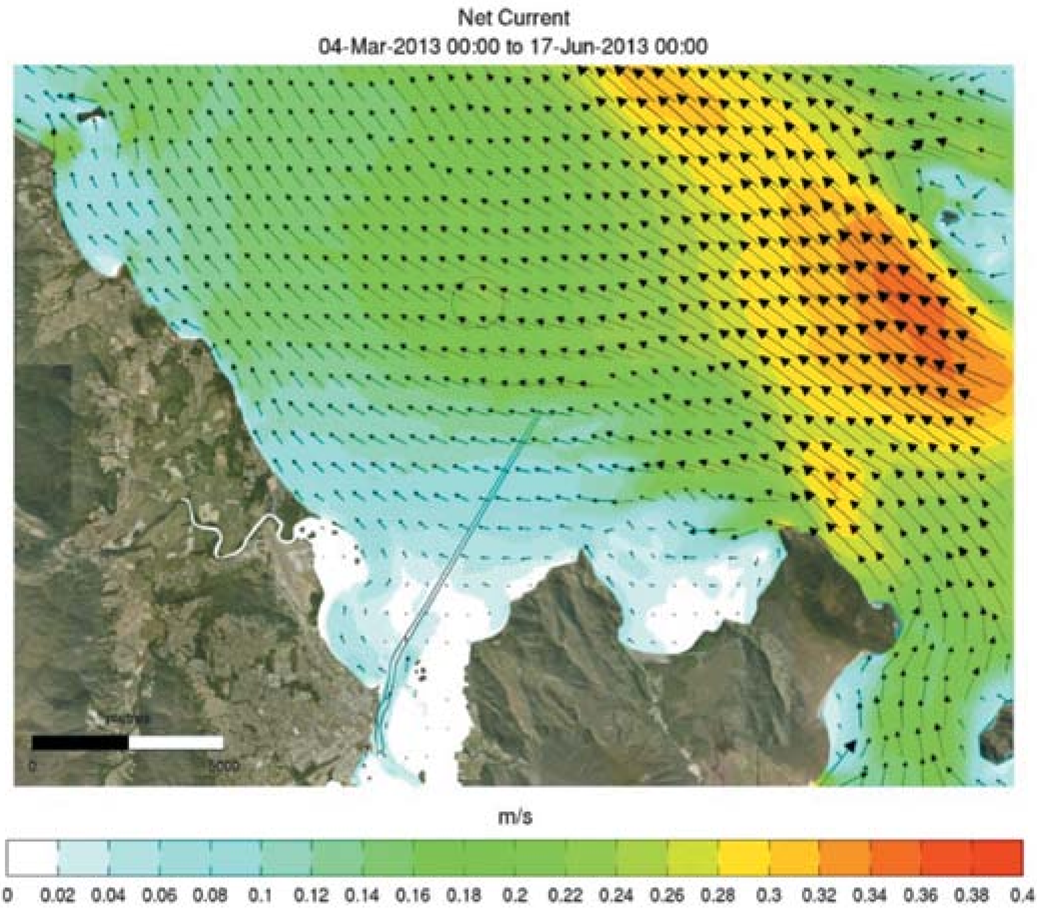


Figure B3.4.9f Modelled Net Current 4 March to 17 June 2013



B3.4.10 Wave Climate

On a regional scale, the Great Barrier Reef partially shelters the North Queensland coastline from the deep ocean waves propagating westward from the Coral Sea. As shown in **Figure B3.4.10a**, Trinity Opening is a natural channel to the north-east of Cairns which allows some swell to penetrate into the GBR lagoon from the Coral Sea, albeit with significantly attenuated energy. Similarly Grafton Passage to the east of Cairns also allows some limited ocean swell penetration.

On a more local scale, Cape Grafton shelters the beaches from the south-easterly waves generated within the GBR lagoon. Fetches within the GBR lagoon are illustrated in **Figure B3.4.10a** and are generally limited to 30-50km by the large mid shelf reef complexes. Non-cyclonic winds rarely exceed 25 knots and locally generated sea wave heights are typically less than 1.4m. East-south-easterly sea waves within the 3-5 second period band are the most prevalent wave energy component measured at the Cairns waverider buoy (BPA, 1984). Waves approaching the study area from the east-south-east are refracted as they propagate into Trinity Bay.

Due to the complex arrangement of reef passes, fetch lengths and local bathymetry, the wave climate in the study area can at times be multi-modal, meaning that it is made up of multiple component wave trains with distinct wave periods and directions. **Figure B3.4.10b** is a photograph showing an instance of ocean swell with nine-second peak period propagating into Clifton Beach from the Trinity Opening to the north-east.

Waves are the key driver of elevated turbidity in shallow waters throughout the study area. Naturally occurring plumes generated by swell and sea wave processes that suspend fine silty bed sediments are often visible in the nearshore zone (up to 500m offshore). This pattern of increased wave-driven turbidity is common for many locations along the central and north Queensland coast. The baseline turbidity conditions throughout Trinity Bay are described using long term datasets in **Chapter B5, Marine Water Quality**.

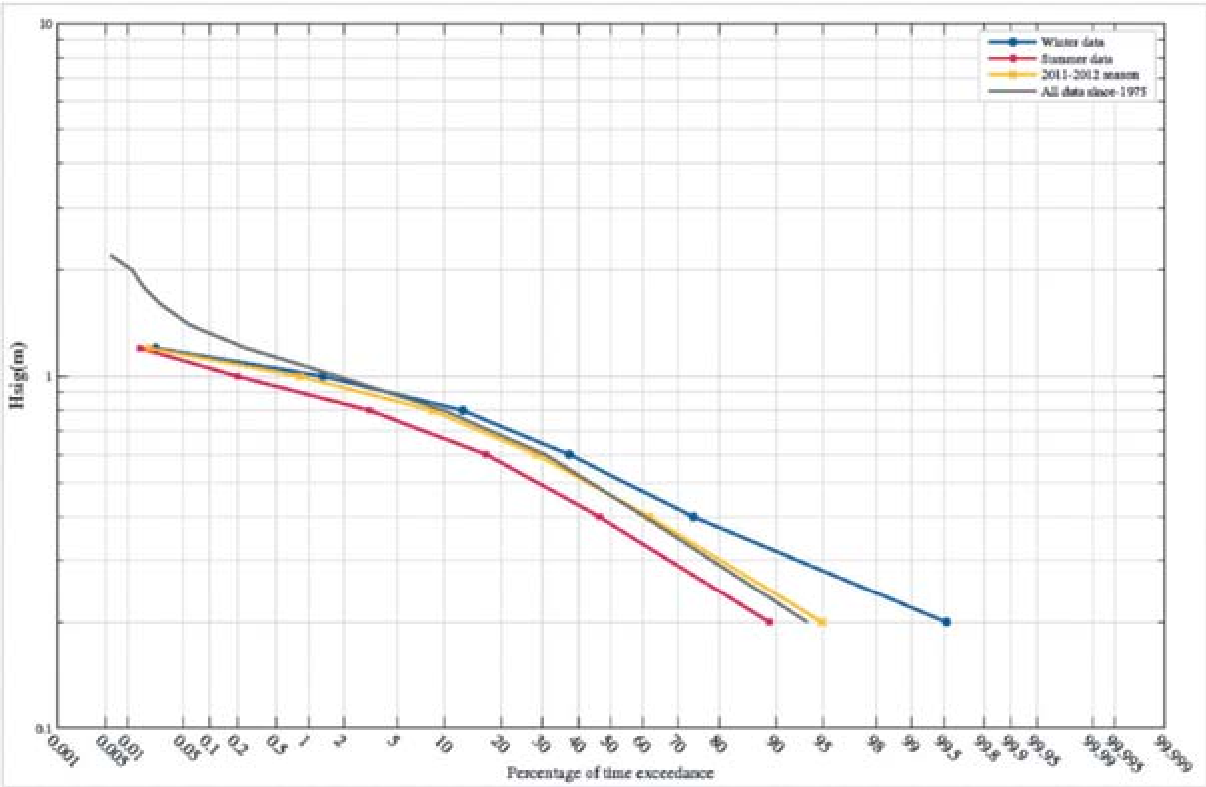
Figure B3.4.10a Trinity Bay Wave Fetch and Swell Penetration (BPA, 1984)

Figure B3.4.10b Ocean Swell (9s peak period) at Clifton Beach (BPA, 1984)

B3.4.10.1 Cairns Offshore Waverider

The Cairns Offshore waverider buoy has been operated by the Queensland Government since 1975. The buoy collects non-directional wave measurements and has been stationed in 18m of water depth offshore of Palm Cove (**Figure B3.3.2.7a**). A wave height exceedance plot comparing the summer and winter wave climate from the 2011-2012 season with the corresponding distribution derived from all data since 1975 was supplied by DEHP and is shown in **Figure B3.4.10.1a**. The median Hsig is in the range 0.4-0.5m with Hsig greater than 1m occurring approximately 1% of the time. **Figure B3.4.10.1a** suggests the wave climate during the 2011-2012 season was representative of the long term average. This period was adopted for marine water quality impact assessment modelling presented in **Chapter B5, Marine Water Quality**.

Figure B3.4.10.1a Wave Height Exceedance Plot for Cairns Offshore Wavrider (DEHP)



B3.4.10.2 Cairns DMPA

A wave rose for conditions measured at the Cairns Port DMPA between February 2013 and February 2014 is shown in **Figure B3.4.10.2a**. Recent bathymetric surveys of the DMPA suggest the average bed elevation at the site is around -11m AHD. The wave rose clearly shows that the modal wave condition at this location is 0.5-1m Hsig with peak energy from the East to East-South-East sector.

A directional wave energy spectra from the ADCP instrument deployed at the Cairns Port DMPA for a period of north-east swell and east-south-easterly sea waves is shown in **Figure B3.4.10.2b**.

Figure B3.4.10.2a Wave Rose (Hsig, Dirp) at the Cairns DMPA for February 2013 to February 2014

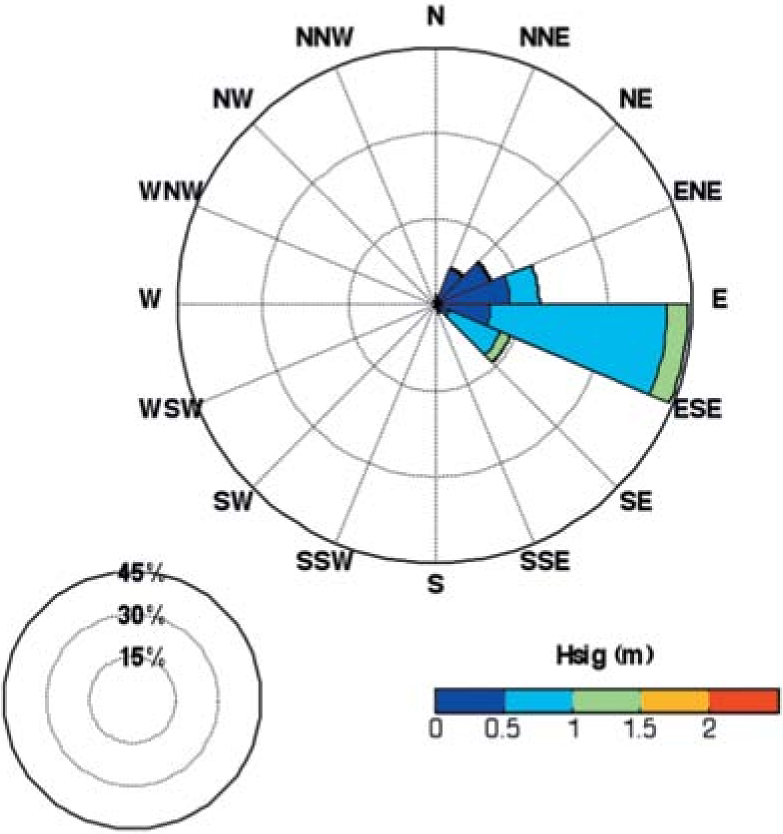
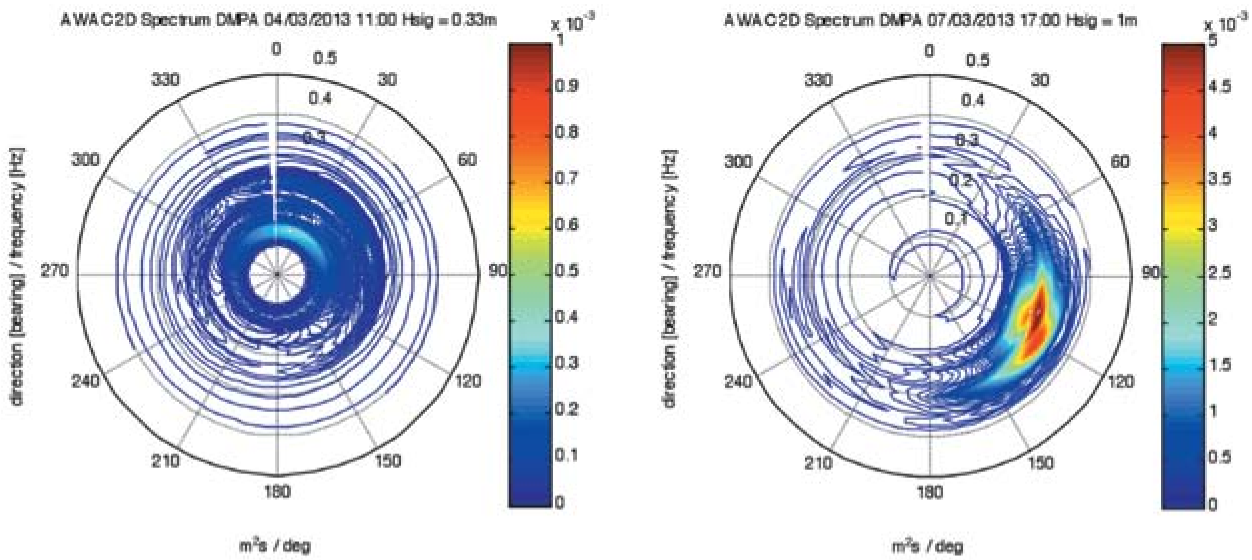


Figure B3.4.10.2b ADCP Directional Wave Energy Spectra at the Cairns DMPA: North-East Swell *(left)* and South-Easterly Sea *(right)* Dominant



B3.4.10.3 Wave Modelling

Comprehensive spectral wave models covering the broader region surrounding and within Trinity Bay were established to assess in more detail the wave climate and wave propagation in the context of the proposed development, particularly for assessment of shoreline processes and for coupling with the sediment transport model.

Measured wave data from the EHP Waverider Buoy and the four ADCPs deployed in 2013 were used to calibrate and validate the SWAN wave models. **Figure B3.4.10.3a** shows the correlation between the modelled and recorded waves at Cairns offshore waverider, confirming good agreement in terms of regional wave generation. The results of the nested wave model calibration for Trinity Bay are shown in **Figure B3.4.10.3b** for the DMPA location and **Figure B3.4.10.3c** for the most inshore Beacon C11 site. Agreement between the measured and modelled wave heights and peak periods is generally very good. It is noted that the directional scatter associated with small, locally-generated wind waves seen in the data isn't resolved by SWAN.

Typical patterns of Coral Sea swell, and GBR lagoon wind generated wave conditions based on the regional SWAN model are illustrated in **Figure B3.4.10.3d** and **Figure B3.4.10.3e** respectively. The pattern of east-south-easterly wave refraction across Trinity Bay is shown based on the 100m grid SWAN model in **Figure B3.4.10.3f**. Wave height is represented by the colour contours and the vector arrows show the wave direction. The substantial sheltering afforded by Cape Grafton can clearly be seen.

Figure B3.4.10.3a Wave Model Validation at the Cairns Offshore Waverider

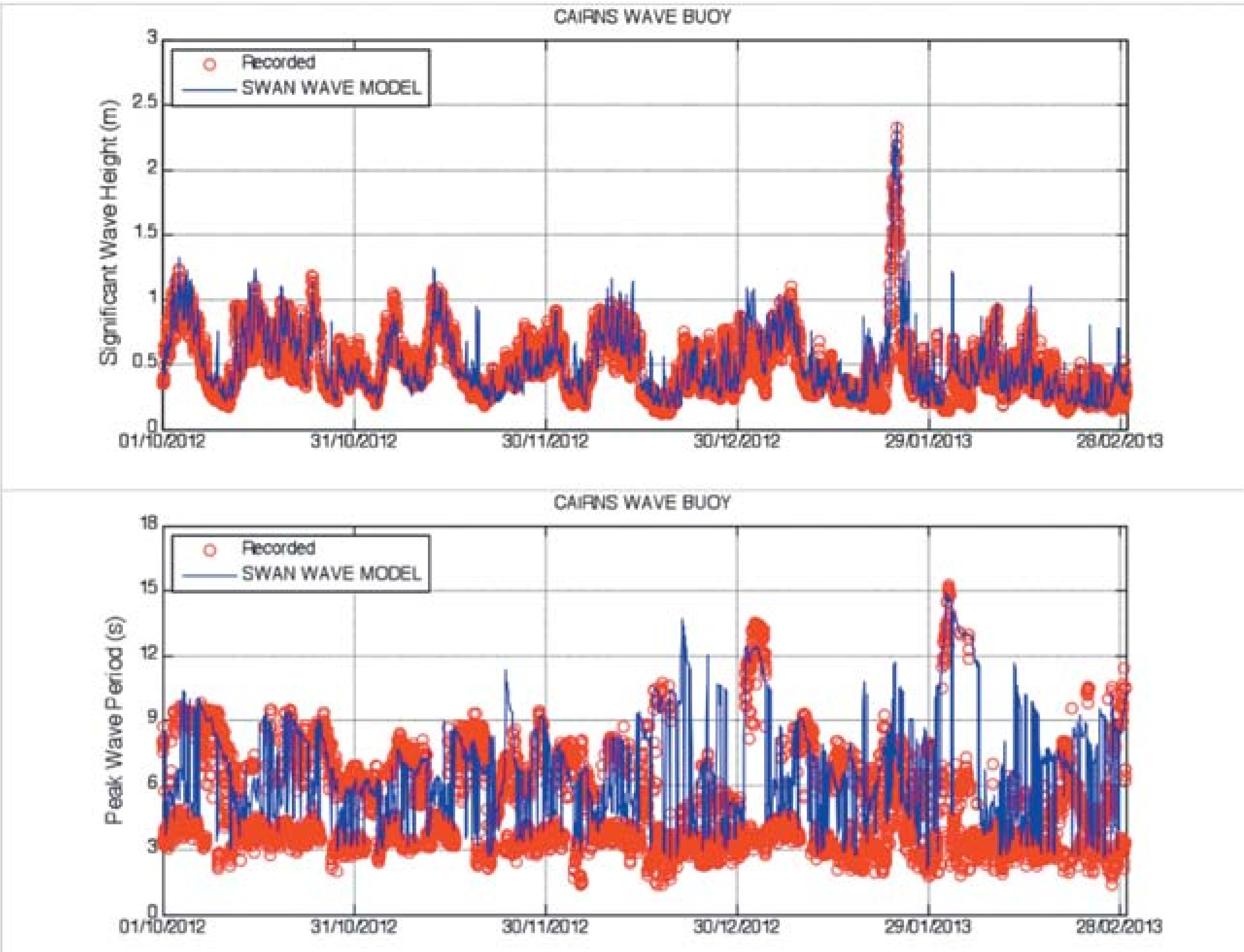


Figure B3.4.10.3b Wave Model Validation at the DMPA

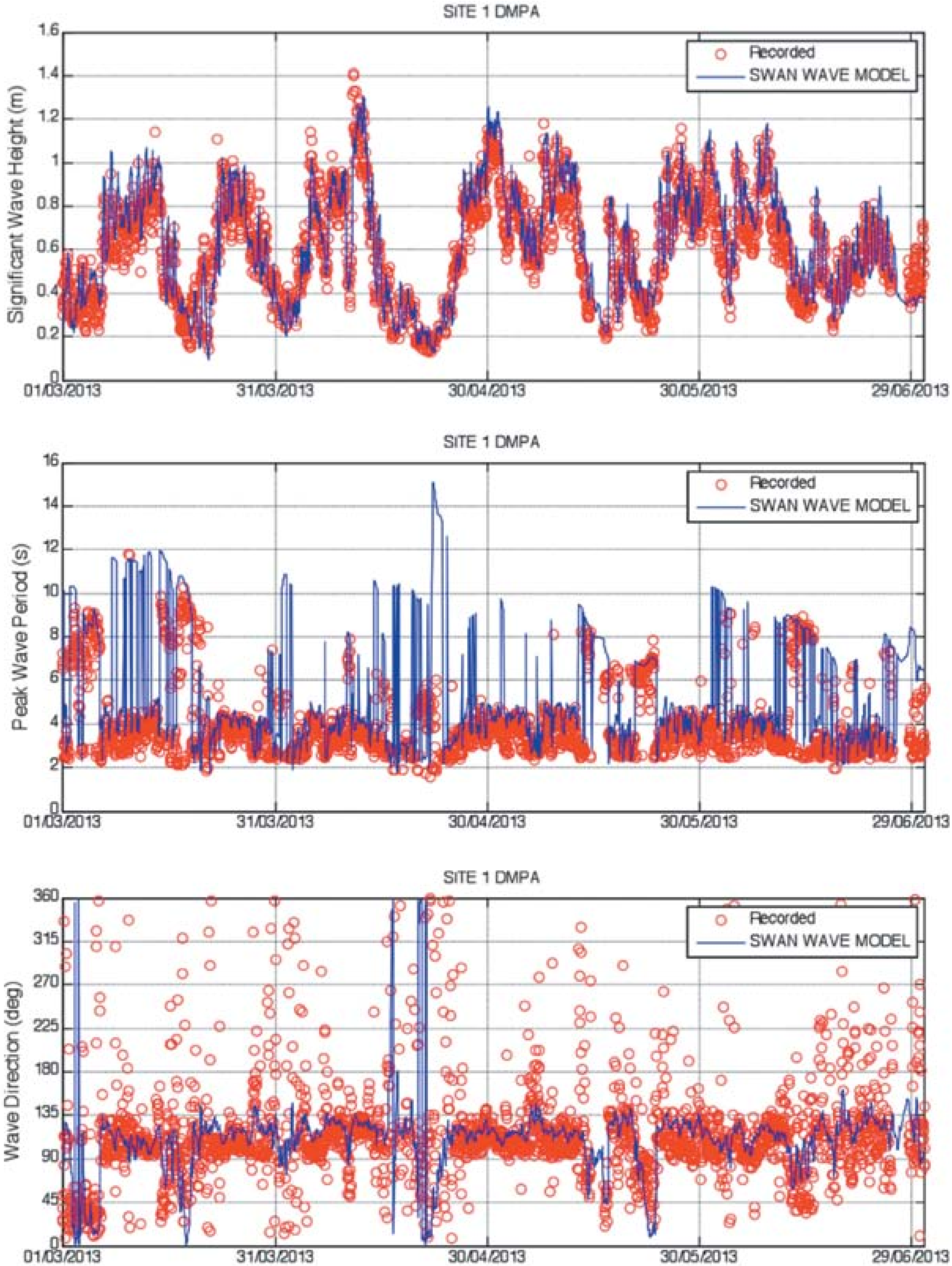


Figure B3.4.10.3c Wave Model Validation at Beacon C11

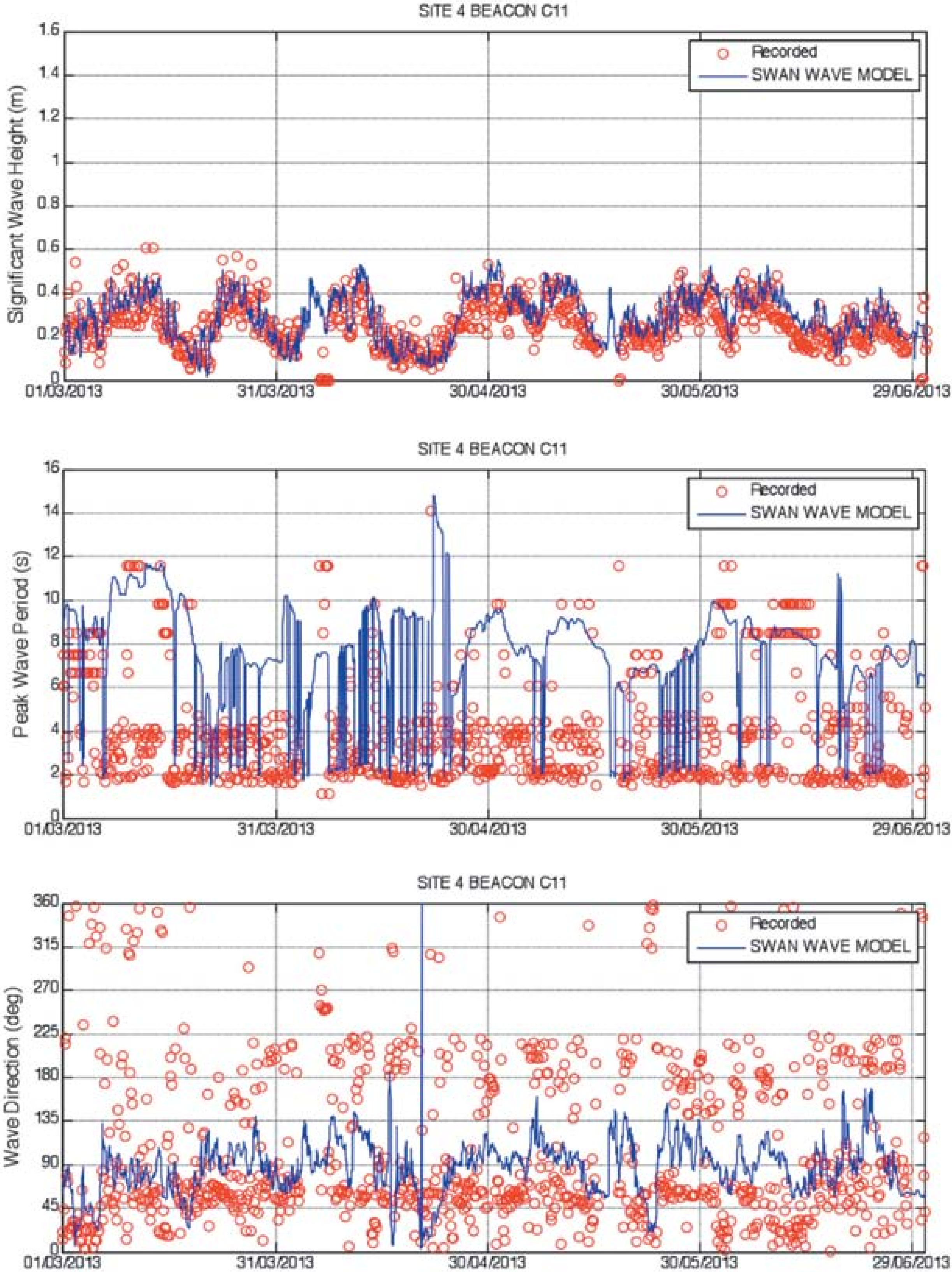


Figure B3.4.10.3d Coral Sea North-East Swell Penetration into the GBR Lagoon

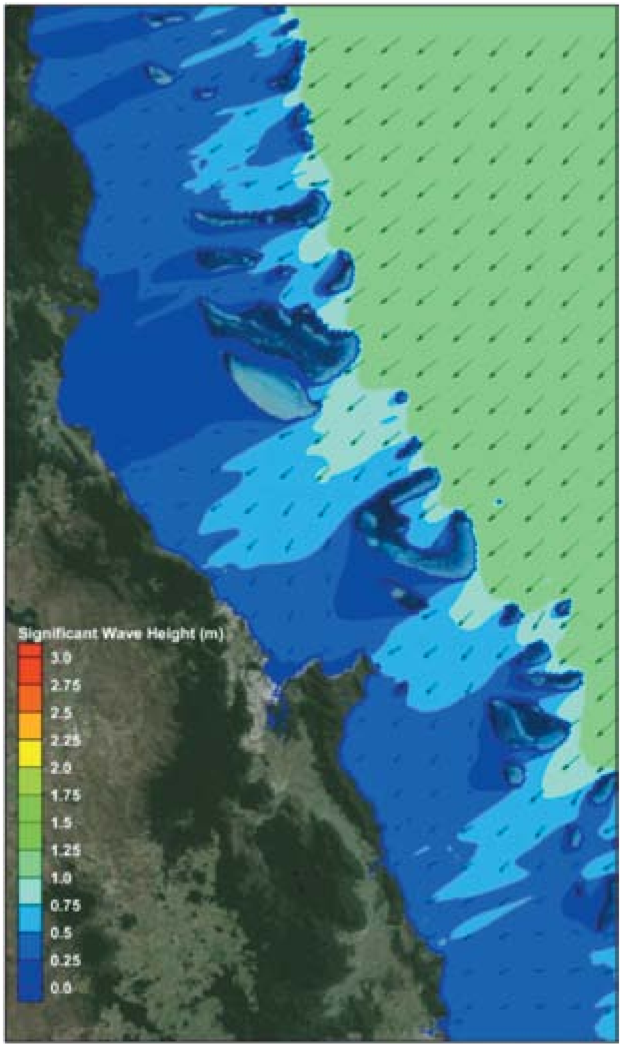


Figure B3.4.10.3e Regional Wave Patterns Established by a Prevailing South-East Trade Wind

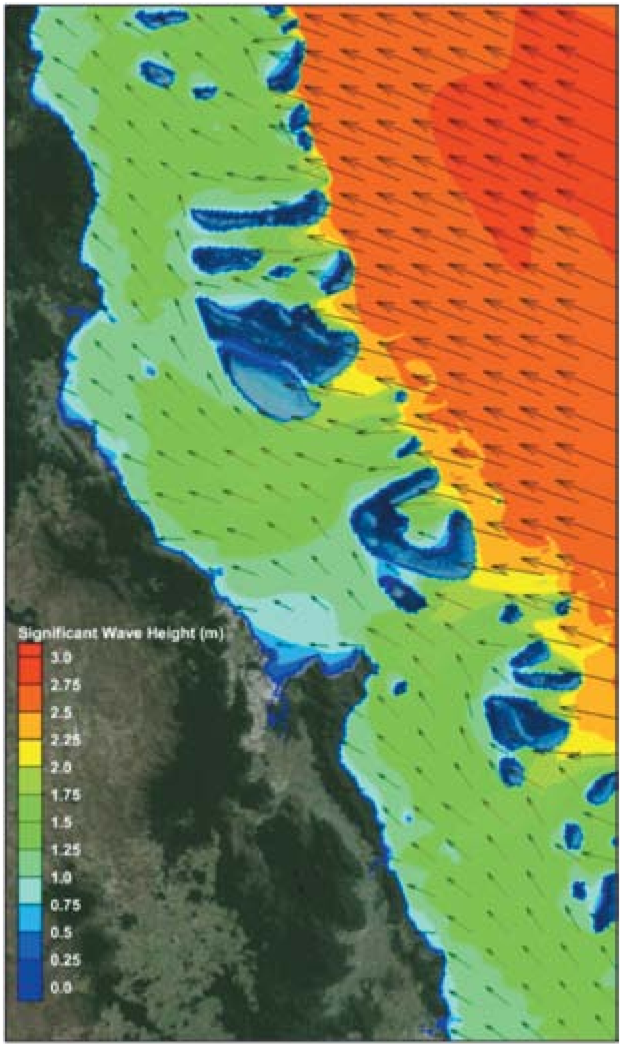
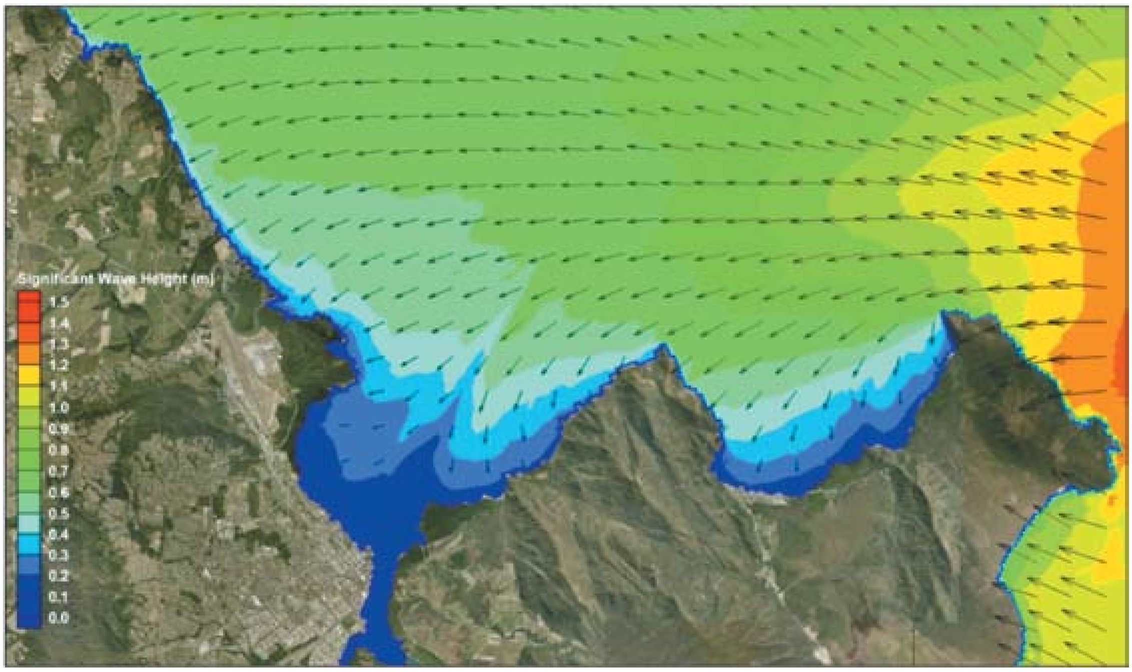


Figure B3.4.10.3f Trinity Bay Wave Refraction



B3.4.10.4 Tropical Cyclone Waves

Tropical cyclones are responsible for the majority of the highest waves in the region. Extreme wind speeds within tropical cyclones can generate significant wave heights well in excess of 1.4m with associated spectral peak periods of 5-10s. The five highest recorded significant wave heights at the Cairns Offshore buoy which has been measuring since 1975 are summarised in **Table B3.4.10.4a**. All of these events were associated with the passage of a tropical cyclone within the GBR lagoon.

Table B3.4.10.4a Highest Measured Waves at Cairns Offshore buoy (data from DSITIA)

Rank	Date	Hs (m)	Tropical Cyclone Name (if applicable)
1	27/02/2000	2.8	TC Steve
2	11/02/1999	2.5	TC Rona
3	03/02/2011	2.4	TC Yasi
4	23/12/1990	2.2	TC Joy
5	19/03/1990	1.9	TC Ivor

The Cairns Region storm tide study (BMT WBM, 2013b) undertook statistical modelling of tropical cyclone wave heights, which derived the design levels provided in **Table B3.4.10.4b**. It should be noted that these wave heights were extracted from a location coinciding with the 5m AHD contour and are likely to be at least partially depth limited.

Table B3.4.10.4b Design Tropical Cyclone Wave Heights at Cairns (BMT WBM, 2013)

Average Recurrence Interval (years)	Significant Wave Height (m)
100	2.79
200	2.86
500	2.92
1000	2.96

B3.4.11 Marine Sedimentation

The marine sediment dynamics within Trinity Bay / Inlet is of relevance to the CSDP due to the interaction between these processes and the existing and proposed port infrastructure, including channels and DMPA. The intersection of sediment transport pathways and the channel infrastructure leads to a potential requirement for ongoing maintenance dredging. Furthermore the natural sediment re-suspension dynamics strongly drive the ambient water quality described in **Chapter B5, Marine Water Quality**.

B3.4.11.1 Sediment Sources

Consistent with the evolution of the whole coastal and nearshore region of Trinity Bay, the seabed sediments have their origin predominantly in the fluvial supply from the Barron River. Under the present sea level conditions, deposition of sand is limited largely to the close-in nearshore areas adjacent to the Barron River mouth, from whence it tends to be moved shoreward and alongshore by wave action. Correspondingly, contemporary sediment deposition in deeper water is predominantly the finer (muddy) suspended wash load from the river, forming a high proportion of mud on the seabed.

Discharges of Barron River catchment loads are typically associated with floods caused by tropical cyclone rainfall events. The resultant plumes deliver sediment, nutrients and pollutants to the GBR lagoon and reefs. The discharge of fluvial sediments may also contribute to channel siltation and therefore understanding this process is important when assessing maintenance dredging requirements associated with the proposed shipping channel development.

Most of the Barron River sediment load accumulates in Trinity Bay and contributes to a seaward advancement of the muddy shoreline. Mangroves rapidly colonise the advancing mudflat and act to stabilise the shoreline and enhance sediment trapping. Connell Wagner (1990) suggested the shoreline east of the shipping channel advanced approximately 1250m seaward between 1930 and 1987, as illustrated in **Figure B3.4.11.2a**.

Table B3.4.11.1a summarises Barron River TSS annual loads provided by RRRC. The estimates are derived from fluid concentration measurements at Myola collected at monthly (minimum) intervals.

Table B3.4.11.1a Barron River TSS Annual Loads (data provided by RRRC)

	2006-07	2007-08	2008-09	2009-10	2010-2011
Barron River TSS annual load (tonne)	30,403	396,503	163,366	174,425	239,404

B3.4.11.2 Sediment Size Distribution

The seabed sediment sampling and analysis undertaken by the BPA identified three predominant sediment facies:

- Clean sand (90-100% sand)
- Muddy sand (50-90% sand)
- Sandy mud (0-50% sand)

The spatial distribution of sand content is shown in **Figure B3.4.11.2b** from Carter *et al* (2002) and in **Figure B3.4.11.2c** from sampling undertaken by Geoscience Australia (2007). That mapping shows the effect of the existing shipping channel in the form of a narrow zone of less than 10% sand along the alignment of the channel, transitioning rapidly to about 40-50% sand adjacent to the channel. This is clear evidence that material depositing in the channel is predominantly fine mud with much lower sand content than its source adjacent seabed material.

The sandy mud facies occupies most of the floor of Trinity Bay between Cape Grafton and Double Island. Sand content is low throughout this area but increases sharply along the boundary with the muddy sand facies. The sand occurs almost entirely in the very fine size range and consists of 60-70% quartz, up to 10% feldspar, 5% mica, 3% rock fragments and approximately 20% shell fragments.

Off the Barron River and northern beaches, clean sand extends to a depth of only -2.3m (AHD), beyond which it transitions relatively quickly to the sandy mud facies, with the muddy sands protruding to about 3km offshore locally from the present mouth, Casuarina Point and Ellie Point and into Trinity Inlet.

Carter *et al* (2002) indicate that:

- Trinity Bay contains deposits of mid-Holocene (approximately 5,000 to 7,000 years ago) and younger land-sourced terrigenous sediments of sand and mud up to 20m in thickness and prograding seawards at rates of up to 1m per year, continuing today. This suggests that Trinity Bay is naturally accumulating sediments. Mapping of the Holocene sediment layer thickness is shown **Figure B3.4.11.2e**
- Six major sediment facies were identified (**Figure B3.4.11.2c**) ranging from clean well-sorted sand at the beach shore-face through muddy sand to sandy mud and mud on the inner shelf (5-20m depth), with also locations of muddy shell hash, tidal channel lag deposits of poorly sorted (pebbly) sand and mangrove swamp organic-rich mud, generally consistent with the description in BPA (1984)
- Sediments are provided to the Bay from both the Barron River and past Cape Grafton. Mud suspended during cyclones enters the Bay from the mid-shelf and is derived from both the reef tract and seabed re-suspension, or from far-field river flooding
- The Barron River sediment input is partitioned along several pathways with sand retained on the beaches and transported north along the coast, finer sand and coarse silt moved south to accumulate in pro-delta areas of Trinity Bay and fine silts/clays passing offshore and along-shelf to the northwest
- The sediments are mostly polymodal in their grain size distribution, the fine silt being typically 3-5µm and the medium silt to very fine sands ranging up to about 200-230µm. Fine to medium quartz sands are typically 100-300µm
- The bed sediments within Trinity Inlet adjacent to the port and along the upstream reaches are predominantly very fine, comprising mainly muddy sand and silt to very fine sand with some areas of coarse sand along the upstream channel (**Figure B3.4.11.2f**).

Figure B3.4.11.2a Historical Changes in the Cairns Shoreline (Connell Wagner, 1990)

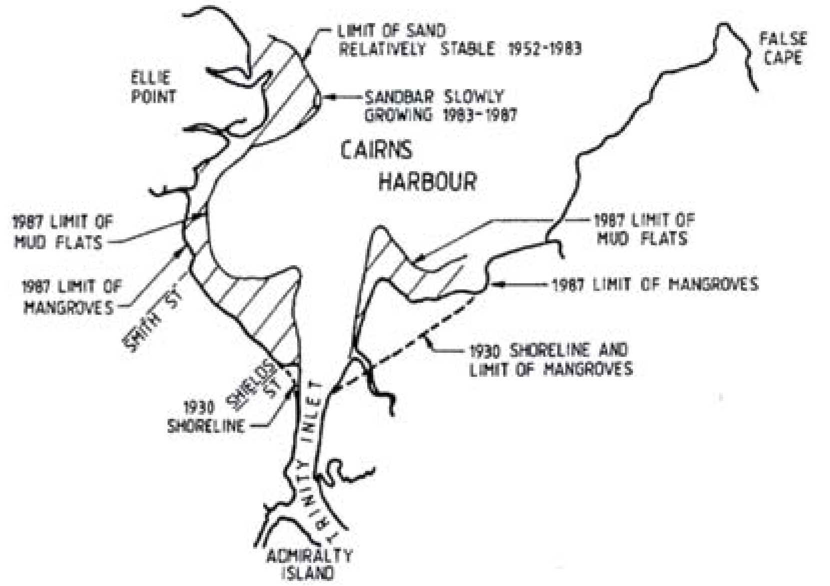


Figure B3.4.11.2b Sand Content in Seabed Sediments of Trinity Bay (BPA, 1984)

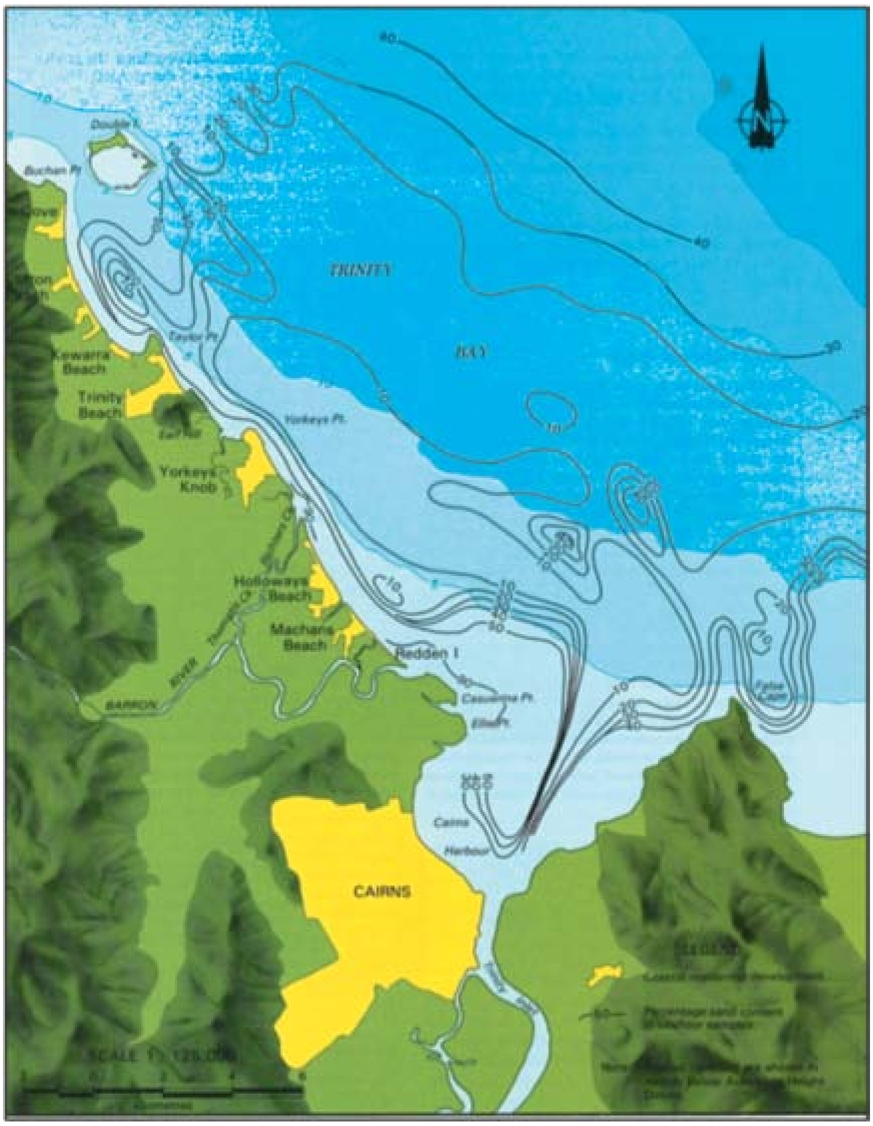


Figure B3.4.11.2c Seabed Sediment Facies in Trinity Bay (Carter *et al*, 2002)

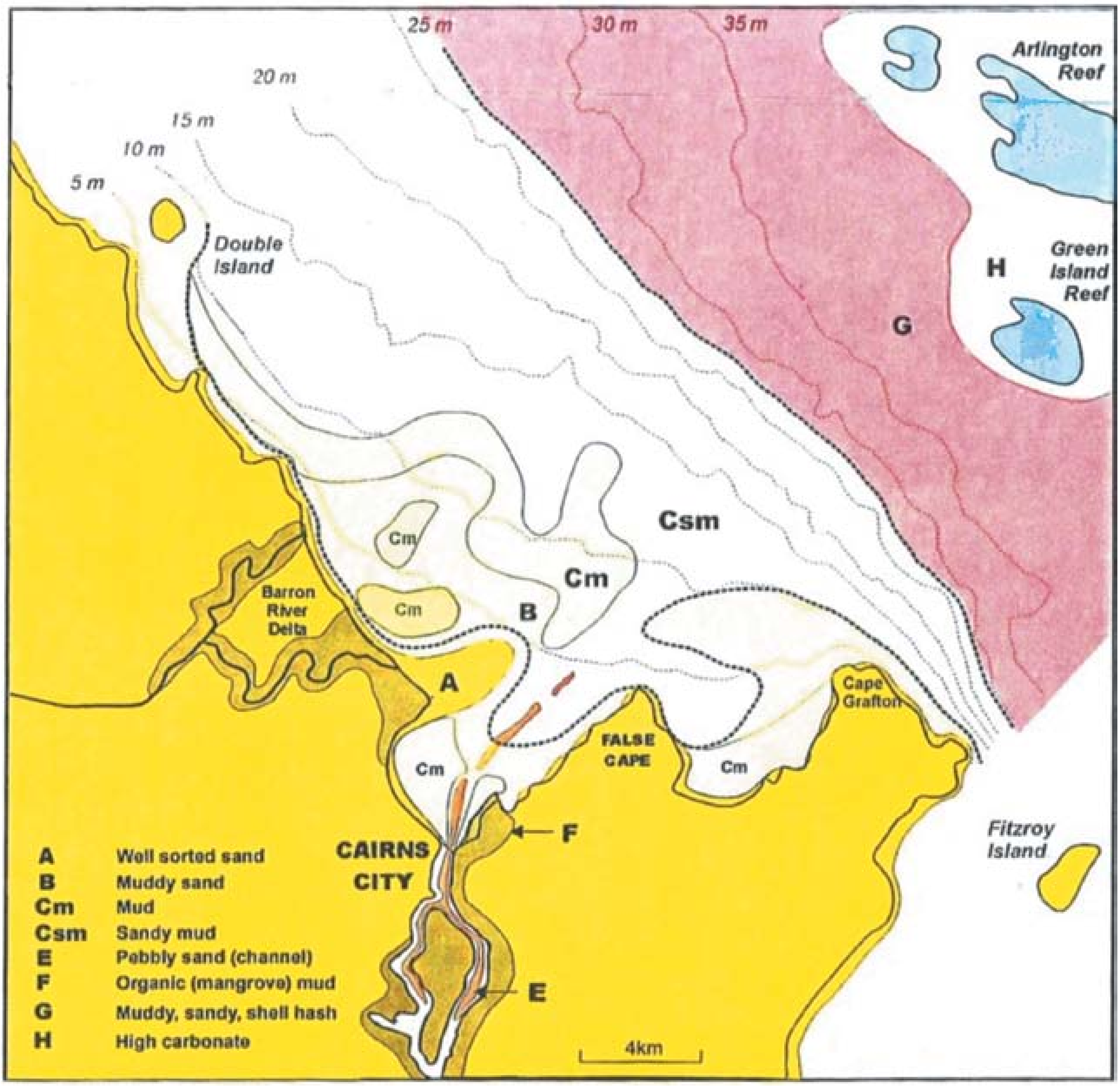
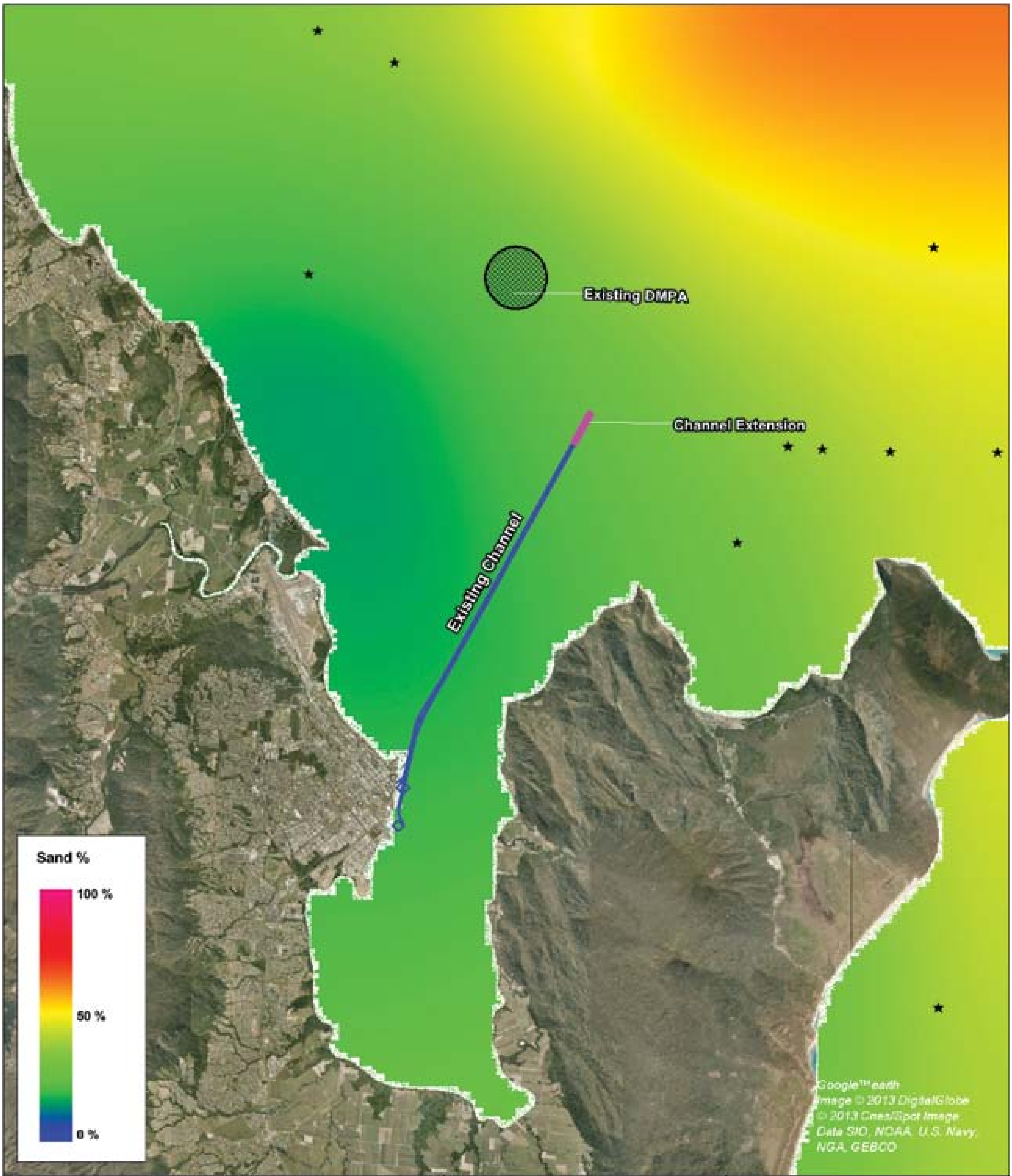


Figure B3.4.11.2d Interpolated Sand Distribution from Geoscience Australia (2007) PSD Data



Legend

★ Geoscience Australia (2007) Sampling Site

Ports North

ARUP

BMT WBM

Job Title: Cairns Shipping Development Project Environmental Impact Statement

Map Title: Interpolated sand distribution from Geoscience Australia (2007) PSD data

Kilometer: 0 – 3 – 6km

Issue	Date	By	Chkd	Appd
1	31/10/2014	MB	IT	BG

Scale at A4: 1 : 153,400

Map Status: Final

Coordinate System: GDA 1994 MGA Zone 55

Job No: 230377-00

Figure No: B3.4.11.2d

Figure B3.4.11.2e Thickness of Holecene Sediments in Trinity Bay (Carter *et al*, 2002 after Hudson, 1998)

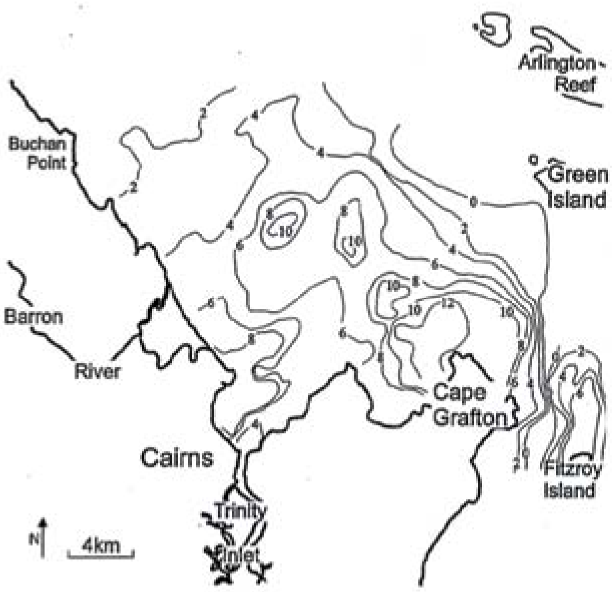
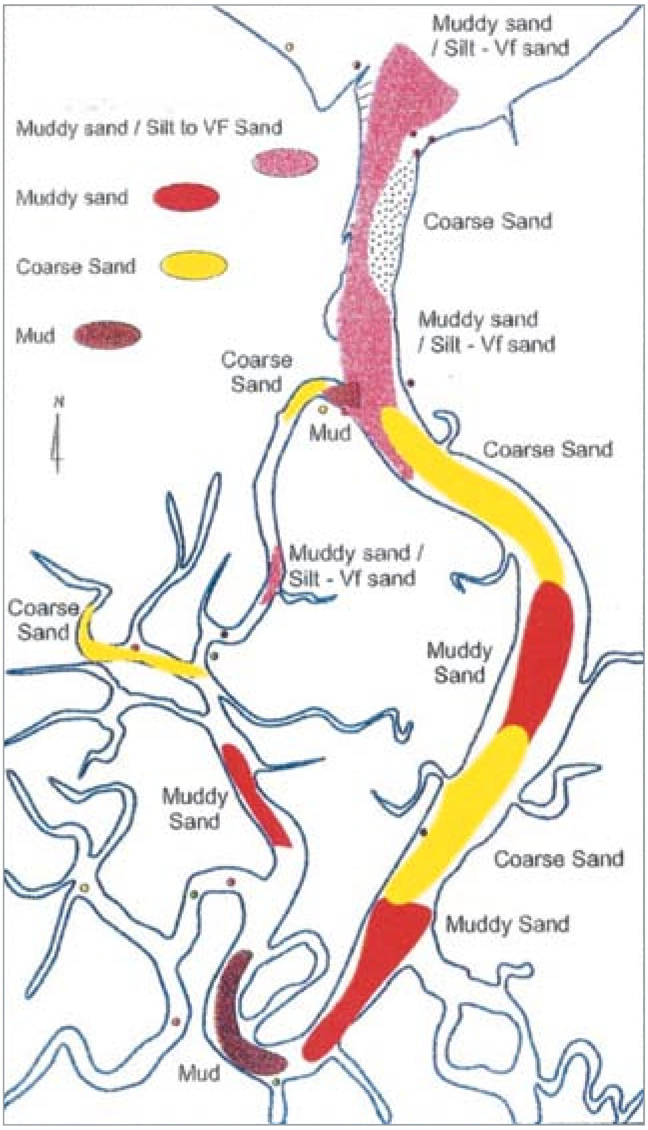


Figure B3.4.11.2f Trinity Inlet Bed Sediments (Carter *et al*, 2002)



B3.4.11.3 Marine Sediment Transport Mechanisms

The major mechanisms for sediment transport within the GBR lagoon have been summarised by Orpin et al. (1999), and include:

- Combined wave and current induced sediment re-suspension
- Sediment advection by prevailing wind driven currents (both cross-shore and longshore)
- Flood plume sediment advection
- Tidal asymmetry driven net transport
- Energetic sediment transport during tropical cyclones.

This study concluded that over a regional scale the combined action of the first two mechanisms accounted for the vast majority of sediment transport within the GBR lagoon. While flood plumes have been responsible for the delivery of sediment onto the inner shelf, they do not in themselves have a large potential for transporting sediment within the GBR lagoon (relative to the wave-current driven mechanism).

At a local scale the nature and rates of sediment transport depend on the prevailing waves and currents and the nature of the sediments. The seabed sediments are re-suspended and transported by the combined action of waves and currents. Erosion of sediment from the seabed and deposition of suspended material from the water column are both dependent on local bed shear stress. Cohesive sediments tend to erode when bed shear stress exceeds a critical threshold (for erosion). Deposition of cohesive sediments occurs when shear stress drops below a typically lower critical threshold (for deposition). Broadly, both waves and currents together cause bed shear stresses that mobilise the sediments while prevailing currents advect them, predominantly in suspension, in the direction of the current.

Lou & Ridd (1996) and Orpin et al. (1999) studied the relative contributions of swell-waves, wind-waves and currents to sediment re-suspension events in around 10m water depth at Cleveland Bay, Townsvile. Their analysis concluded that while all components contributed to the shear stress causing sediment re-suspension, it was the swell-waves rather than the wind-waves or currents that were the most significant. Even though the swell-wave heights were generally only a fraction of the wind-wave height the long-period waves have a much greater tendency to generate significant orbital velocities at depth. Within the sea-bed boundary layer these orbital motions interact with the steady current velocities in a non-linear fashion to generate bed shear stresses with the potential to resuspend sediment.

The above processes in conjunction with the predominantly muddy surficial seabed sediments are responsible for the generally high (and highly variable) background turbidity in Cairns' nearshore waters. This pattern of regular, natural increases to nearshore turbidity is characteristic of many locations along the central and north Queensland coast. Water quality issues relevant to the CSDP are considered separately in **Chapter B5, Marine Water Quality**.

B3.4.11.4 Siltation of Dredged Channels

The first capital dredging works to develop the Port of Cairns occurred in 1887, and incremental channel widening and deepening has occurred throughout the early twentieth century. The most recent capital dredging expansion occurred in 1990, widening the channel to 90m and a design depth of 8.3m LAT (Worley Parsons, 2010). The outer channel is approximately 11.2 km in length and the inner port shipping channel extends for approximately another 2.4 km in length.

Regular maintenance dredging has been required since the development of the port in 1887. Dredging of the outer shipping channel is undertaken annually by a trailing suction hopper dredge (TSHD Brisbane since 2001).
The accumulated sediments in the outer channel range typically from fine silts to sands. The spatial distribution of outer channel siltation between 1980-1990 (pre-channel widening) and 1990-2010 (post-channel widening) is shown in **Figure B3.4.11.4a** and indicates the presence of two hotspots adjacent to Beacons C18 and C11.

Approximately 220,000 m^3 – 460,000 m^3 of in-situ material is dredged annually[1] from the outer channel by the TSHD, usually taking around three weeks to complete (Worley Parsons, 2010). Dredged material is placed at the approved DMPA following approval by the Determining Authority.

Maintenance dredging of the inner port takes place throughout the year using the grab bucket dredge ***Willunga*** and two hopper barges. The accumulated sediments in the inner port are typically fine silty clay. Information provided by Ports North suggest an average of approximately 30,000m^3 of ***in-situ*** material is dredged annually from the inner port and is placed at the approved DMPA following approval by the Determining Authority. Of this total volume, approximately 15,000m^3 is attributed to the HMAS Cairns Navy Base inner and outer berth areas which are dredged on a contractual basis by the ***Willunga***. The accumulated sediments are typically fine silty clay.

[1] Long term maintenance dredging quantities have been reviewed as part of the CSDP EIS and the following annual ***in-situ*** volumes have been derived (Ports North, pers. Comm., 2014):
- Outer Channel: 320,000m^3
- Inner Port: 30,000m3

Figure B3.4.11.4a Historical Distribution of Outer Channel Siltation (Beacon C19 to C1): 1980-1990 (Pre-Channel Widening) and 1990-2010 (Post-Channel Widening)

Analysis supplied by Ports North

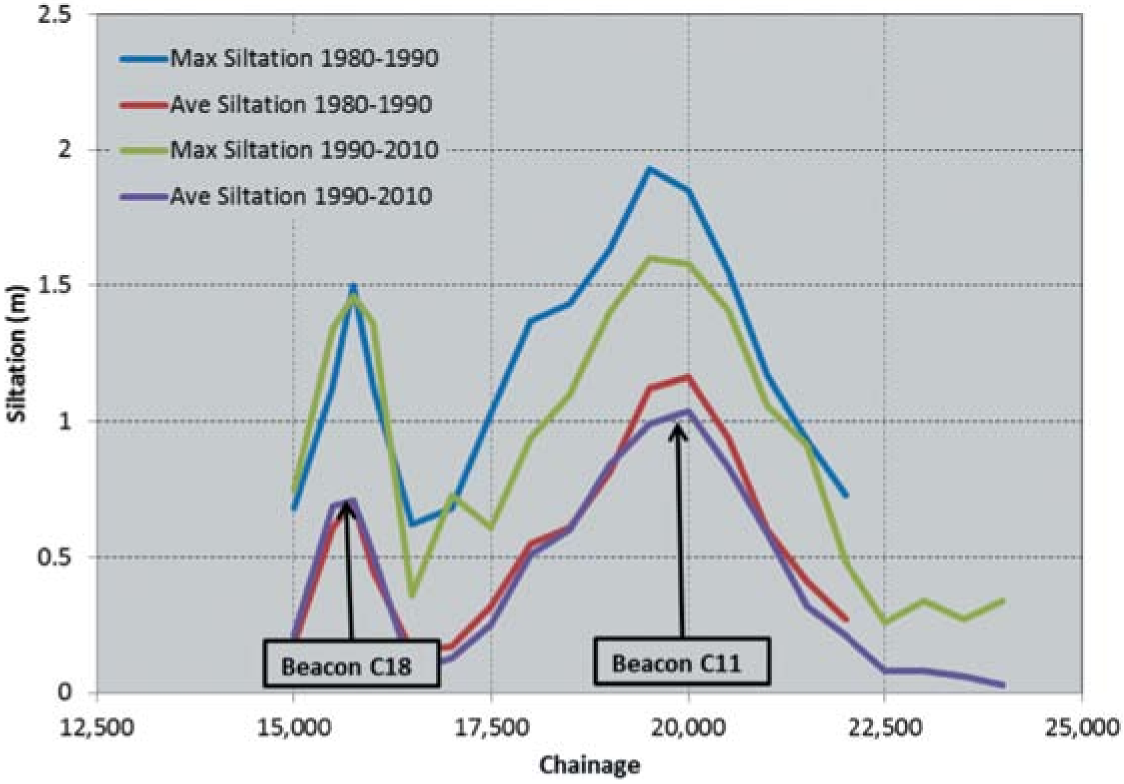
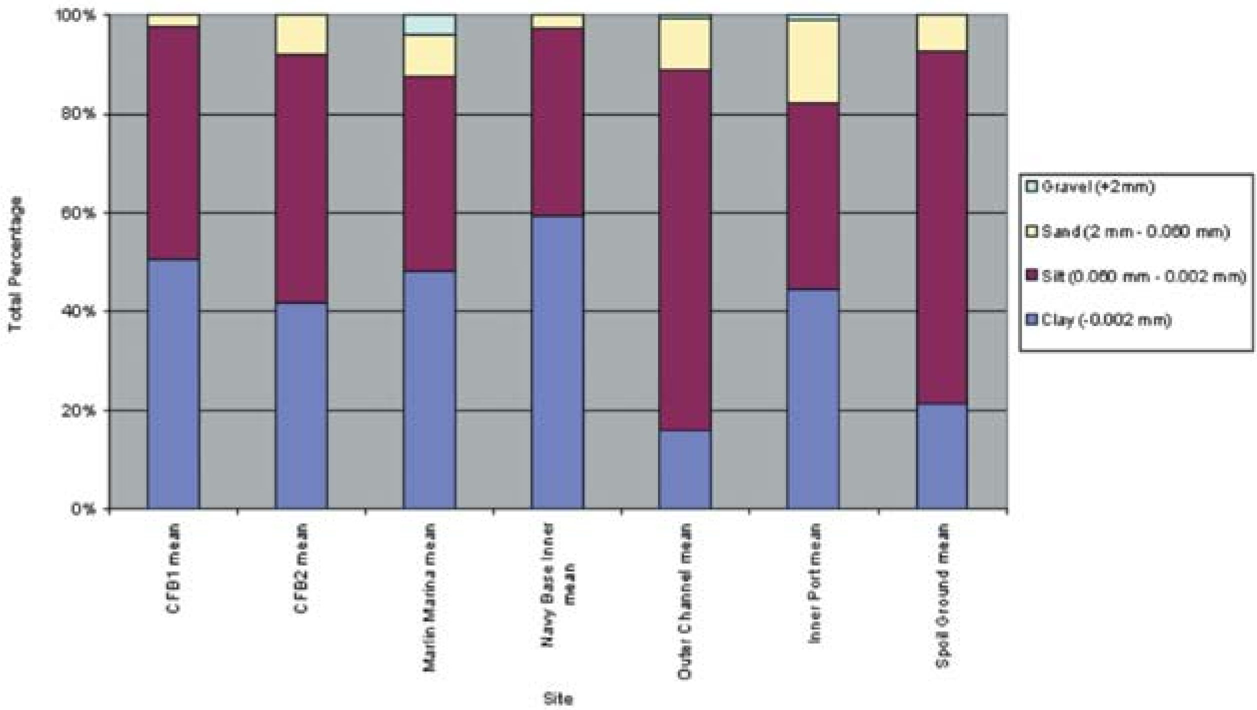


Figure B3.4.11.4b Maintenance Dredge Material Physical Composition (from Worley Parsons, 2010)



B3.4.11.5 Dredge Material Placement

Disposal of dredged material has been undertaken at the approved offshore DMPA since 1991, located approximately 14km north of the Port Entrance. The placement site was moved here from a location further inshore following a detailed site selection study by Connell Wagner (1991). One of the key parameters in selecting the existing DMPA over the previous placement locations was that of increased depth and the reduction in wind derived subsurface currents (Connell Wagner, 1991). The locations of the existing and former DMPA's can be seen as areas of raised bathymetry in **Figure B3.4.4a**. The present day sea bed elevations at the two sites are approximately -11m AHD and -9m AHD respectively and can be seen to be higher than the surrounding areas, indicating sediment retention within the two sites. Originally, the DMPA was located outside the Great Barrier Reef Marine Park; however the Marine Park boundaries were expanded in 2001 by the Great Barrier Reef Marine Park Authority and now include the DMPA which is located within a General Use Zone.

Connell Wagner (1991) undertook extensive "short term dredge dump" monitoring at the old site and concluded that:

> *"…large movements of deposited material from the spoil dump do not occur and that the small amount of material that is resuspended during strong wind events is transported parallel to the coast, is not deposited on the Northern Beaches and rapidly becomes mixed with natural bay bed material (around the dump and in the shallower parts of the bay generally) also brought into suspension under strong wind conditions. Chemically and physically the resuspended deposited spoil material is identical to the natural bed material being brought into suspension. The quantities of deposited dredged material being carried along parallel to the coast are very small and are not considered to have any significant effect on the range of natural turbidities experienced in the bay in general."*

Additional long term monitoring at the new site by Connell Wagner (1993) further concluded that:

> *"The Long Term Monitoring Program has clearly demonstrated that even during severe cyclonic events, such as cyclone Joy, very little material is brought into suspension from the spoil dump and transported away from the dump i.e. the dump remains stable."*
>
> *"The Monitoring Program has also demonstrated that in years devoid of cyclonic influence, only very small quantities of deposited material are transported from the spoil dump."*

Pre- and post-placement surveys presented by Worley Parsons (2010) show that the DMPA is functioning well, and becoming shallower at an average rate of 12 cm/year, with minimal apparent sediment loss or environmental impact. The rate of accumulation estimated by Worley Parsons (2010) is approximately consistent with distributing the total annual average maintenance ***in-situ*** volume (360,000 m^3 for outer channel and inner port areas) over the 2,700 km^2 area of the existing DMPA. This simple analysis yields an average accumulation across the DMPA close to 13 cm/yr and further supports the retentiveness of the site[2].

Carter et al. (2002) directly considered the question of environmental impacts associated with the existing DMPA (referred to as "CPA spoil dump") operation on the Cairns shoreline. This study concluded that placement site was not contributing directly to enhancement of turbidity along the Northern Beaches due to the prevailing sediment transport pathways that are predominantly along shelf transport with very limited potential for onshore transport:

> *"Intermittently, residents of the Northern Beaches report "mud lumps" washing up of the beach and enhanced turbidity of coastal water, which they attribute to reworking from the offshore CPA spoil dump. Our studies show (i) that most transport from the spoil dump takes place in either an offshore or a northerly long-shelf direction; and (ii) that the "mud lumps" are derived by intermittent erosion of a sticky, grey Holocene mangrove clay which forms the substrate to e.g. Clifton Beach, and which becomes exposed during periods of beach erosion. Thus neither the water turbidity, nor the presence of mud-lumps, on the Northern Beaches is in any way related to the presence of the offshore spoil heap."*

[2] The relatively small percentage of the total maintenance volume that is lost as plumes during the dredging and placement operation has not been considered in this simple assessment, nor has the extent of sediment consolidation at the DMPA.

B3.4.11.6 Marine Sediment Transport Modelling

Numerical modelling of marine sediment transport processes was undertaken using the ST module of the TUFLOW FV software package, in conjunction with the predictive modelling of currents (**Section B3.4.9**) and waves (**Section B3.4.10**). Details of the modelling system, formulae used, and parameters adopted in the sediment transport modelling are provided in **Appendix D2, Sediment Quality Report**. The calibrated modelling system is considered capable of representing the major sediment transport mechanisms within the CSDP study area and the larger Great Barrier Reef Lagoon.

Bed shear stress is calculated in the ST model from the non-linear interaction of currents and waves using the procedure of Soulsby (1997). A Root-Mean-Square combined wave-current bed shear stress is used as the representative value in the sediment erosion and deposition calculations.

It is commonly considered that the behaviour of sand-mud mixtures with sand content >90% will be dominated by the sand processes, with the mud being released from or trapped within the sand interstices (e.g. Whitehouse et al., 2000). Sediments with >5-15% mud content will tend to become cohesive with behaviour dominated by the finer fraction (e.g. Mitchener & Torfs, 1996). The majority of surficial bed sediments within the study area comprise sand-mud mixtures where the erosion properties are dominated by the cohesive sediment fractions.

A typical example of a wave-current driven seabed sediment re-suspension event measured in 11m water depth at the existing Cairns DMPA is provided in **Figure B3.4.11.6a**. As is typical, both current and wave magnitudes are highly correlated with wind speed. The resulting bed shear stress due to these measured forcing conditions has been estimated using the formulae applied in TUFLOW FV and based on the predicted time history in **Figure B3.4.11.6a** it is expected that sediment re-suspension will be initiated when the bed shear stress exceeds around 0.2Pa.

The sediments existing in the natural bed were represented using four sediment classes within the ST model. A distinction between the siliceous and carbonaceous sands has been made because the typical shape of the particles result in markedly different settling velocities. The erosion and settling characteristics of each sediment class is summarised in **Table B3.4.11.6a**.

Table B3.4.11.6a Characteristics of Simulated Sediment Classes

Sediment Characteristic	Siliceous Sand	Silt	Clay	Carbonaceous Sand
Still Water Fall Velocity, Ws (m/s)	3 x10-2	1 x10-3	1 x10-4	1 x10-2
Critical Shear Stress Erosion, Tce (Pa)	0.2	0.2	0.2	0.2
Critical Shear Stress Deposition, Tcd (Pa)	0.2	0.18	0.18	0.2
Erosion Rate Constant, E (g/m^2/s)	0.1	0.1	0.1	0.1
Sediment Particle Density, ρs (Kg/m^3)	2650	2650	2650	2650

The measured data from March to July 2013 was used to undertake the ST module calibration. Simulated ambient TSS concentration was calibrated to continuous recordings of near-bed turbidity converted to TSS using the site specific NTU-TSS relationship shown in Figure 3.4mm. This relationship is based on the laboratory analysis for TSS in 84 water samples collected with synchronised turbidity (NTU) measurements over numerous campaigns in 2011 and 2013 (including both dredging and non-dredging periods). The derivation of this relationship is further described in **Appendix D3, Climatic and Coastal Oceanographic Data Collection Report**.

Comparisons between predicted TSS from the calibrated model and TSS derived from continuous nephelometer recording at two sites are shown in **Figure B3.4.11.6c**. Site 2 (Alternative DMPA in **Figure B3.3.2.7a**) is located in around 10m water depth and is characterised by episodic re-suspension events associated with wind driven elevated current/ wave conditions. The model is seen to reproduce both the timing and magnitude of the water column TSS at this site. The instrument adjacent to Beacon C11 was located further inshore in around 4m water depth and is seen to have a more regular tidally driven signal of elevated TSS, much of which has been advected from the nearby inlet and mudflats. The model under predicts the TSS signal at this site, some of which can be attributed to the influence of biological sources of turbidity (e.g. algae and detritus) which are present in the data but not simulated by the model. Generally, ambient TSS concentration prediction throughout the calibration period is considered adequate, particularly at offshore locations.

The mass of sediment which settled in the dredged channel during the calibration period was used to derive an annual siltation depth. As a validation of the sediment transport model performance this estimate was compared with the measured sedimentation provided by Ports North and presented in **Figure B3.4.11.6d**. The measured localised peaks in siltation close to Beacon C11 and C18 are represented by the model. The derived annual siltation volume of approximately 480,000m^3 (from Berth 1 to Beacon C1) is larger than the long-term average (for years 1990-2010) provided by Ports North however less than the maximum (approximately 760,000m^3) for the reported period. The predicted siltation rates and total volume are therefore considered to be towards the upper end of the historical limit. It should be noted that when undertaking impact assessments the predictive model is used to determine relative changes compared with the modelled baseline conditions, for instance to determine a percentage change in channel siltation. Some bias in the baseline predictions (within reasonable limits) should not undermine the ability of the model to determine the relative impacts of the proposed development.

The model net sediment transport predictions for the period 04/03/2013 to 17/06/2013 are shown in **Figure B3.4.11.6e**. This period is considered to be reasonably representative of long-term prevailing conditions and includes equal sampling of spring-neap cycle periods; however it is noted to not include either a significant tropical cyclone or flood event. The current DMPA remains within the active marine sediment transport zone, which is consistent with the measurements of occasional episodic re-suspension events at this location (**Figure B3.4.11.6a**); however it is located well offshore of the depth of peak transport capacity, which is predicted to occur around Cape Grafton to depths approximately -8m AHD.

As shown in **Figure B3.4.11.6e**, the dominant sediment transport pathway from the existing DMPA is predicted to be shore-parallel to the north-west. The dominance of alongshore transport potential at the DMPA can also be seen in the current data previously presented in **Figure B3.4.9.2e**. This data also indicates that near bed current speeds greater than 0.2m/s occur relatively infrequently at the DMPA.

Downdrift of the DMPA surficial sediments are expected to be predominantly muds with similar physical and chemical properties to the placed material. Downdrift sensitive receptors are located around 13km away from the DMPA in the vicinity of Double Island. Sediment resuspending from the DMPA would be expected to both disperse and mix with the naturally occurring surficial muds. Given that the DMPA area represents only a small proportion of the naturally available surficial mud within the study area it is unlikely to have a significant influence on sediment transport and water column turbidity, except in its immediate vicinity.

The sediment transport modelling results would appear to confirm the findings from the Connell Wagner (1991; 1993) and Carter *et al*. (2002) studies, that the placement of port dredging material at the existing DMPA is unlikely to have a significant influence on coastal processes along the Cairns and Northern Beaches foreshores.

Barron River fluvial discharge and sediment loads for the 2010/11 wet season were simulated using the hydrodynamic and sediment transport modelling system described in **Appendix D**. This period was selected due to the availability of the following data:

- Barron River TSS annual load estimates provided by RRRC
- Barron River daily flow and turbidity (NTU) recordings at Myola (station 110001D Barron River) obtained from the DNRM Watershed data service.

For the period of available estimates, **Table B3.4.11.6a** suggests the 2010/11 TSS annual load was representative of above average conditions.

Figure B3.4.11.6f shows a surface TSS prediction from the TUFLOW FV model on 5 February 2011 together with the MODIS satellite image from the same date (http://oceancolor.gsfc.nasa.gov/). The date shown corresponds to Barron River flood flow due to rainfall associated with Tropical Cyclone Yasi, which made landfall south of the study area on 3 February 2011. The peak daily mean discharge in the Barron River associated with this event was approximately 400m^3/s. The model results show good qualitative agreement with the plume spatial distributions which are discernible from the MODIS satellite images.

Figure B3.4.11.6a Measured Sediment Re-Suspension Event in 11m Water Depth at Existing DMPA

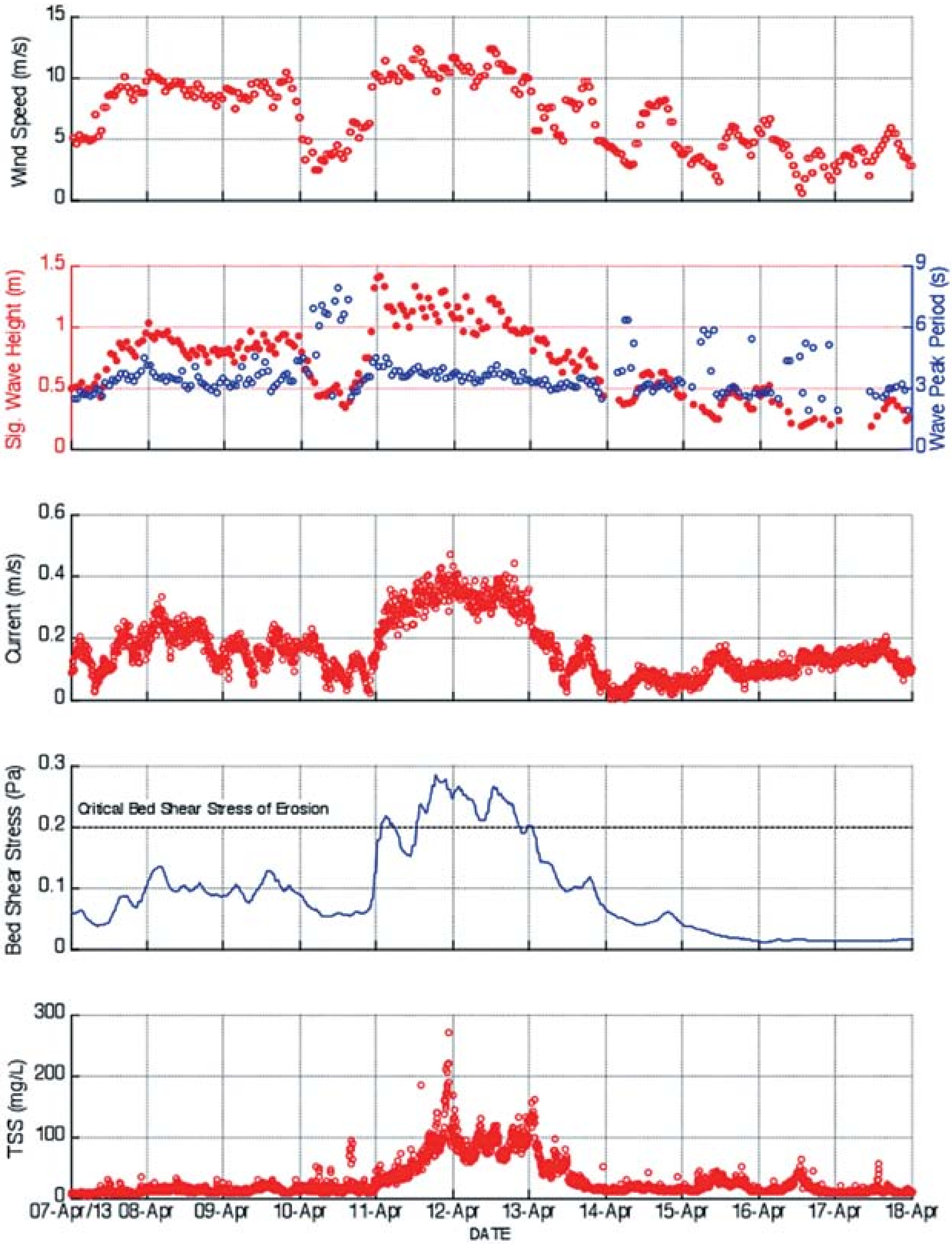


Figure B3.4.11.6b Total Suspended Solids versus Turbidity Relationship derived for the Study Area

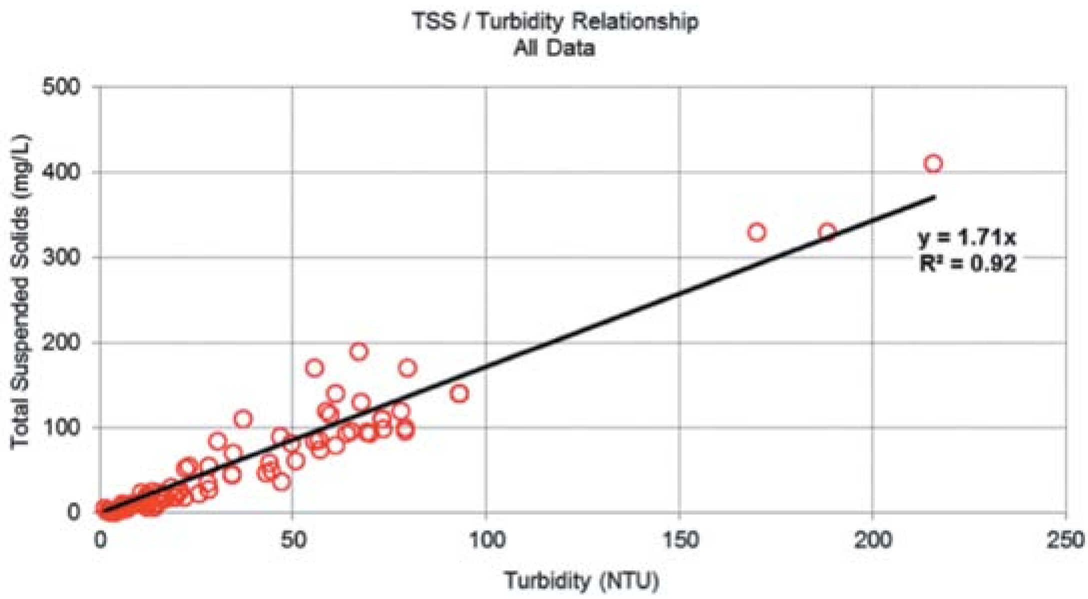


Figure B3.4.11.6c Sediment transport model validation against near bed nephelometer measurements (data collected over different periods)

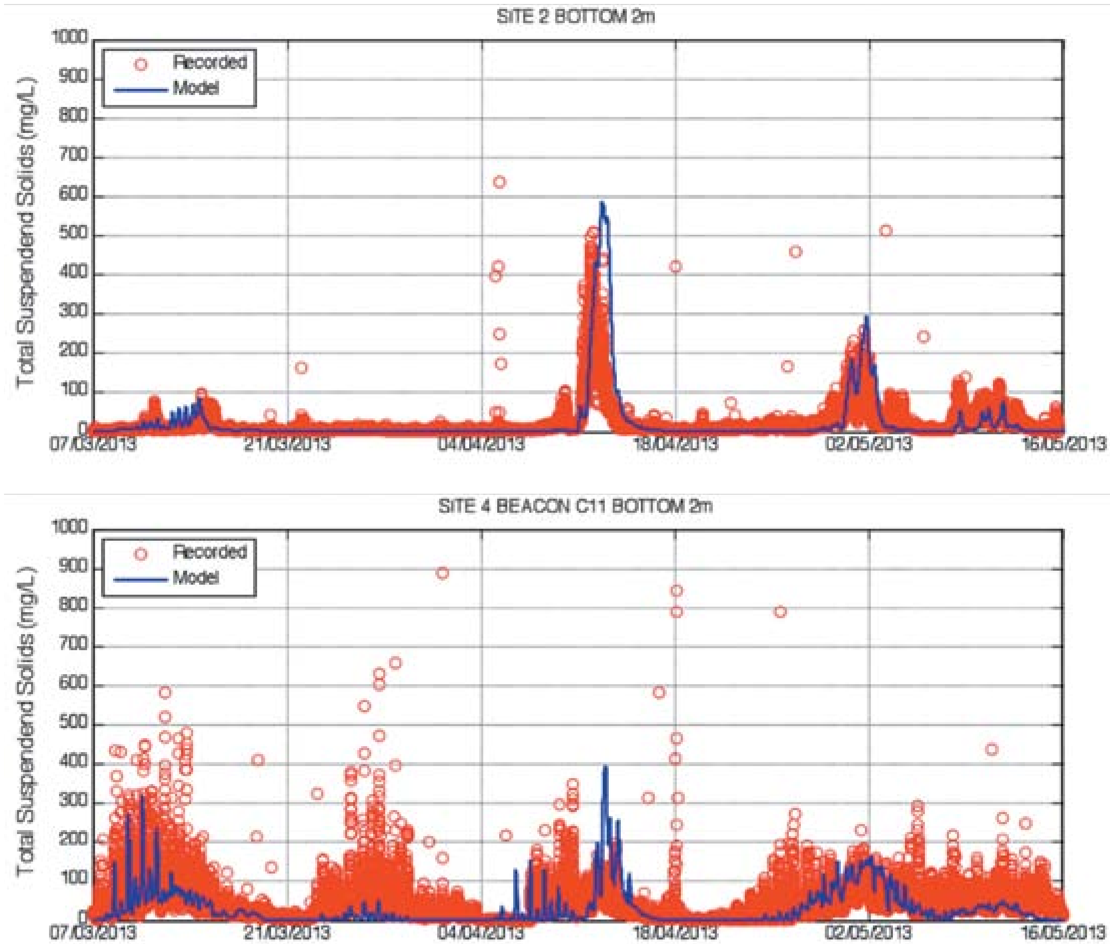


Figure B3.4.11.6d Estimated and Measured Annual Siltation of Shipping Channel (modelled total volume calculated from Berth 1 to Beacon C1)

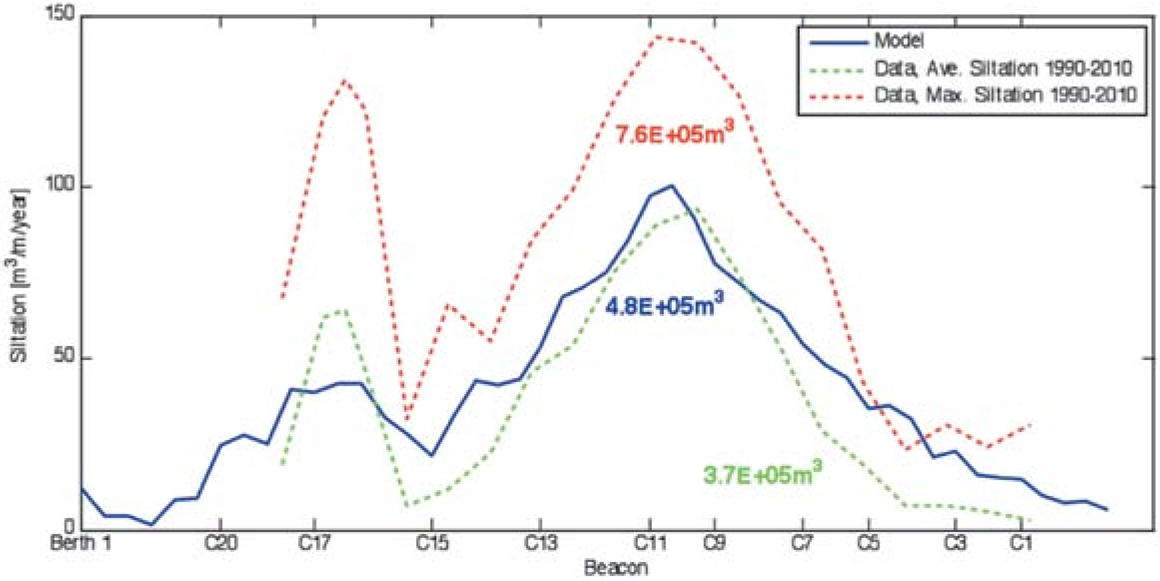


Figure B3.4.11.6e Modelled Net Sediment Transport 4th March to 17th June 2013

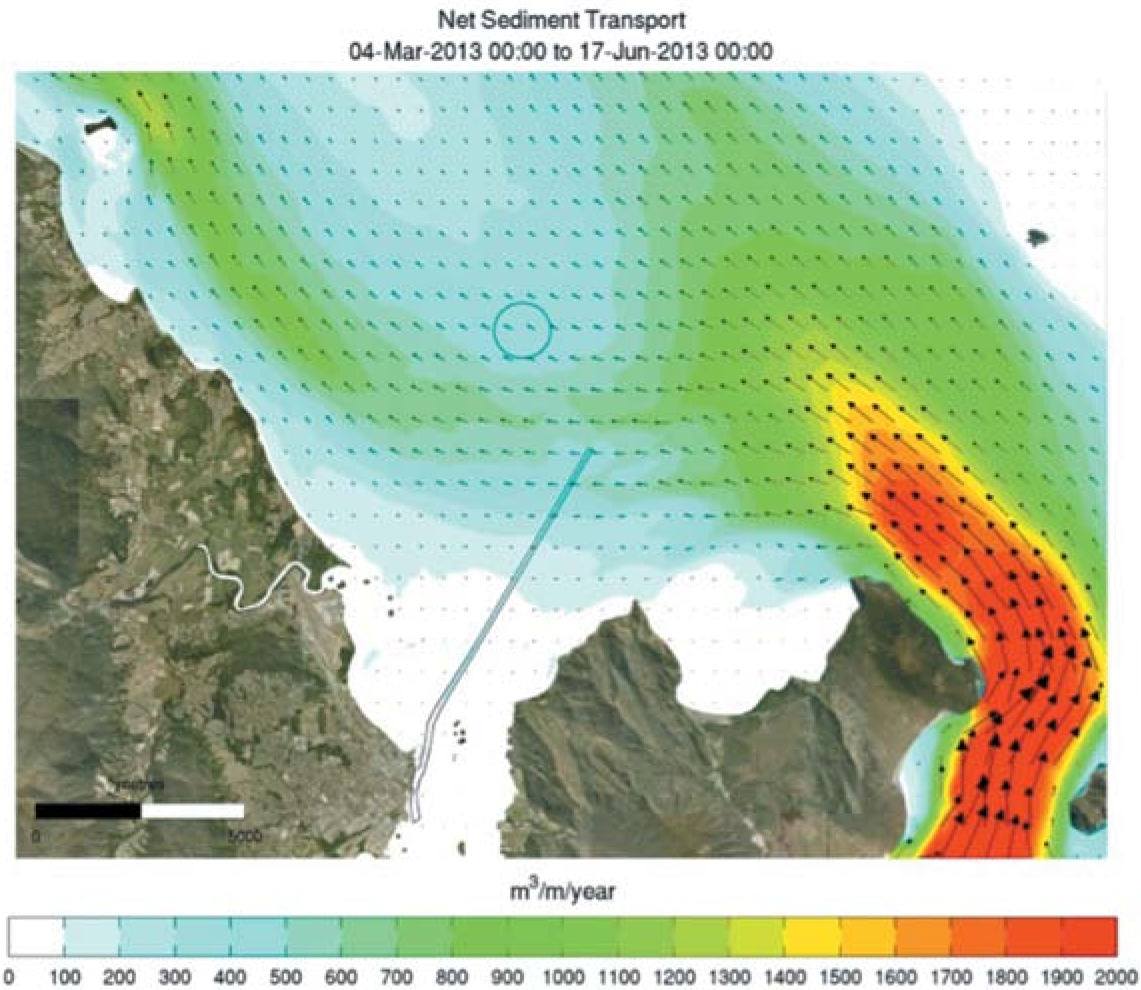
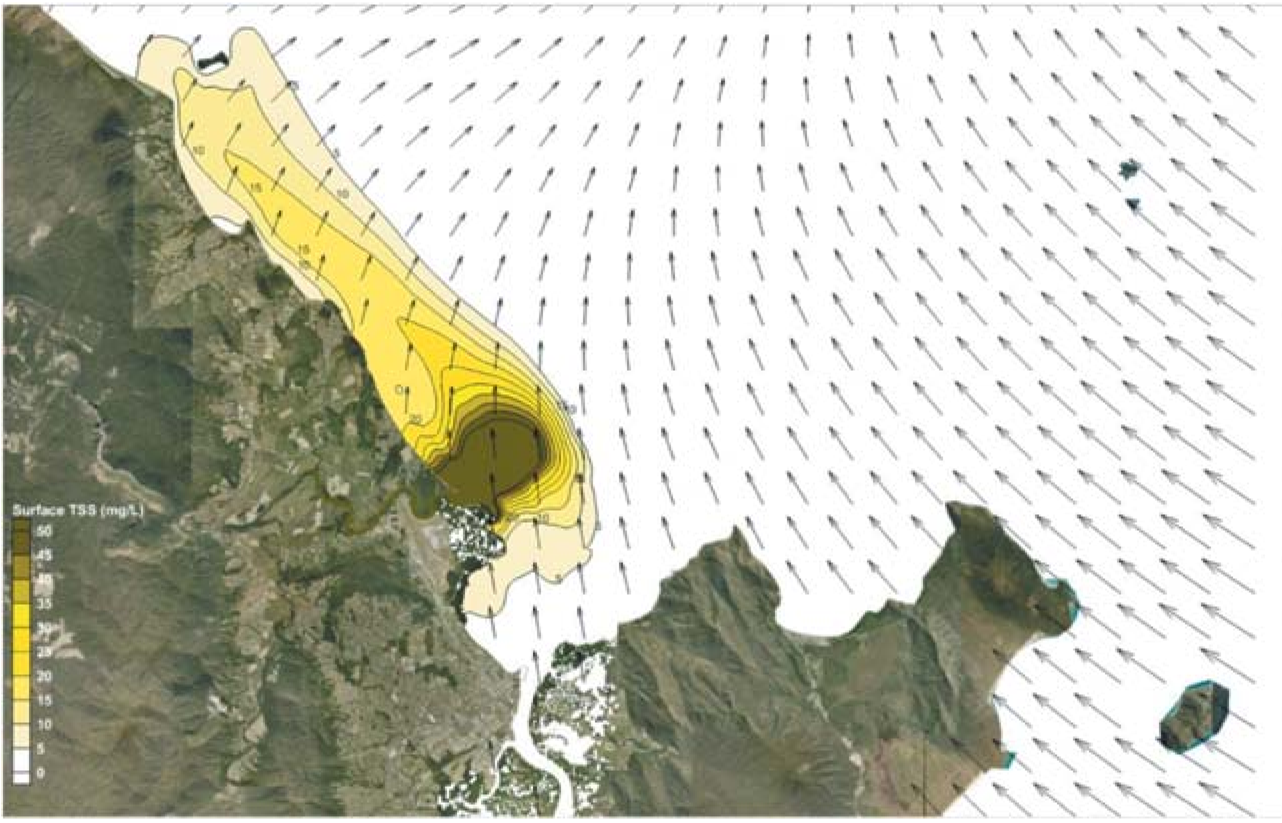


Figure B3.4.11.6f Barron River Flood Plume on 05/02/2011 - MODIS Satellite Image *(top)* and Predicted Surface TSS with Wind Vectors *(bottom)*



B3.4.12 Littoral System – Northern Beaches

Because of the northward distribution of the sand sediments from the Barron River and its adjacent delta by the prevailing predominantly east to southeast sector waves, only the northern beaches (**Figure B3.4.12a**) may be characterised as an active littoral beach system along the coastline directly flanking Trinity Bay. The most comprehensive investigation of beach system processes for the Cairns region is that of the Beach protection Authority (BPA, 1984), which covered the entire northern beaches extent.

Of those beaches, only the region from the Barron River north to Yorkeys Point are influenced by the wave and current processes prevailing in the Cairns Port area (**Figure B3.4.12b** and **Figure B3.4.12c**). The Barron River delta has undergone considerable change since the mouth switched some 1.5km to the north in 1939 from its former position adjacent to Ellie Point. Since that time, the Barron Beach/Casuarina Point area has evolved in a complex way with both strong shoreward sand supply from the inter-tidal delta shoals and alongshore re-distribution of the sand along the beach by wave action.

The BPA (1984) describes the littoral processes north of the river mouth in terms of the three compartments:

- Machans Beach, considered in two parts
- Machans South (redden Island)
- Machans North (between Redden Creek and Barr Creek)
- Hollaways Beach
- Yorkeys Knob beach.

A shoreward supply of sand from the river delta also feeds onto Machans Beach South (Redden Island) and is the primary source of the littoral longshore transport system of these beaches. The BPA study identified an accretion of that beach above RL-1.0m (AHD) of 13,000m^3 between 1970 and 1980, reducing to 5,000m^3 for Machans Beach North. While unable to carry out direct alongshore transport rate calculations there because of the nearshore bathymetric complexity, the study found an alongshore transport of about 3,000m^3/year northward from Machans Beach into Hollaways Beach, suggesting a shoreward supply from the delta of 21,000m^3/year. This net onshore supply has continued to accrete the Redden Island shoreline, although the Machans Beach North beach continues to be depleted of sand in front of the seawall, as evidenced in recent satellite imagery (**Figure B3.4.12d**).

Hollaways Beach is significantly affected at its southern end by movements of Barr Creek, which involve northward spit growth and mouth migration followed by breakout direct to the sea. The BPA found a net deficit of about 14,500m^3 of sand from Hollaways Beach from 1970 to 1980. They attributed that to a differential in the alongshore sand supply from 3,000m^3/year at the south to 17,500m^3/year to Richters Creek at the north. This is equivalent to an average shoreline recession of 1m/year, although significantly higher rates were observed at the southern and northern ends. Erosion appears to have continued along Hollaways Beach over the ensuing 30 years to date, with evidence of significantly narrower dune system in front of the development than existed in 1982 (**Figure B3.4.12e**).

Yorkeys Knob beach was quite eroded in 1982 and BPA (1984) describe events during the 1950s and 1960s in which it appears considerable southward alongshore sand transport occurred, depleting the beach and accreting the area immediately north of Richters Creek. The groyne built at Yorkeys Knob in 1959/60 following severe cyclone erosion did not appear to be trapping any significant northward transported sand. However, substantial changes since 1982 appear to have involved the northward re-distribution of sand from the shoreline sand bulge and delta north of Richters Creek to build out the dune and beach system along Yorkeys Knob (**Figure B3.4.12f**). It is most probable that these historical changes are part of a natural long term cycle of behaviour that is intimately related to medium to long changes in the prevailing wave climate.

In summary, it is apparent from the information reported in BPA (1984) and the subsequent behaviour over the past 30 years that:

- The beach system is very dynamic, in particular the response to the sand supply and movements of the various river and creek mouths
- The alongshore sand transport regime involves only a modest northward net movement of sand, however this may vary substantially under the influence of the varying prevailing wave climate and interruption by creek deltas
- The Barron River appears to supply about 20,000m^3/year of sand to the southern end of the beach system, however only a minor proportion (3,000m^3/year) of that moves northward to Hollaways Beach, resulting in accretion of the Redden Island part of Machans Beach
- A net northward supply of sand from Hollaways Beach to and past Richters Creek has led to erosion along Hollaways Beach
- The sand supply from and past Richters Creek to Yorkeys Knob Beach appears to have been relatively substantial, however circumstances during the 1950s and 1960s led to that supply accreting at the southern end of Yorkeys Knob Beach, with erosion at the northern end. This pattern has altered since 1982, with much of that sand being re-distributed northward to accrete the beach and dune system, most probably due to the occurrence of more favourable wave conditions.

Figure B3.4.12a Mulgrave Shire Northern Beaches (BPA, 1984)

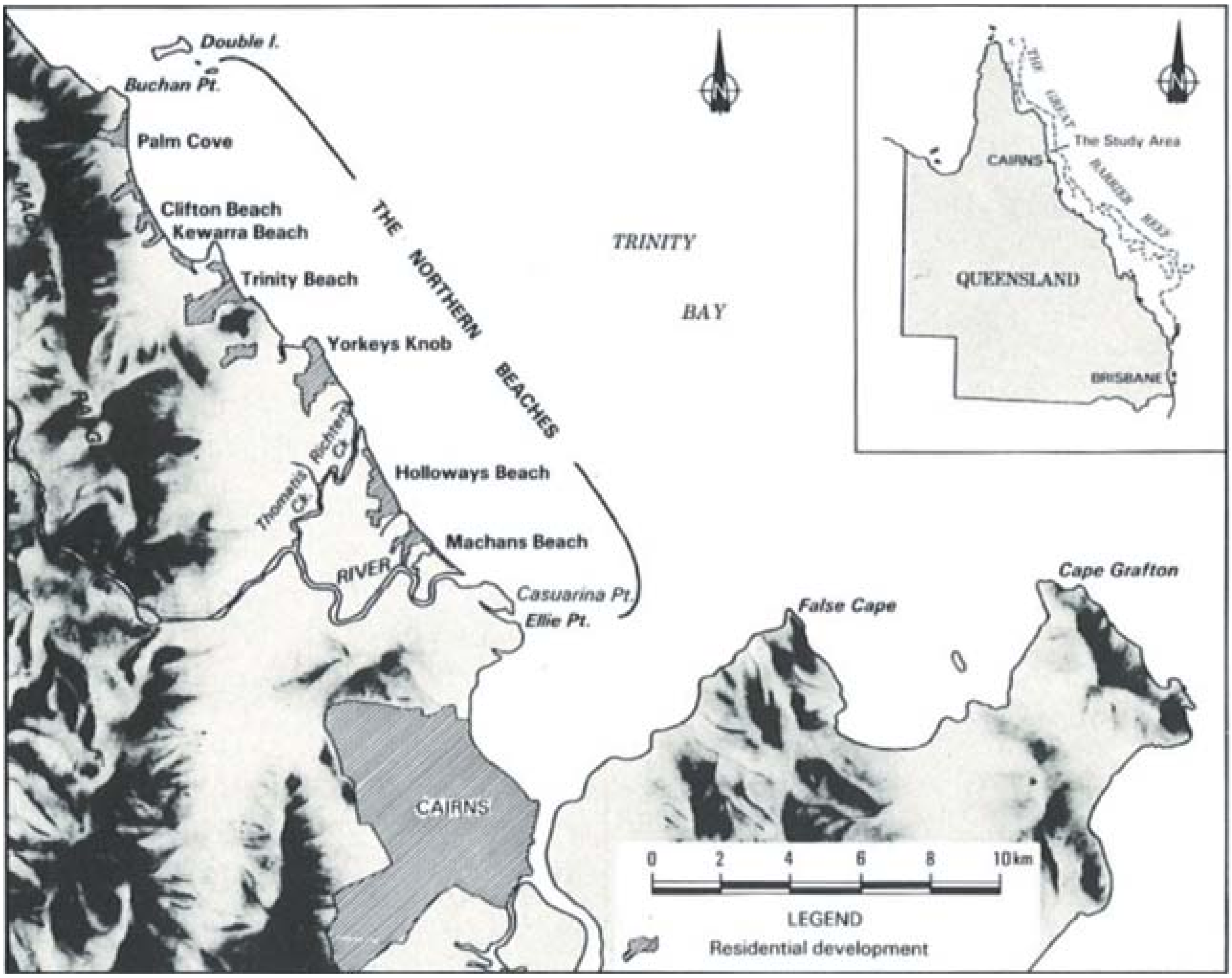


Figure B3.4.12b Barron River Delta and Machans Beach (from BPA, 1984)

Figure B3.4.12c Hollaways Beach to Yorkeys Knob beach (from BPA, 1984)

Figure B3.4.12d Redden Island-Machans Beach September 2011 (Google image)

Figure B3.4.12e Redden Island-Machans Beach September 2011 (Google image)

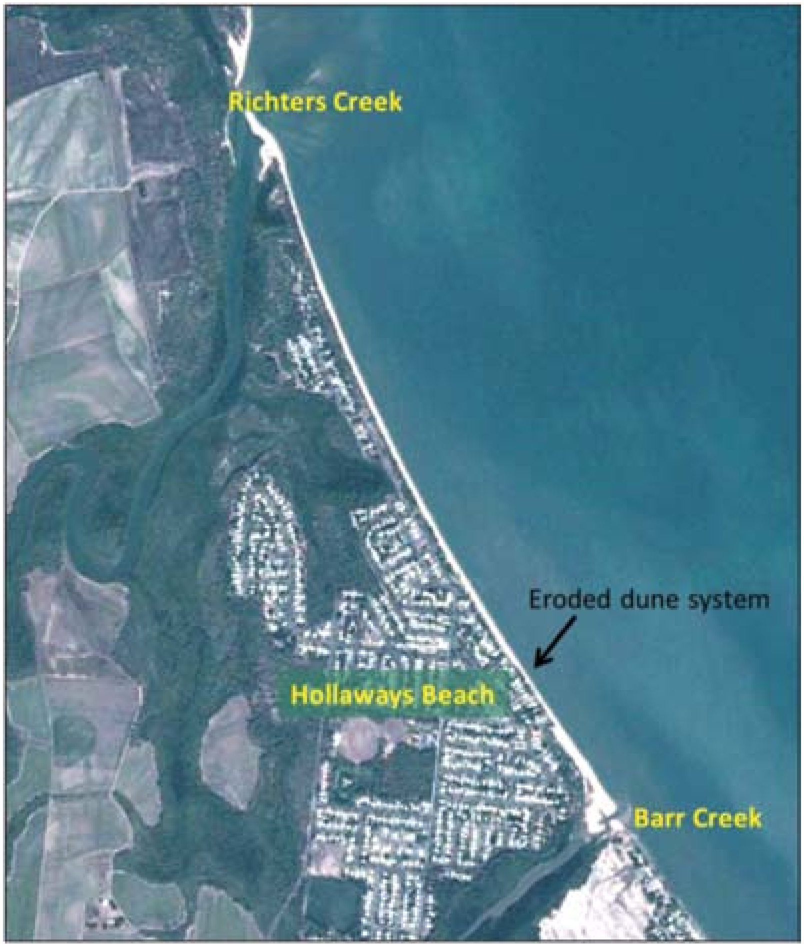


Figure B3.4.12f Yorkeys Knob Beach 2011 (Google image)

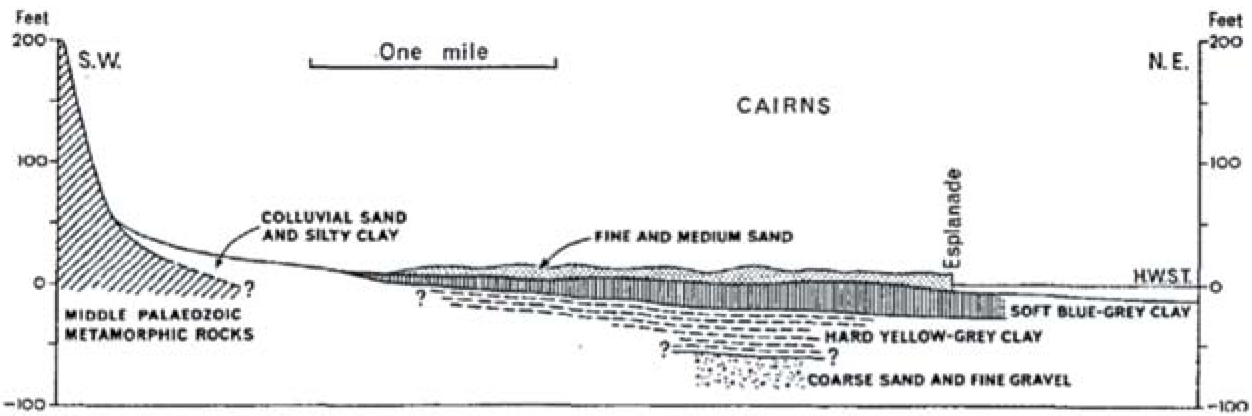
B3.4.13 Cairns Esplanade

Historical photos from the late 1800s and early 1900s show a narrow sandy beach and wide mudflats along the Cairns Esplanade. Bird (1979) proposed that the sandy material was delivered to the Esplanade area during a period when the Barron River entrance was located in the vicinity of the Cairns airport and delivered its sediment load directly to Trinity Bay. Under this scenario, the foreshore acquired a sandy veneer and a succession of small beach ridges were built by wave processes. The phase of beach ridge development ended when the Barron River entrance shifted to a more northerly position. During this period the supply of sand to Trinity Bay was essentially removed and mudflats and mangrove habitat dominated the Esplanade shoreline. In more recent decades, the Barron River has discharged in a south-easterly direction and sand drifting south along the shore has been built into a series of spits that have been stabilised by mangroves (Ellie Point and Casuarina Point).

The city of Cairns is built on the low-lying beach ridges described above. Bird (1979) presented the conceptual illustration of the stratigraphic sequence (rock and sediment layering) for the Cains City region shown in **Figure B3.4.13a**. The beach ridges, built during a period when sand was being supplied to Trinity Bay, are located upon a soft clay layer which extends to the intertidal mudflat at the Esplanade.

As previously discussed in **Section B3.4.11**, the baseline sediment transport modelling undertaken for the CSDP suggests that contemporary port operations do not contribute to mud accumulation at the Esplanade or Northern Beaches. This finding is broadly consistent with the Connell Wagner (1991; 1993) and Carter et al. (2002) studies.

Figure B3.4.13a Conceptual Section Through Cairns City Showing Sediment Layers (Bird, 1979)



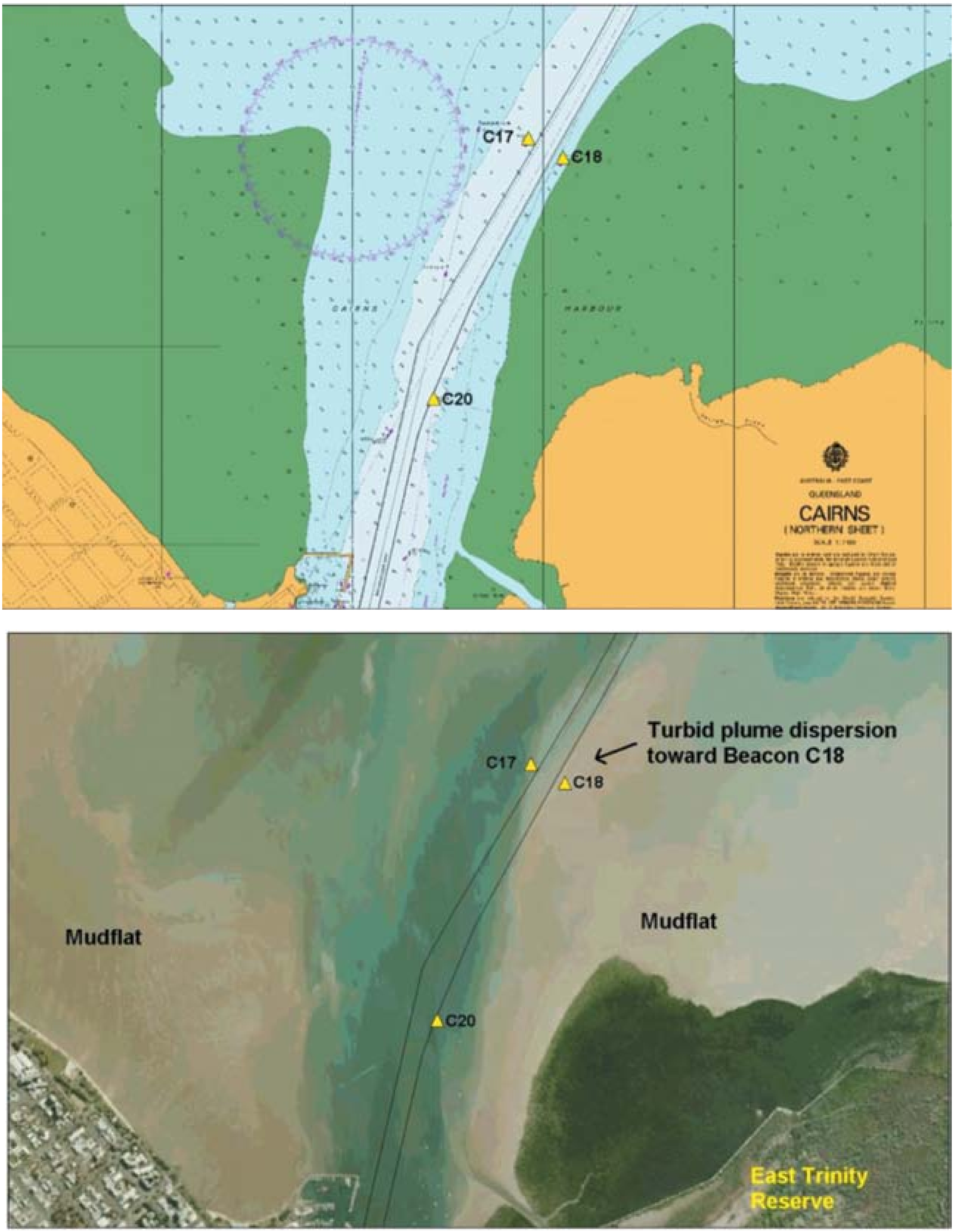
B3.4.14 East Trinity

Originally a mangrove and saltmarsh habitat, the East Trinity area was bought by CSR Pty Ltd in the 1970's to grow sugar cane. A bund wall was constructed through foreshore mangroves to prevent salt water entering the site, floodgates were installed to allow water to leave the site (but not enter) and the enclosed area was drained. Draining of the area exposed acid sulphate soils leading to acidification of onsite soils and discharges of sulphuric acid and heavy metals to Trinity Inlet following rainfall. Sugar cane production was not successful (as a result of the soil becoming acidic) and the remaining natural vegetation onsite was seriously degraded.

In 2000, the Queensland Government purchased the site, designated it as an Environmental Reserve (the East Trinity Reserve) and has been undertaking a variety of management measures to rehabilitate the site and reduce acidic discharges to Trinity Inlet. Progress has been significant but slow given the scale of the problem. A variety of native flora and fauna are returning to the site.

Historical Cairns shipping channel maintenance dredging requirements provide anecdotal evidence of an accreting mud flat to the north of the East Trinity Reserve. As illustrated in the top panel of **Figure B3.4.14a**, the channel alignment impinges on the East Trinity mudflat (green shading indicates an intertidal mudflat or mangrove area). Historical channel siltation estimates provided by Ports North and previously shown in **Figure B3.4.11.4a** indicate relatively high levels of siltation in the vicinity of Beacon C18. This is due to the re-suspension of fine sediment from the adjacent mudflat and the net currents moving the suspended material in a westerly direction (refer 0) towards the channel. The satellite image in the bottom panel of 0 was captured at a time when a visible sediment plume can be seen moving through the vicinity of Beacon C18. Any suspended sediment that settles near Beacon C18 will tend to accumulate since the bed shear stresses in the relatively deeper channel rarely exceed the threshold for sediment re-suspension.

Figure B3.4.14a East Trinity Mud Flat: Australian Hydrographic Service Navigation Chart AUS263 *(top)* and Turbid Plume Advection-Dispersion (Google image)



B3.5 Assessment of Potential Impacts

A risk-based approach has been adopted in this environmental impact assessment. This is based on the identification of potential impacting processes and characterisation of the likely level of impact to the existing environment. The risk assessment process is described in **Chapter A1, Project Introduction** of this EIS.

For the purposes of coastal processes chapter, impacts levels and risks were defined on the basis of the following:

- Significance of Impact – made up of assessment of the intensity, scale (geographic extent), duration of impacts and sensitivity of environmental receptors to the impact. **Table B3.5a** is a summary of the categories used to define impact significance
- Likelihood of Impact – which assesses the probability of the impact occurring. **Table B3.5b** is a summary of the categories used to define impact likelihood
- Risk rating – which assesses the level of risk for key impacting processes. The risk rating was generated from the Significance and Likelihood scores, based on the matrix shown in **Table B3.5c**.

Table B3.5a Impact Significance Criteria

Significance	Definition
Very High	The impact is considered critical to the decision-making process as it would represent a major change to the coastal processes of Trinity Bay and Inlet. This level of impact would be indicated by: • Very large changes to the natural physical processes in Trinity Bay and Inlet, such as major shoreline erosion or major changes to tidal currents and/or sediment transport patterns
High	The impact is considered important to the decision-making process as it would a detectable change to the coastal processes of Trinity Bay and Inlet. This level of impact would be indicated by: • Large changes to the natural physical processes in Trinity Bay and Inlet, such as shoreline erosion or large changes to tidal currents and sediment transport patterns
Moderate	While important at a state or regional or local scale, these impacts are not likely to be critical decision making issues. This would be indicated by: • Moderate changes to the natural physical processes in Trinity Bay and Inlet, such as significant shoreline realignment or moderate changes to tidal currents and/or sediment transport patterns
Minor	Impacts are recognisable/detectable but acceptable. These impacts are unlikely to be of importance in the decision making process. Nevertheless, they are relevant in the consideration of standard mitigation measures. This would be indicated by: • Minor changes to the natural physical processes in Trinity Bay and Inlet, such as subtle shoreline realignment or minor changes to tidal currents and/or sediment transport patterns
Negligible	Minimal change to the existing situation. This could include, for example, impacts that are below levels of detection, impacts that are within the normal bounds of variation or impacts that are within the margin of forecasting error.
Beneficial	Any beneficial impacts as a result of the project such as for example, the creation/establishment of new habitat.

Table B3.5b Likelihood of Impact

Likelihood of Impacts	Risk probability categories
Highly Unlikely	Highly unlikely to occur but theoretically possible
Unlikely	May occur during construction of the project but probability well below 50%; unlikely but not negligible
Possible	Less likely than not but still appreciable; probability of about 50%
Likely	Likely to occur during construction or during a 12 month timeframe; probability greater than 50%
Almost Certain	Very likely to occur as a result of the proposed project construction and/or operations; could occur multiple times during relevant impacting period

Table B3.5c Risk Matrix

Likelihood	Significance				
	Negligible	Minor	Moderate	High	Very High
Highly Unlikely/ Rare	Negligible	Negligible	Low	Medium	High
Unlikely	Negligible	Low	Low	Medium	High
Possible	Negligible	Low	Medium	Medium	High
Likely	Negligible	Medium	Medium	High	Extreme
Almost Certain	Low	Medium	High	Extreme	Extreme

Table B3.5d Risk Rating Legend

Extreme Risk	An issue requiring change in project scope; almost certain to result in a 'significant' impact on a Matter of National or State Environmental Significance
High Risk	An issue requiring further detailed investigation and planning to manage and reduce risk; likely to result in a 'significant' impact on a Matter of National or State Environmental Significance
Medium Risk	An issue requiring project specific controls and procedures to manage
Low Risk	Manageable by standard mitigation and similar operating procedures
Negligible Risk	No additional management required

In the context of coastal processes, the impacts associated with the Cairns Shipping Development Project are generally related to the proposed dredging works. These works entail widening the existing channel (to 130m in the outer channel), deepening to a declared depth of -9.4mLAT (plus overdredge allowances), which also involves extending the dredged channel by around 1km offshore. Additional dredging is also proposed for a cruise ship berthing facility and deepening of the Crystal and Smith's Creek swing basins. The total volume of sediment to be dredged as part of the CSDP capital development is 4.4Mm^3.

The difference in bed elevation between the "Existing Case" and "Developed Case" channel scenarios is shown in **Figure B3.5.1.1a**. These two bathymetric scenarios form the basis for the coastal processes impact assessment. Numerical model simulations were completed for each bathymetric scenario (all other model inputs and settings are identical) and the outputs compared. Differences between the model results are deemed to be impacts associated with the CSDP.

Other potential coastal process impacts are related to the placement and dispersion of dredged material at the proposed DMPA.

The subsequent report sections present the impact assessment of the CSDP for the key coastal processes issues identified in the baseline section which are:

- Hydrodynamics
- Waves
- Morphology and Sedimentation
- Shoreline and Beach System.

Key assumptions and limitations of the impact assessment are outlined and discussed where relevant.

B3.5.1 Hydrodynamic Impacts

The CSDP dredging will induce changes to flow patterns in the immediate vicinity of the development. The 3D hydrodynamic model described in **Section B3.3.3** was used to assess the magnitude and significance of the impacts. As described below, the assessment has considered impacts to current fields, water levels, bed shear stresses and to tidal prism within Trinity Inlet.

B3.5.1.1 Tidal Current Field Impacts

The CSDP channel dredging will increase the conveyance (flow capacity) of the dredged channel entering Trinity Inlet and has the potential to redistribute flow patterns in the immediate vicinity of the works. Depth-averaged current speeds were extracted from the 3D hydrodynamic model Base Case and Developed Case simulations and analysed in order to understand the dredging impacts on current patterns.

Changes to current patterns in the vicinity of the Port were assessed for a flooding tide and an ebbing tide during a period of spring tides. Spatial plots of the changes in velocity magnitudes between the Base Case and Developed Case are shown in **Figure B3.5.1.1c** and **Figure B3.5.1.1d** (zoomed view) for the flooding tide. **Figure B3.5.1.1e** and **Figure B3.5.1.1f** (zoomed view) show the equivalent model predictions for the ebbing tide. Reductions in velocity magnitude are in blue, and increases in yellow/red. The vectors (arrows) on these plots represent both the direction and magnitude of the depth-averaged currents. The developed case vectors are overlain on the impact plots in order to aid interpretation.

Appendix D3, Climatic and Coastal Oceanographic Data Collection Report provides a detailed discussion of the spatial current pattern impacts. In summary, the velocity impact plots show that the changes in velocity magnitudes associated with the CSDP are confined to the Project Area and the immediate surroundings. The highest magnitude changes are not large (generally up to ±0.1m/s). The velocities in the deepened and widened channel are generally reduced, with some localised areas of increased velocities immediately adjacent to the dredging footprint. Further afield on the relatively shallow Trinity Bay mudflats to the east and west of the channel alignment, current velocities are generally slightly reduced (by less than 10% of their existing case values). The minor changes to current patterns are not expected to be of significance to seagrass or other benthos (potential project related impacts to marine ecology are considered separately in **Chapter B7, Marine Ecology**).

Time series of depth-averaged velocity were extracted at the seven analysis sites shown in **Figure B3.5.1.1b**. The timeseries plots are shown in **Figure B3.5.1.1g** for Points 1 to 4, and **Figure B3.5.1.1h** for Points 5 to 7. The timeseries correspond to the period from 7th – 13th March, which includes some relatively large spring tide conditions. Notable features of the timeseries plots are summarised below.

- In general differences between the existing and developed case timeseries are difficult to distinguish
- At Point 1, which is located within 200m upstream from the dredge footprint southern extent, the developed case results are almost indistinguishable from the existing case model predictions. This is also the case at Point 7, which is located 1.8km further upstream within Trinity Inlet
- Point 2, which is located on the eastern bank of the Trinity Inlet channel, occasionally exhibits developed case current speeds that are up to 0.2m/s higher than the existing case during ebbing spring tide flows. This could indicate an area of flow separation that may be sensitive to the channel dredging works
- The very slight reduction in current speeds on the adjacent Trinity Bay mudflats can be observed during peak currents at Points 3-6.

Figure B3.5.1.1a Cairns Shipping Channel and Surrounds Bed Elevation: Existing case *(top left)*; Developed case *(top right)* and Difference *(bottom)*

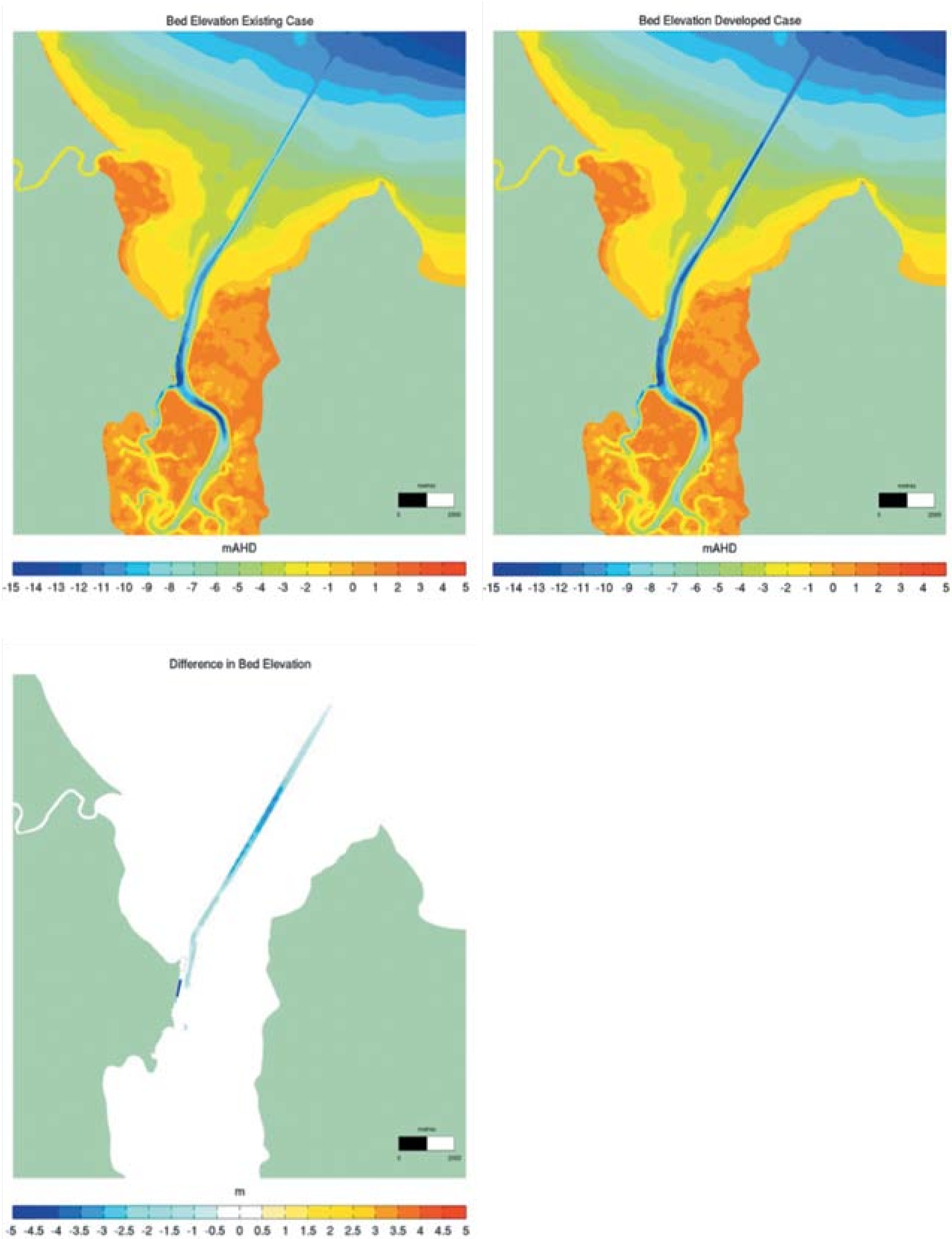


Figure B3.5.1.1b Impact Reporting Points and Transect Locations

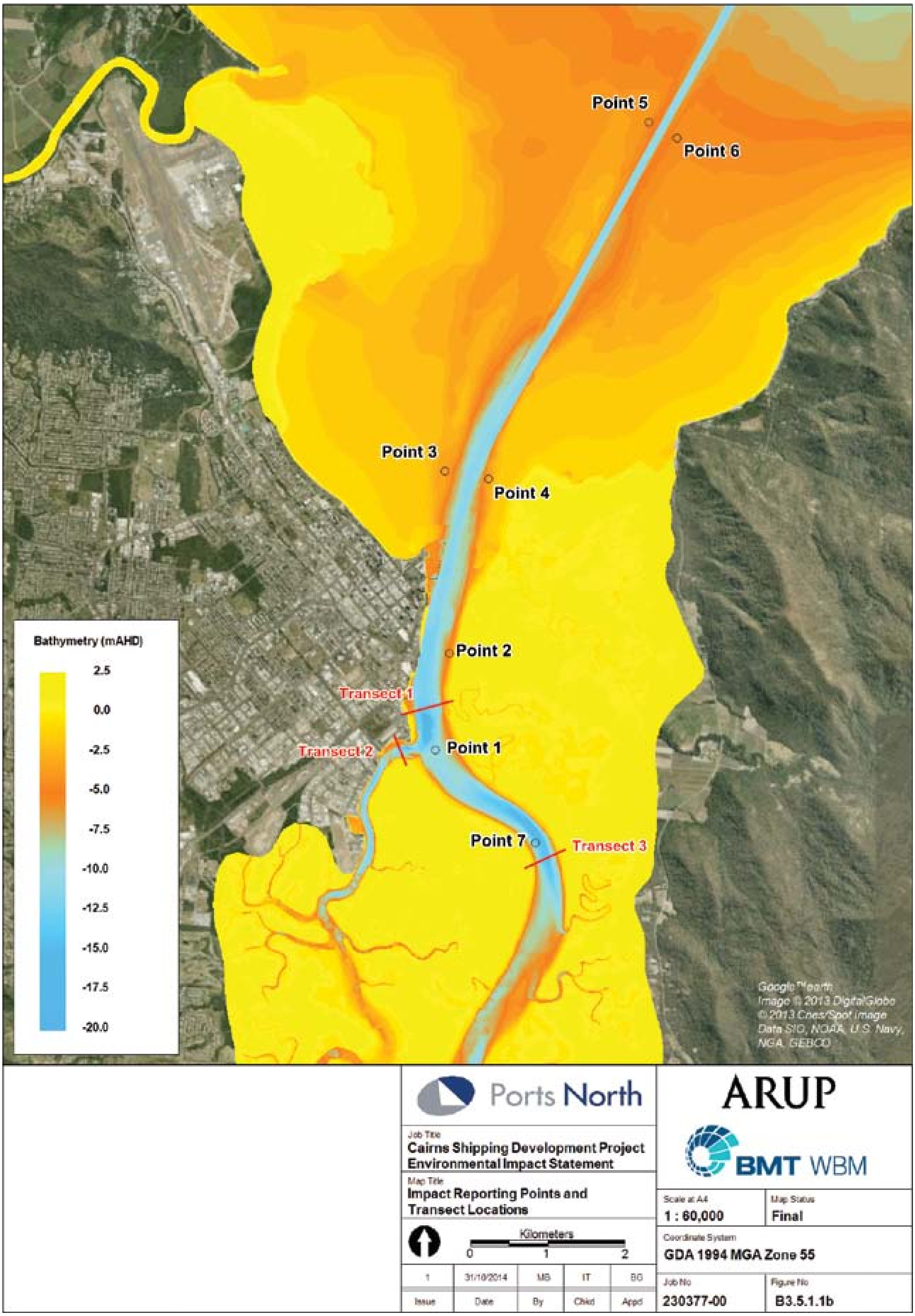


Figure B3.5.1.1c Modelled Spring Tide Flood Currents and Impacts. Existing case *(top left)*; Developed case *(top right)* and Impacts *(bottom)*. Vectors indicate Direction; Contours indicate Magnitude

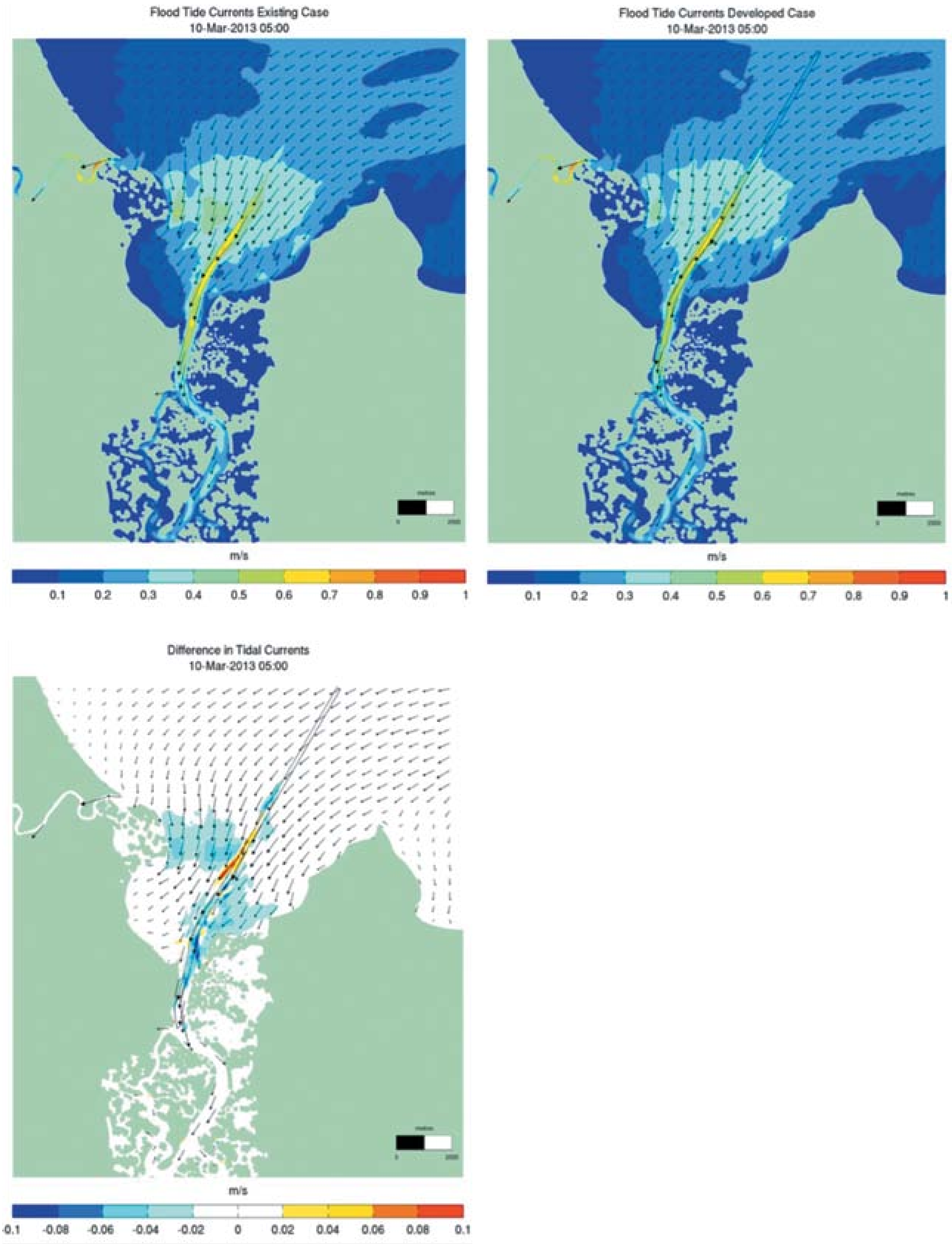


Figure B3.5.1.1d Modelled Spring Tide Flood Currents and Impacts – zoomed. Existing case *(top left)*; Developed case *(top right)* and Impacts (bottom). Vectors indicate Direction; Contours indicate Magnitude

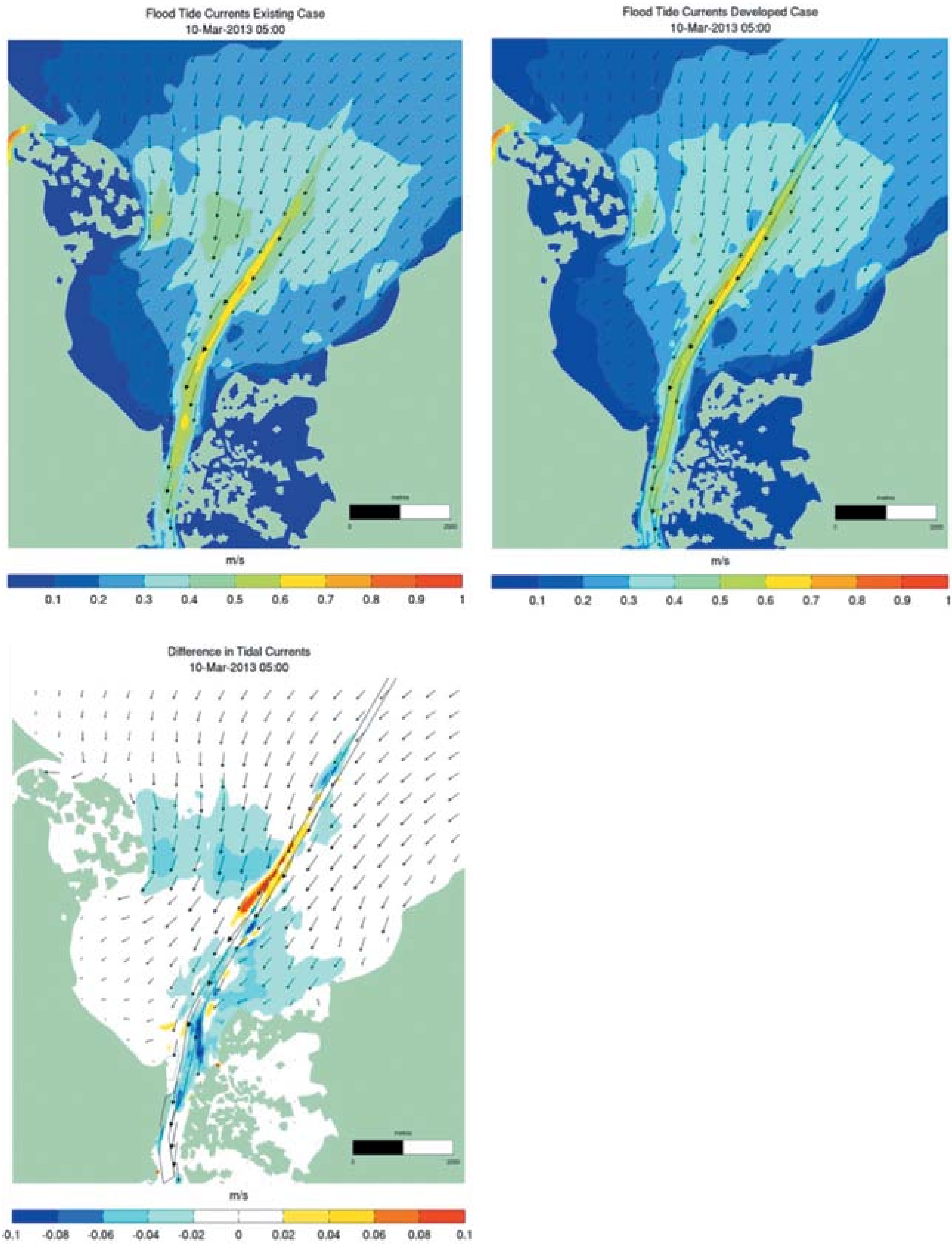


Figure B3.5.1.1e Modelled Spring Tide Ebb Currents and Impacts. Existing case *(top left)*; Developed case *(top right)* and Impacts *(bottom)*. Vectors indicate Direction; Contours indicate Magnitude

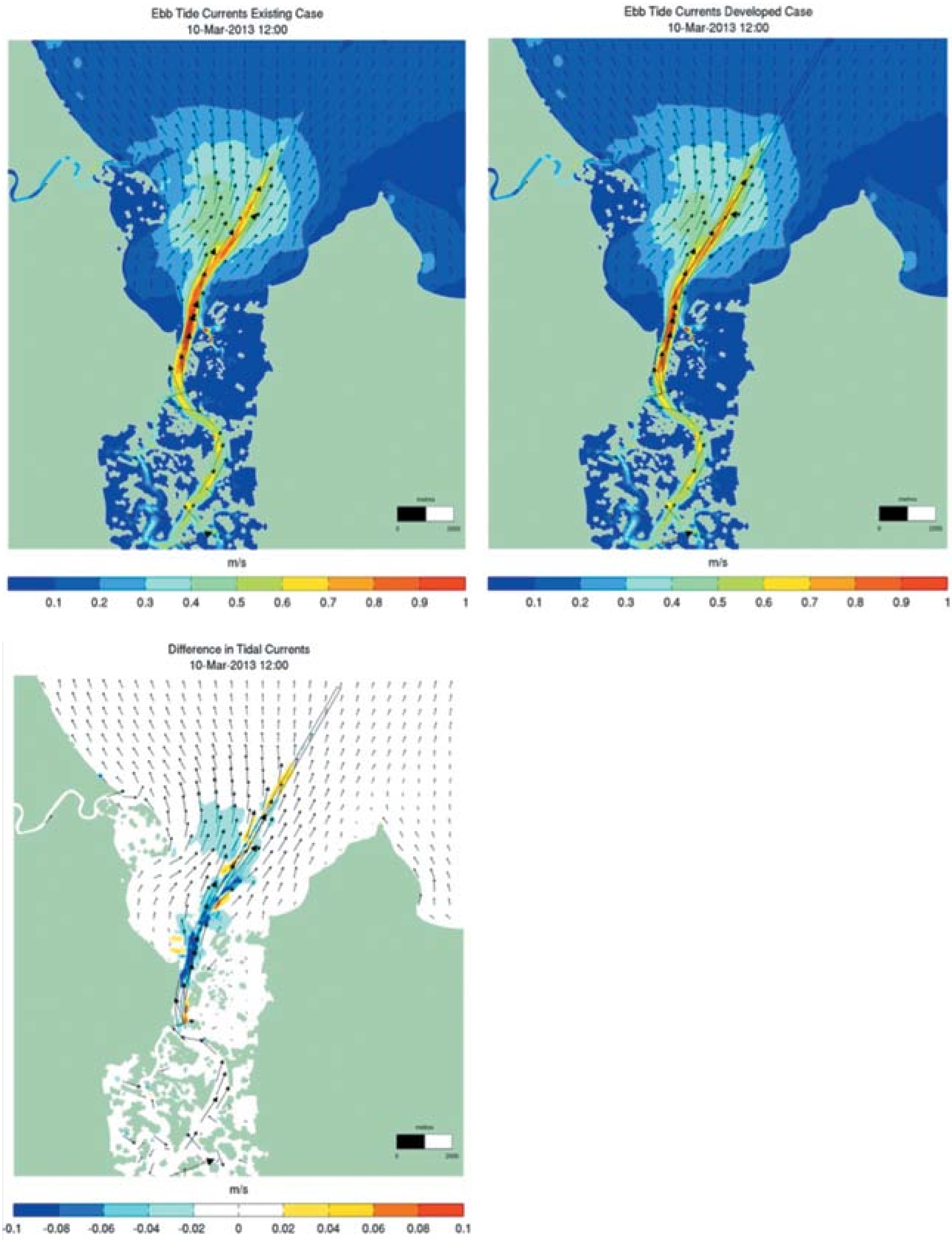


Figure B3.5.1.1f Modelled Spring Tide Ebb Currents and Impacts – zoomed. Existing case *(top left)*; Developed case *(top right)* and Impacts *(bottom).* Vectors indicate Direction; Contours indicate Magnitude.

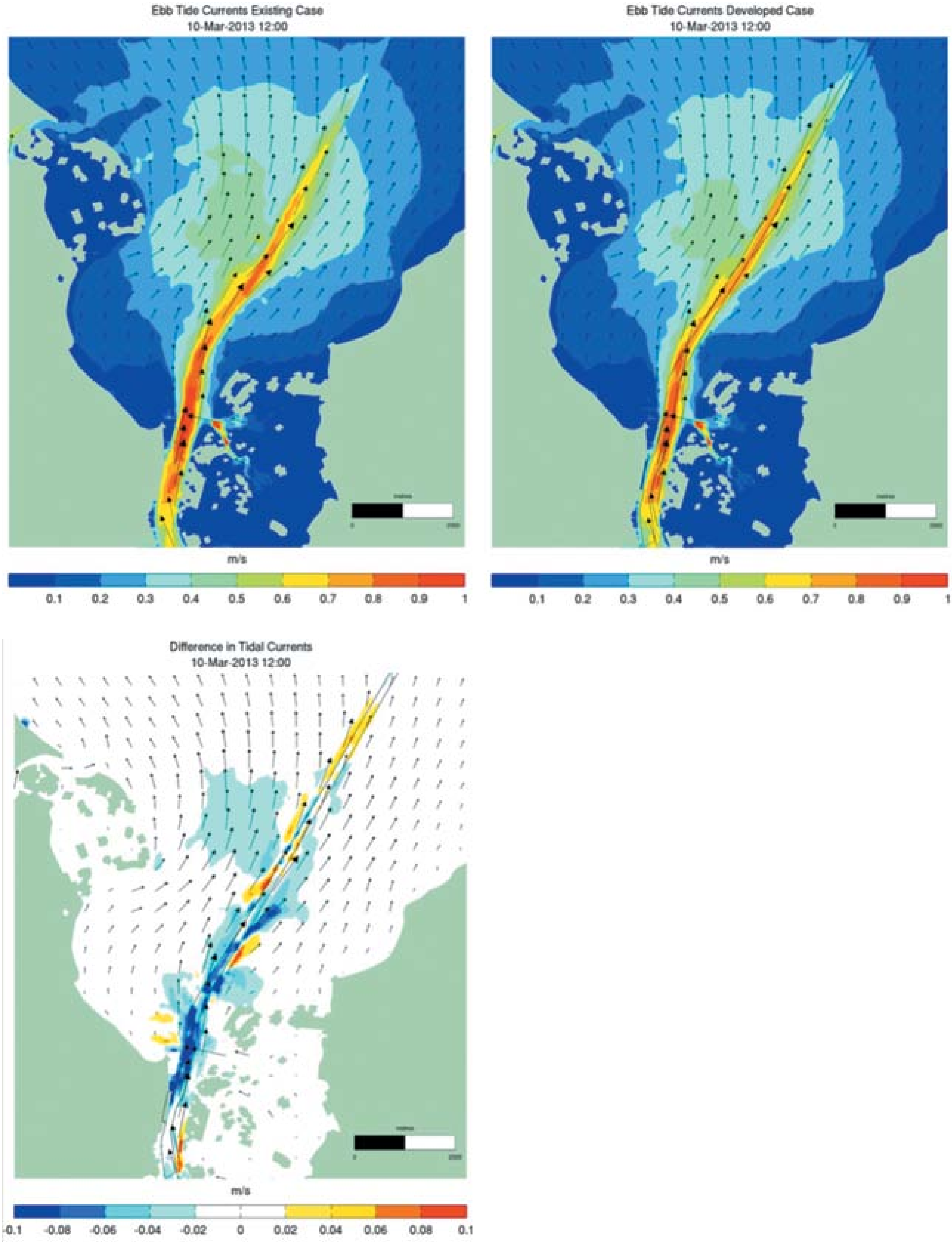


Figure B3.5.1.1g Existing and Developed Case Current Speed Timeseries (Points 1 to 4) Positive current speeds are during flooding tides

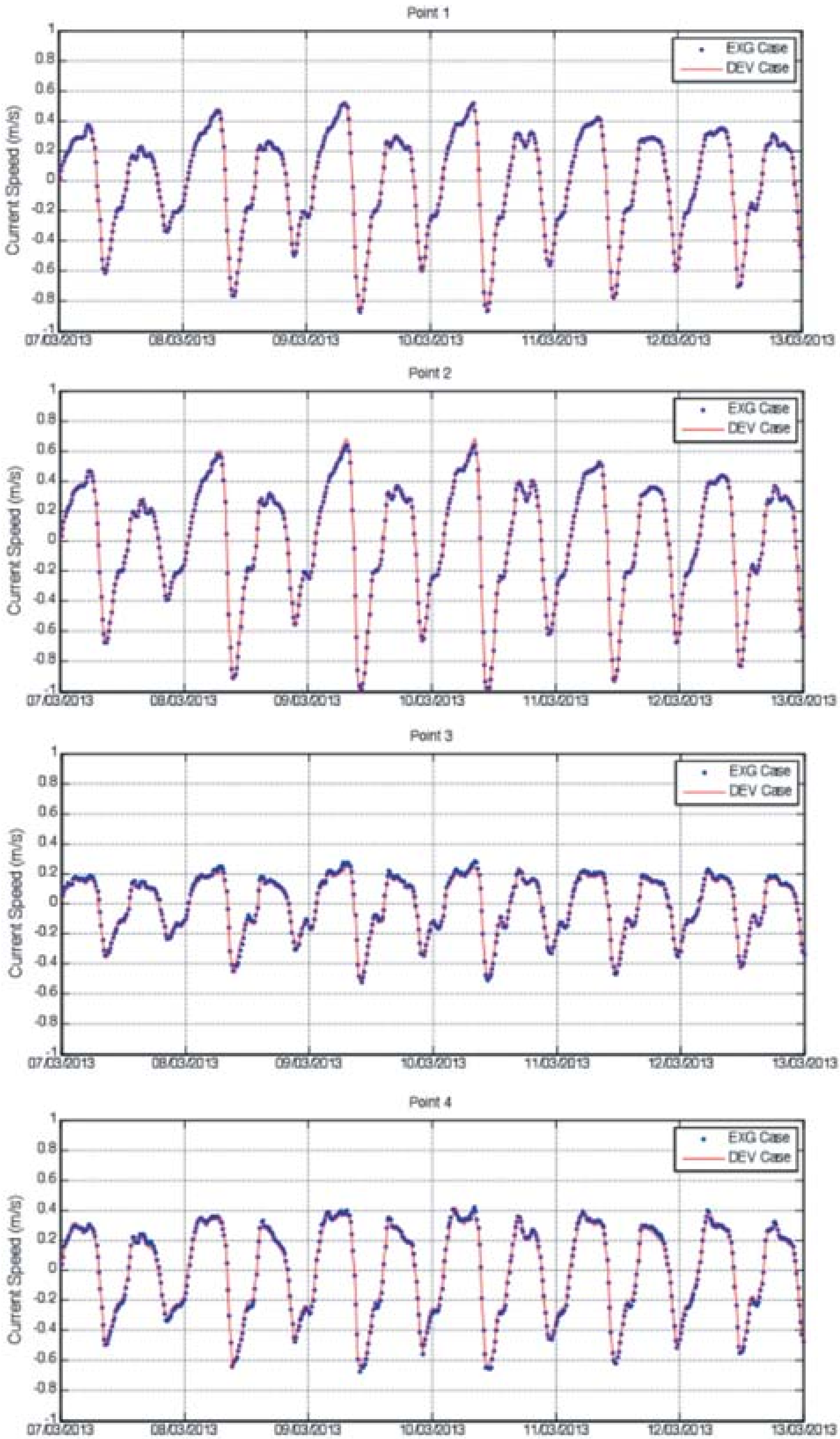
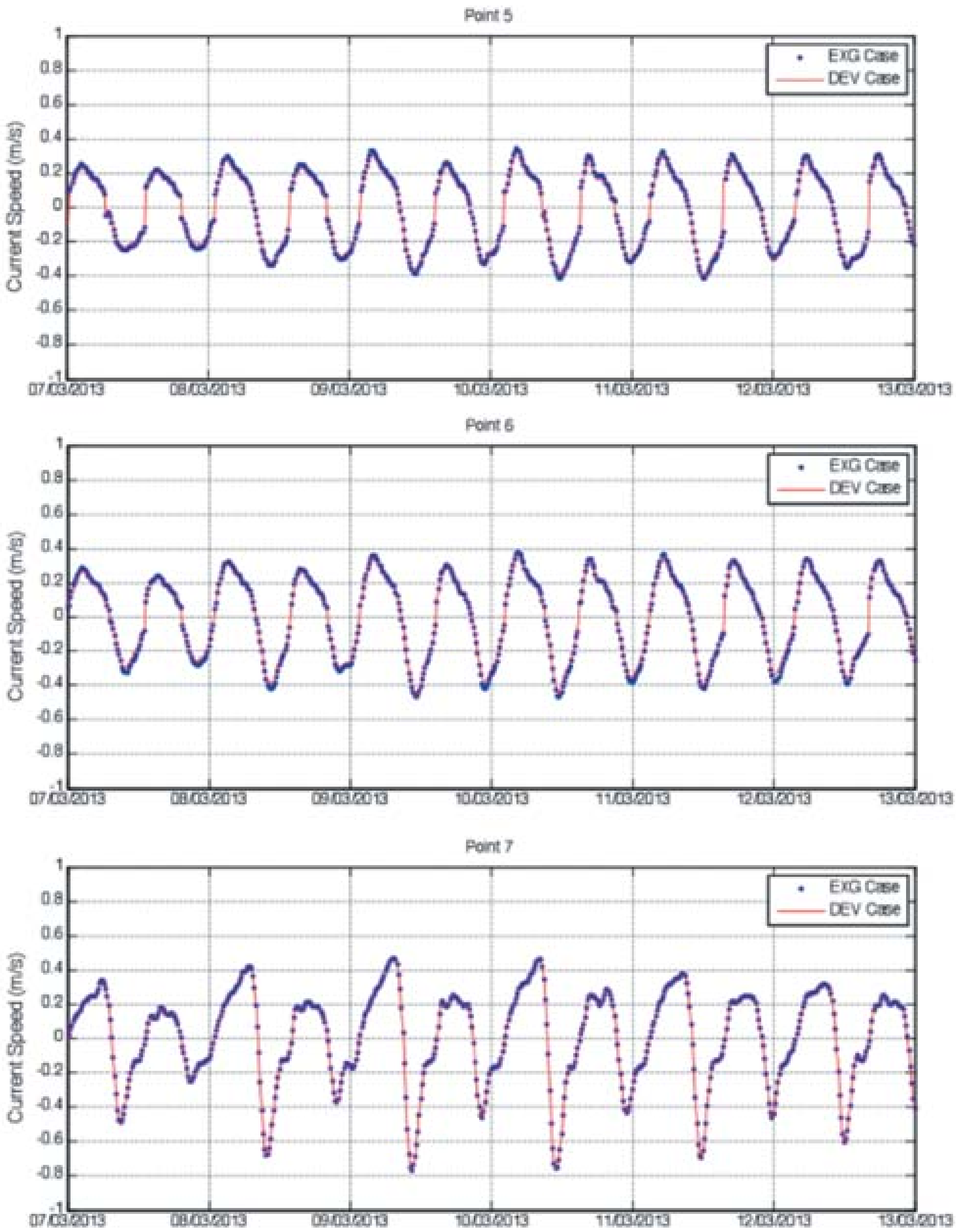


Figure B3.5.1.1h Existing and Developed Case Current Speed Timeseries (Points 5 to 7) Positive current speeds are during flooding tides



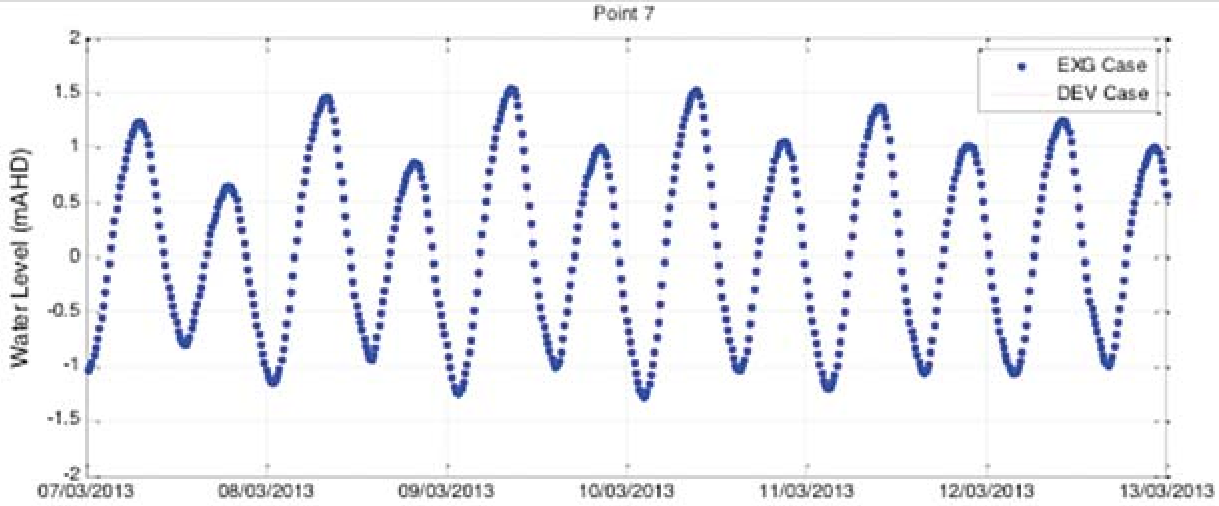
B3.5.1.2 Water Level Impacts

Water level variations within Trinity Bay are predominantly driven by tidal oscillations (**Section B3.4.7**). The dredging works have some (limited) potential to impact on flow patterns and hence water levels in the vicinity of the works as well as further upstream within Trinity Inlet. Water level impacts could potentially be significant in terms of morphological processes (e.g. bank stability) and ecological processes (e.g. Mangrove health).

Spatial water level impacts were analysed by differencing the Base Case and Developed Case simulation results. The results of this analysis were that water level differences due to the CSDP dredging were everywhere and at all times negligible. Spatial plots of the water level impacts are not shown due to the negligible magnitude of the changes.

Time series of water level were extracted from Base Case and Developed Case simulations at the analysis sites shown in **Figure B3.5.1.1b**. The timeseries comparisons also show no discernible difference between existing case and developed water levels. Only the water level timeseries at Point 7 (within Trinity Inlet) are shown below in **Figure B3.5.1.2a** in order to illustrate this result.

Figure B3.5.1.2a Existing and Developed Case Water Level Timeseries (Point 7 – Trinity Inlet).



B3.5.1.3 Tidal Flow and Volume Impacts

The impact of the CSDP dredging on tidal flow rates and volumes were analysed in order to assess the implications of the project on tidal flushing of Trinity Inlet.

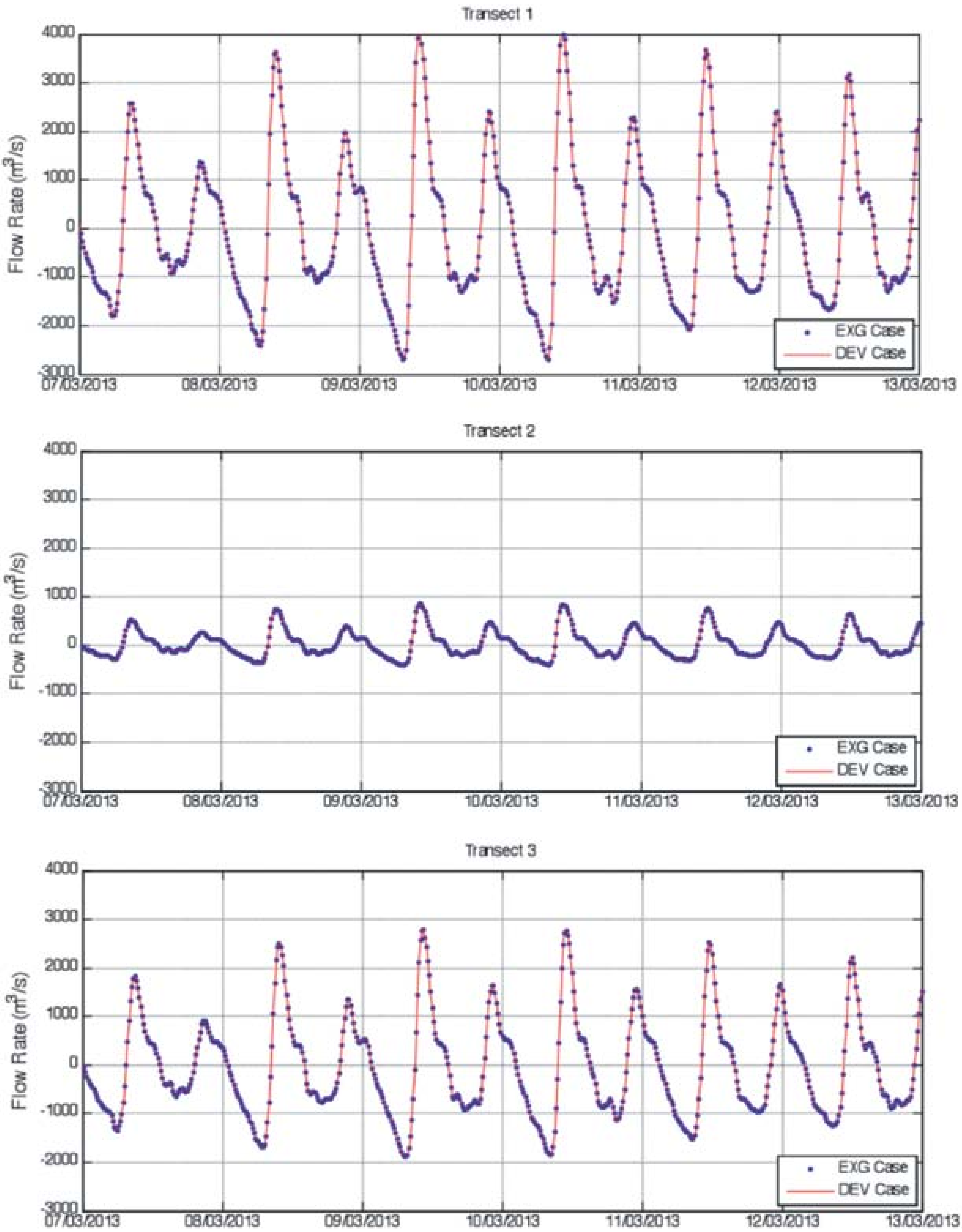
Flow timeseries were extracted from the existing and developed case model simulations at the three transect locations shown in **Figure B3.5.1.1b**. Transect 1 is located across the main Trinity Inlet channel across the Smith Creek swing basin. Transect 2 is located across the northern arm of Smith Creek. Transect 3 is located across the main Trinity Inlet channel around 1.8km upstream of the Smith Creek swing basin. The timeseries comparisons presented in **Figure B3.5.1.3a** show no discernible difference between existing case and developed case flows.

Tidal prism volumes were derived from the extracted flows and are presented in **Table B3.5.1.3a**. The 50th percentile and 95th percentile tidal prism volumes and percentage impacts are reported. The 50th percentile represents a typical tidal range, while the 95th percentile represents a fairly large spring tidal range. The change in tidal prism within Trinity Inlet due to the CSDP is less than 0.2%.

Table B3.5.1.3a Tidal Prism Impacts

Transect ID	Tidal Prism (m^3) 50th Percentile			Tidal Prism (m^3) 95th Percentile		
	Existing	Developed	Change	Existing	Developed	Change
1	14,814,300	14,824,700	0.07%	33,652,100	33,664,000	0.04%
2	2,191,700	2,192,300	0.02%	5,465,900	5,475,500	0.17%
3	10,565,400	10,557,500	-0.07%	22,590,100	22,597,200	0.03%

Figure B3.5.1.3a Existing and Developed Case Flow Timeseries at the Transects shown in Figure B3.5b



B3.5.1.4 Bed Shear Stress Impacts

Bed shear stresses represent the capacity of current (and wave) induced water motions to re-suspend sediment from the seabed and to transport it as bedload. Impacts to current related bed shear stresses have been analysed using the 3D hydrodynamic model output in order to provide a high-level understanding of the potential for morphological change induced by the CSDP dredging.

The 95th percentile current related bed shear stress magnitudes, which represent conditions that are typically exceeded during spring tide flows, are shown in **Figure B3.5.1.4a** and **Figure B3.5.1.4b** (zoomed in). These figures present spatial plots of Existing Case, Developed Case and predicted impacts (the difference between the Existing Case and the Developed Case).

The spatial impacts to current related bed shear stress generally follow the current velocity impacts presented in **Section B3.5.1.1**. The changes in bed shear stress magnitude associated with the CSDP are confined to the Project Area and the immediate surroundings. The highest magnitude changes are not large (generally up to ±0.1N/m^2). The bed shear stress in the deepened and widened channel are generally reduced, with some localised areas of increased velocities immediately adjacent to the dredging footprint. Impacts are not predicted within Trinity Inlet or other further afield locations.

Impacts to bed shear stress are not of magnitudes likely to cause undesirable morphological change. The reduced bed shear stresses in the vicinity of the developed channel are likely to cause increased siltation and maintenance dredging requirements. The impact to channel siltation is addressed separately in **Section B3.5.3.3**.

Figure B3.5.1.4a Modelled 95th Percentile Current Related Bed Shear Stress (N/m2) and Impacts. Existing case *(top left)*; Developed case *(top right)* and Impacts *(bottom)*

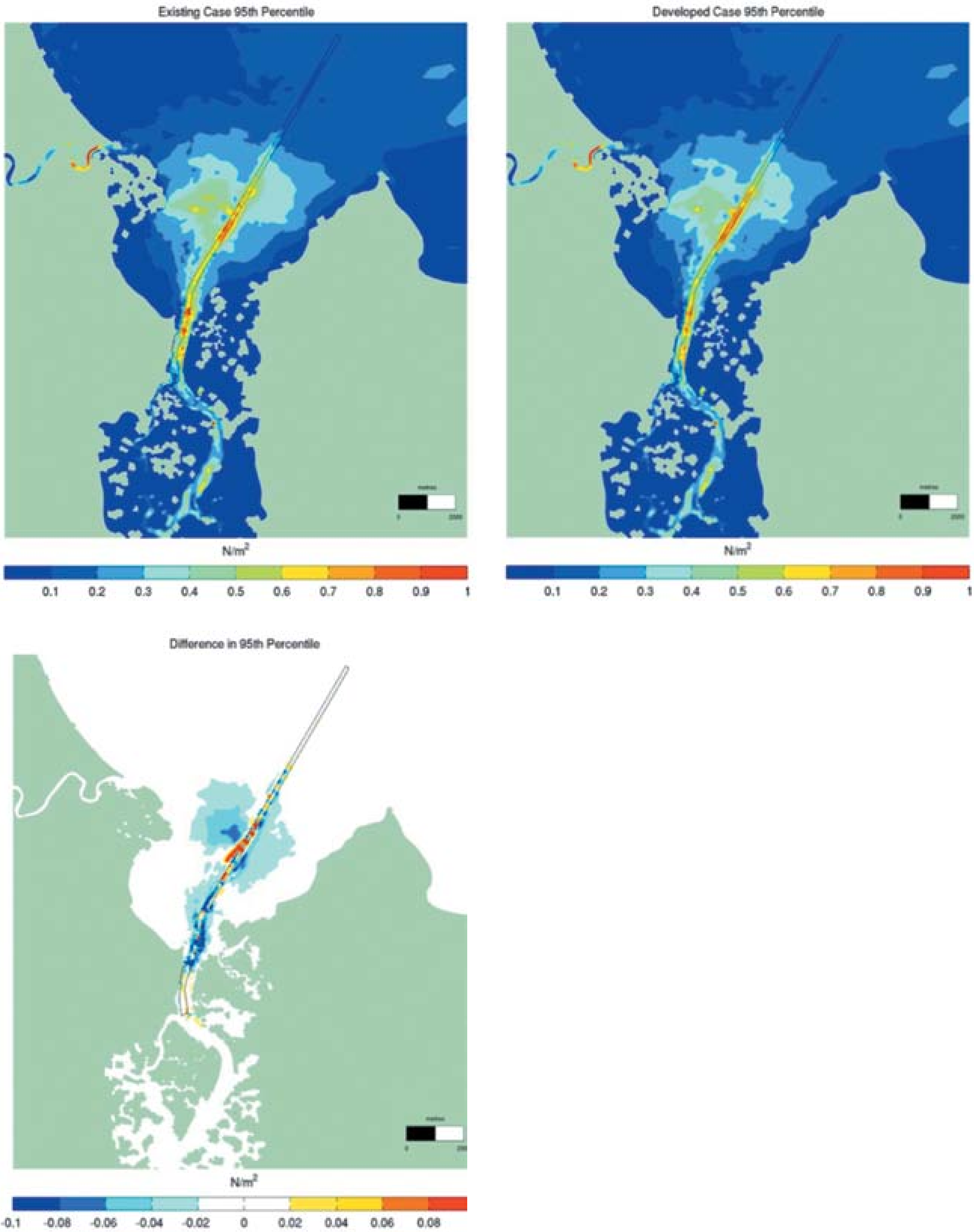
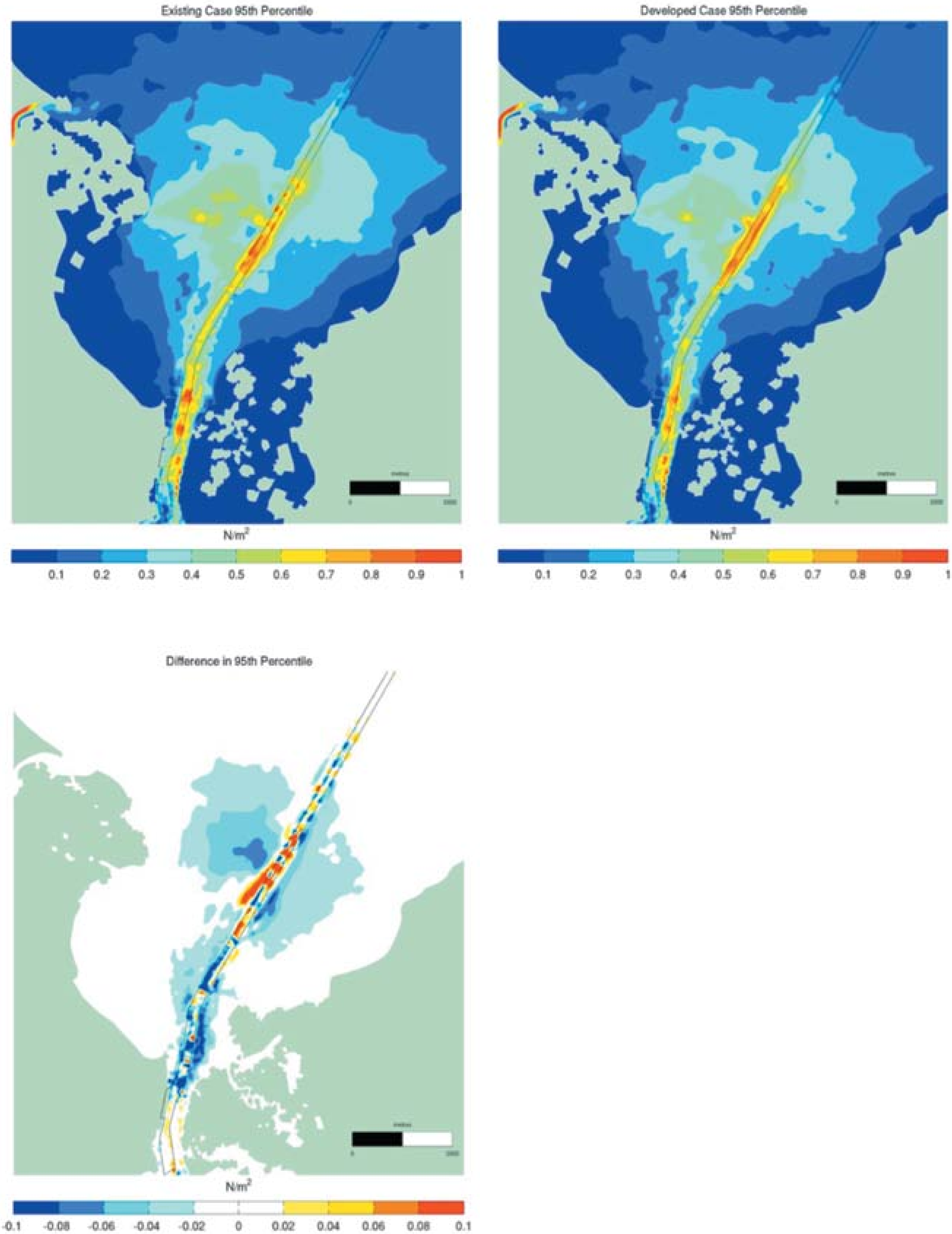


Figure B3.5.1.4b Modelled 95th Percentile Current Related Bed Shear Stress (N/m2) – zoom. Existing case *(top left)*; Developed case *(top right)* and Impacts *(bottom)*



B3.5.1.5 Extreme Water Level Impacts

The impact of the channel development on surge propagation was analysed in order to assess the potential of the CSDP to affect vulnerability to storm tide inundation on adjacent properties.

The hydrodynamic model was used to simulate the surge generated by a severe tropical cyclone event impacting on Cairns. The atmospheric pressure and wind field inputs to the hydrodynamic model were described using the Holland (1980) parametric tropical cyclone model. The synthetic event was developed such that it crossed the coast north of Cairns, generating a surge in Trinity Bay close to 1.5m which is approximately equivalent to the 200-year ARI surge event (BMT WBM, 2013). It is noted that this assessment considered the surge propagation in isolation of the astronomic tide.

Spatial surge level impacts were analysed by differencing the Base Case and Developed Case simulation results. The result of this analysis is shown in **Figure B3.5.1.5b** which demonstrates that the peak surge level difference due to the CSDP dredging is negligible

Time series of surge level was extracted from Base Case and Developed Case simulations at the analysis sites shown in **Figure B3.5.1.5b**. The timeseries comparisons also show no discernible difference between existing case and developed water levels. Only the water level timeseries at Point 1 (within the Inner Port area) is shown below in **Figure B3.5.1.5a** in order to illustrate this result.

Figure B3.5.1.5a Existing and Developed Case Surge Level Timeseries (Point 1 – Inner Port).

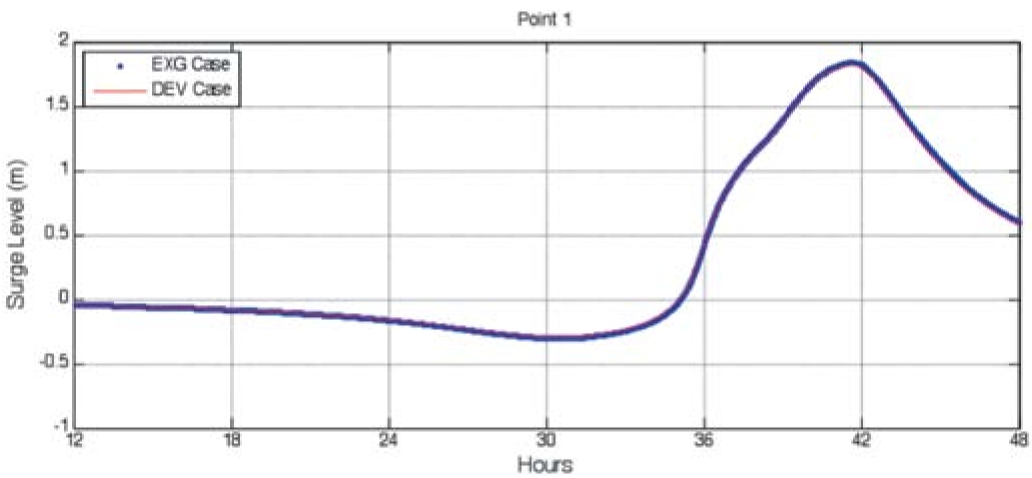
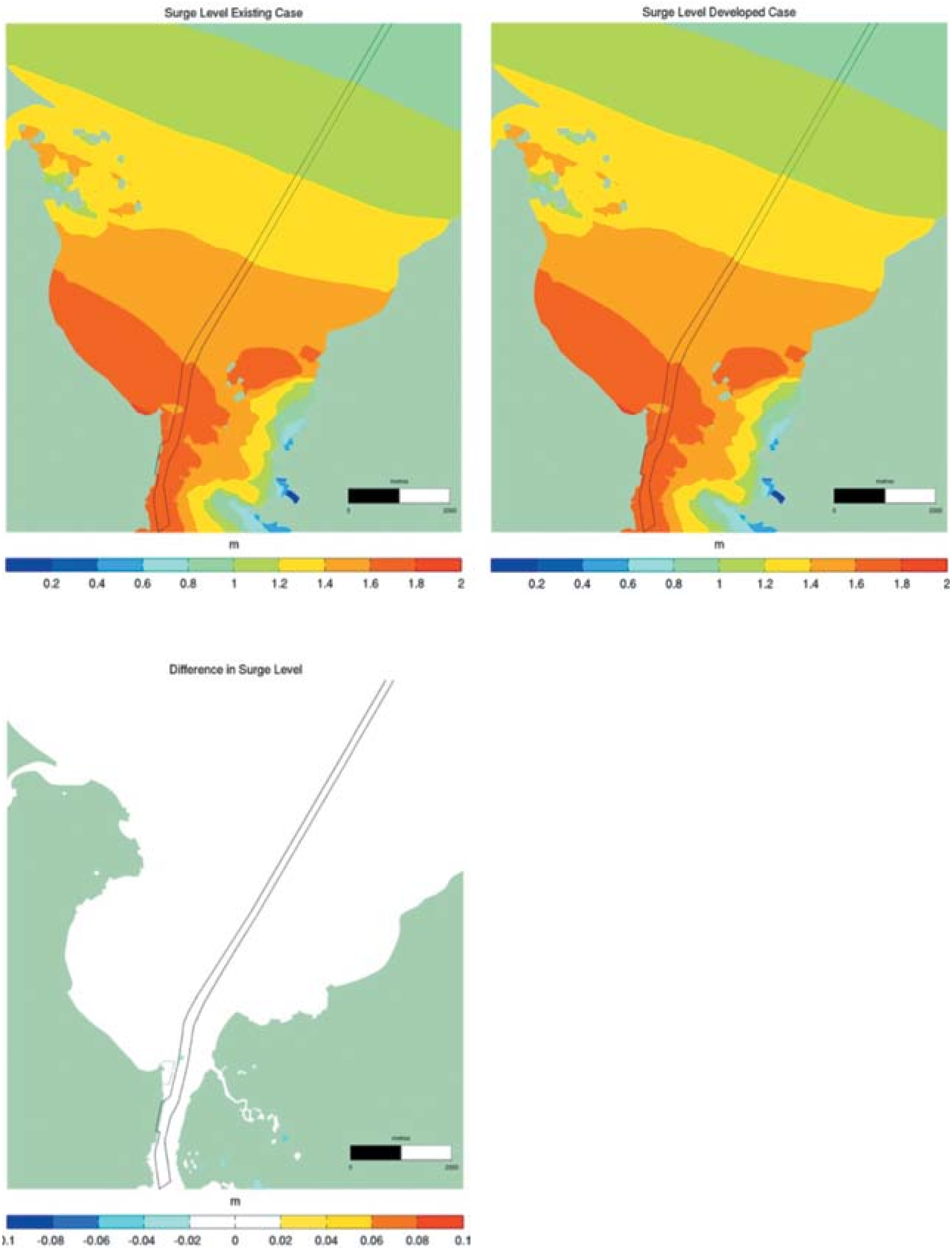


Figure B3.5.1.5b Modelled Peak Surge Level (m): Existing case *(top left)*; Developed case *(top right)* and Impacts *(bottom)*



B3.5.1.6 Summary of hydrodynamic impacts

The hydrodynamic impacts of the CSDP are not large in magnitude or extent, being confined to changes in velocity magnitude in the immediate vicinity of the channel dredging footprint.

Within and immediately adjacent to the CSDP dredging footprint depth-averaged current speeds are predicted to increase/decrease (depending on location) within a range of ±0.2m/s. Smaller magnitude reductions in peak current speeds (<10%) are predicted more broadly within Trinity Bay.

There are no discernible water level impacts associated with the CSDP dredging either within the Project Area or further afield. The tidal prism impacts within Trinity Inlet of the CSDP are also predicted to be negligible.

Current only bed shear stress impacts are generally modest and would not be expected to be associated with broad-scale morphological changes within or beyond the Project Area. As previously stated, the predicted changes to hydrodynamics are not expected to have a measurable influence on the wider ecological processes occurring within Trinity Bay. The potential impacts of the CSDP on marine ecology are assessed separately in **Chapter B7, Marine Ecology**.

B3.5.2 Wave Impacts

The widened and deepened dredge channel may potentially impact the propagation of waves towards the shoreline/s of the CSDP Project Area. The potential wave impacts were analysed using a high-resolution (25m grid) SWAN model of the Project Area. Boundary conditions for the high-resolution SWAN model were obtained from the 100m grid SWAN model covering Trinity Bay (refer **Section B3.3.3**).

Existing Case and Developed Case simulations were undertaken using the high-resolution SWAN model for the six month period from 01/01/2013 to 01/07/2013. Snapshots from the model simulation representing a typical trade-wind driven south-easterly (SE) wave case and a high-energy northerly (N) wave case (driven by Ex-Tropical Cyclone Oswald) were selected to illustrate the CSDP spatial impacts. The modelled wave fields predicted from the 100m grid SWAN model are shown in **Figure B3.5.2a** for the SE waves and **Figure B3.5.2b** for the N waves. The Existing Case, Developed Case and Impact predictions from the high-resolution SWAN model are shown in **Figure B3.5.2c** for the SE waves and **Figure B3.5.2d** for the N waves.

The snapshot model predictions indicate that the existing channel already has some localised influence on wave heights as indicated by larger wave heights on one side than the other. The channel is acting to reflect/refract some of the incident wave energy. This is particularly evident in the N wave case results shown in **Figure B3.5.2d**. The widened and deepened CSDP channel is predicted to have a slightly increased influence on the wave field. As seen in the difference plots (bottom plots in **Figure B3.5.2c** and **Figure B3.5.2d**), wave heights are slightly increased on the "incident" side and slightly reduced on the "transmitted" side of the channel. The magnitude of the wave height differences are generally relatively small (<5%) and localised to the vicinity of the channel.

Timeseries comparisons of significant wave height, wave peak period and direction at the two nearshore locations (Point 3 and Point 4 in **Figure B3.5.2b**) are shown in **Figure B3.5.2e** and **Figure B3.5.2f**. Energy weighted mean heights and directions were also calculated from the entire continuous timeseries with the results confirming that the CSDP is unlikely to have a significant impact on nearshore wave conditions driving littoral and beach system processes.

Figure B3.5.2a 100m Grid Modelled Typical South-Easterly Wave Case (09/04/2013 13:00)

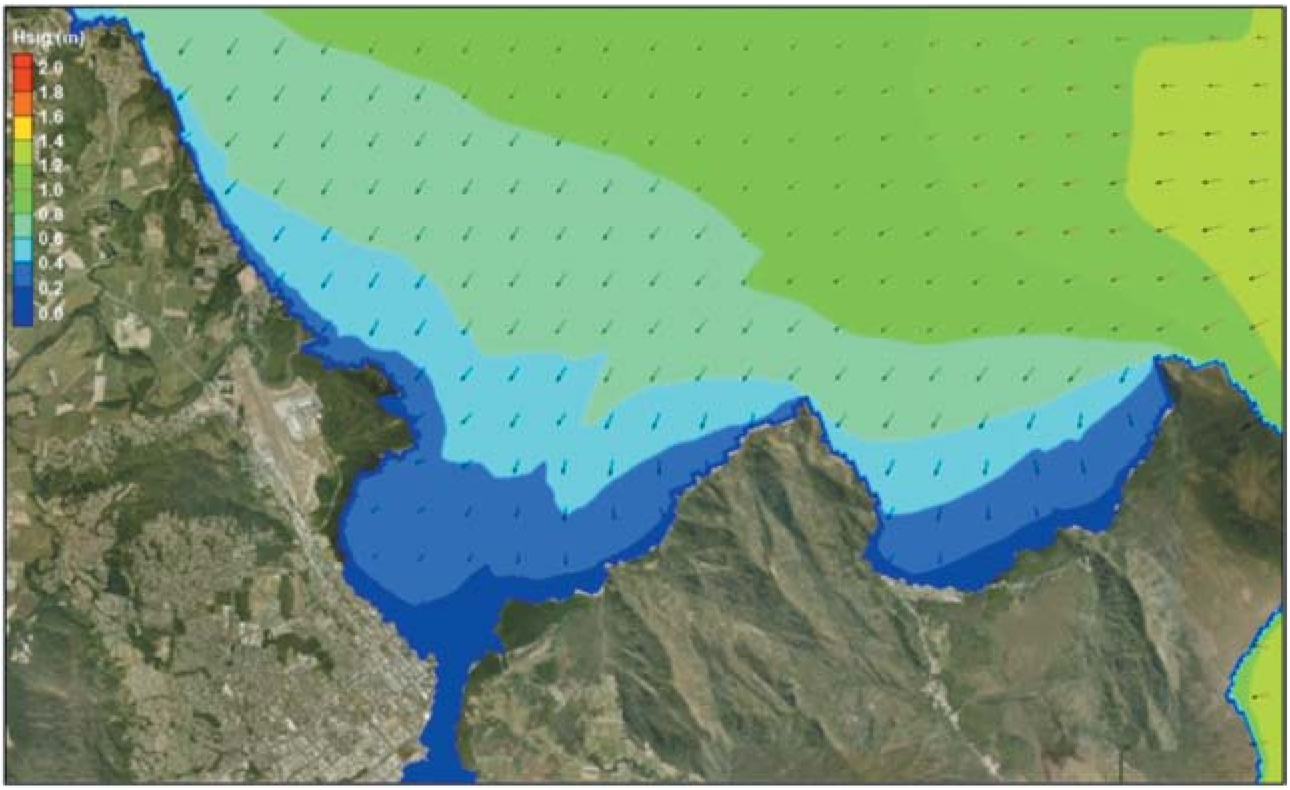


Figure B3.5.2b 100m Grid Modelled Typical Northerly Wave Case (24/01/2013 07:00)

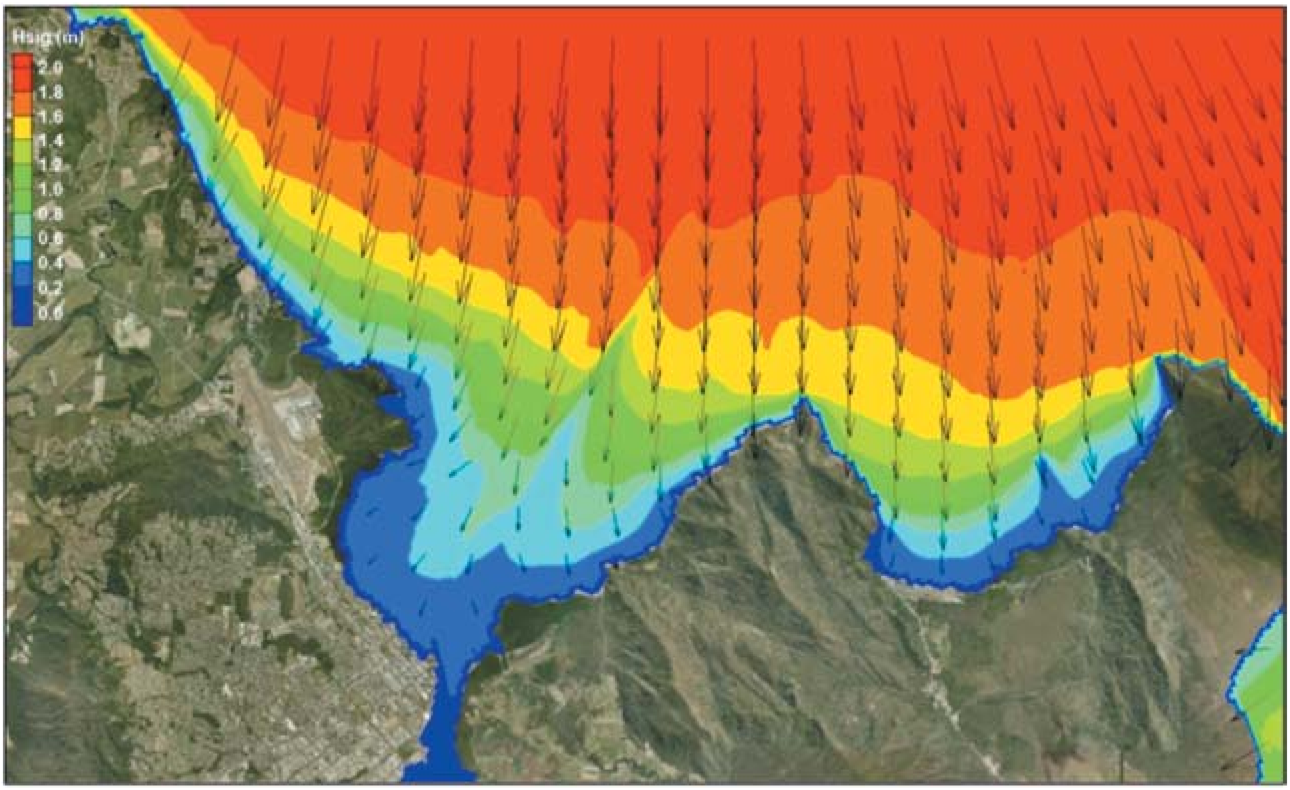


Figure B3.5.2c 25m Grid Typical South-Easterly Wave Case: Base case (top); Developed case (middle); Difference (bottom). Vectors indicate Direction; Contours indicate Magnitude

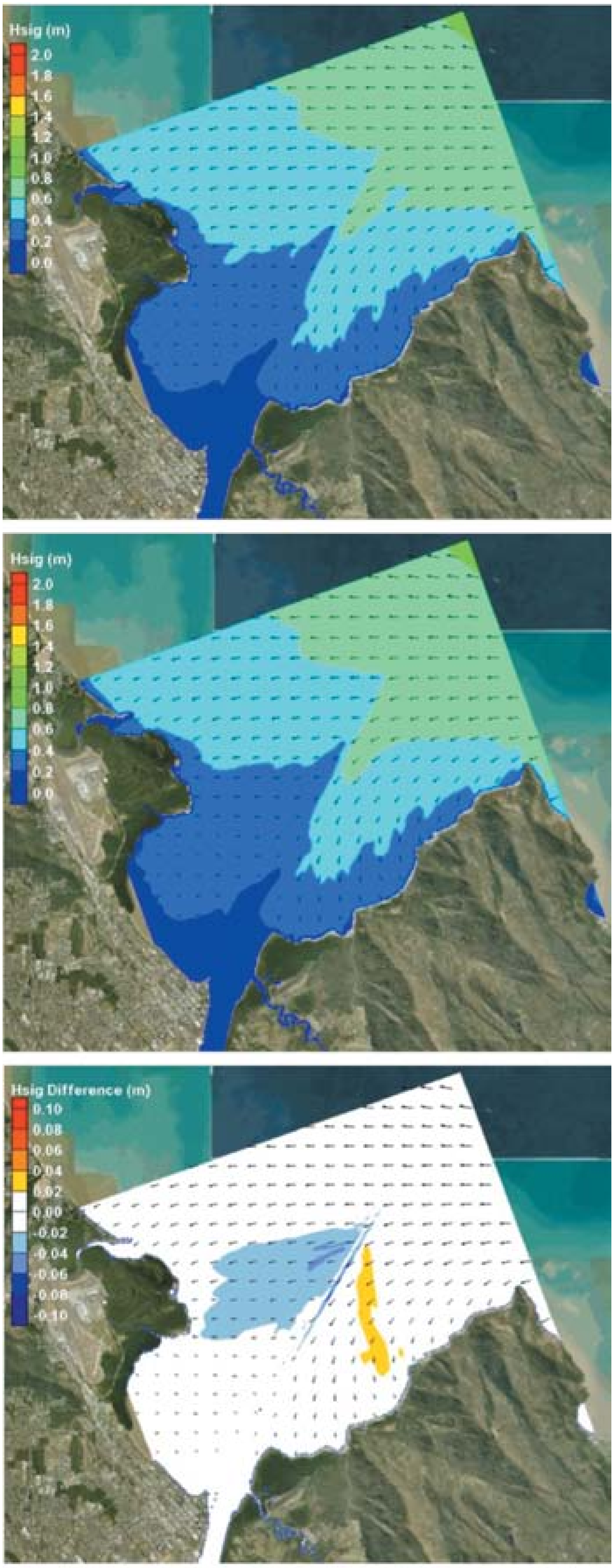


Figure B3.5.2d 25m Grid Northerly Wave Case: Base case (top); Developed case (middle); Difference (bottom). Vectors indicate Direction; Contours indicate Magnitude

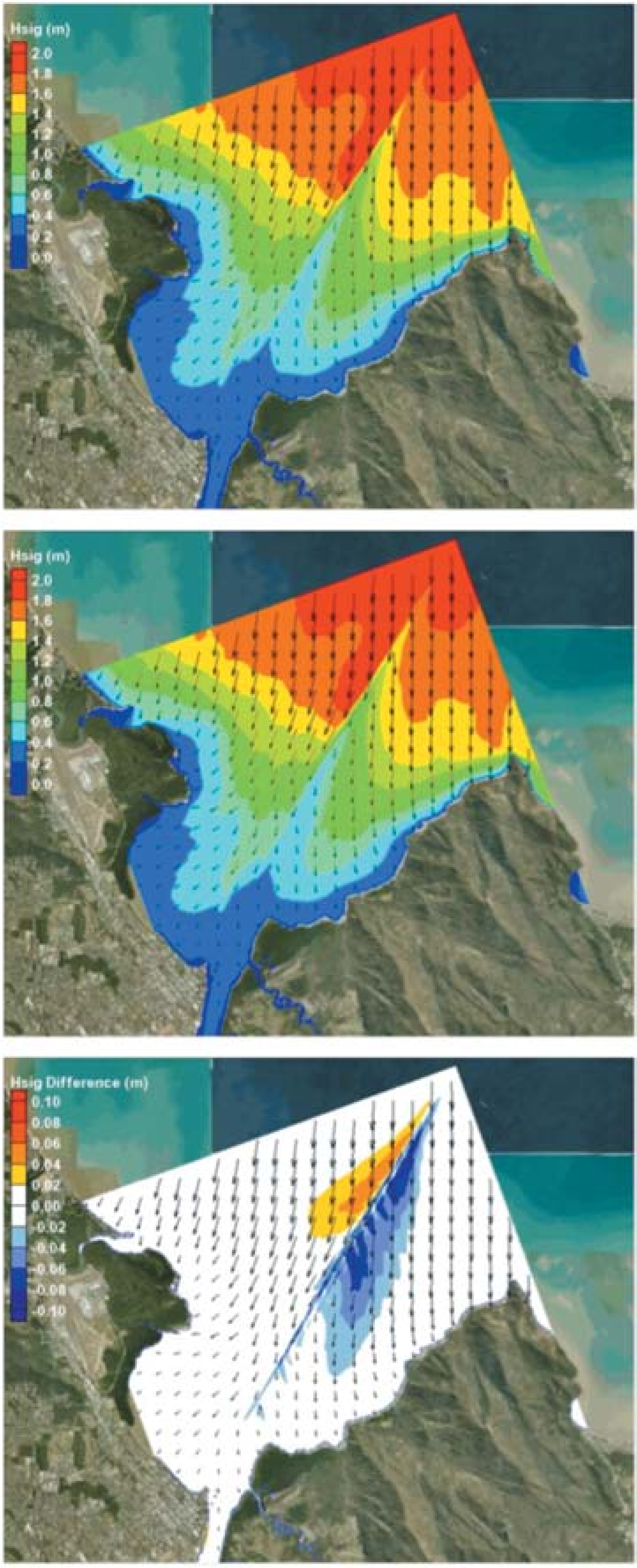


Figure B3.5.2e Existing Case and Developed Case Wave Parameter Timeseries Comparison (Nearshore Location Point 3 in Figure B3.5b)

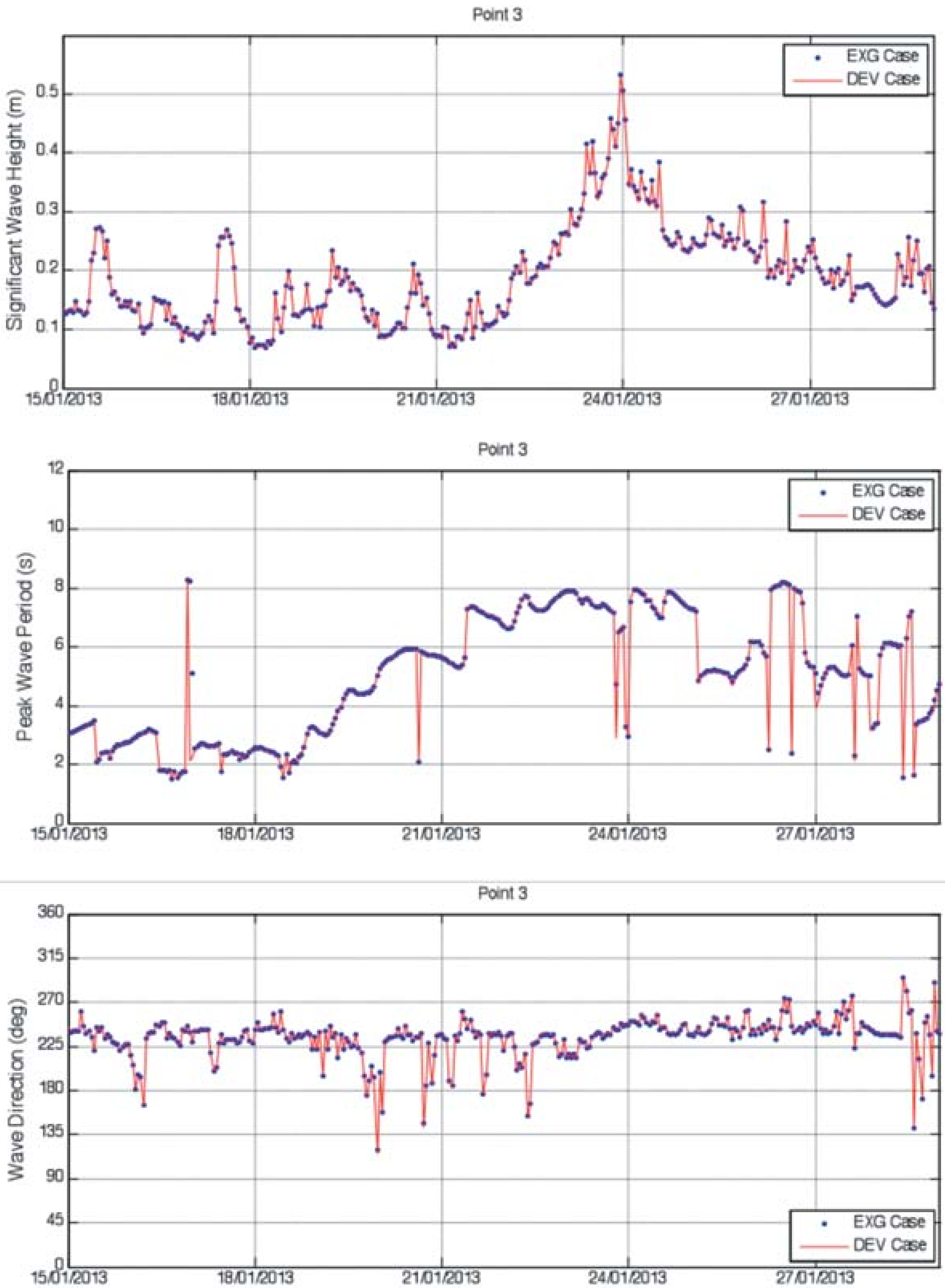
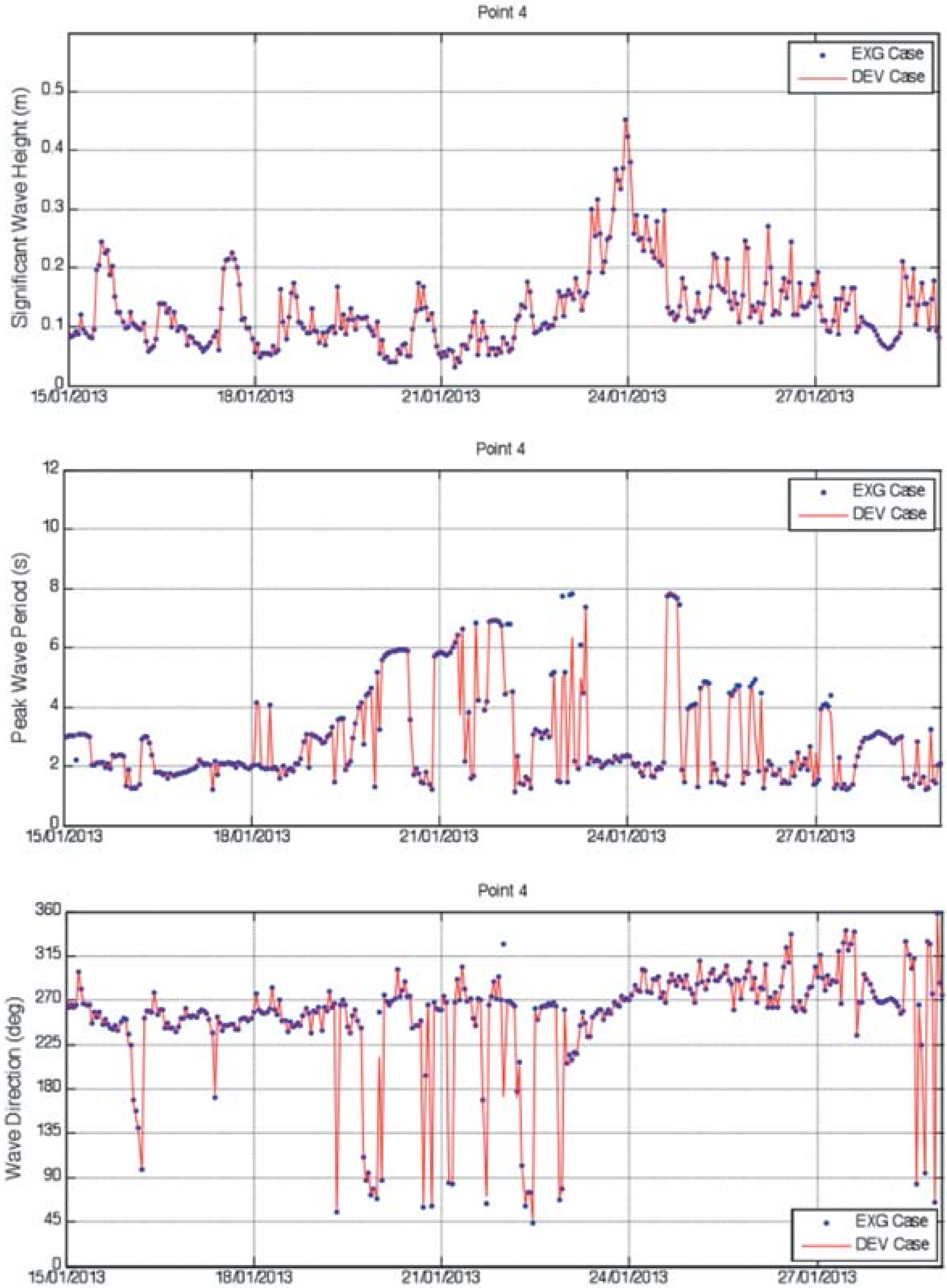


Figure B3.5.2f Existing Case and Developed Case Wave Parameter Timeseries Comparison (Nearshore Location Point 4 in Figure B3.5b)



B3.5.3 Morphology and Sedimentation Impacts

In the context of determining impacts on sedimentation processes, including siltation rates in the harbour and shipping channels, the TUFLOW FV ST model was used to simulate the re-suspension and transport of seabed material due to the action of waves and currents. This analysis was undertaken for both the Base Case and Developed Case to determine the potential impact of the Project on bed morphology and siltation rates.

B3.5.3.1 Littoral Sediment Transport and Shoreline Processes

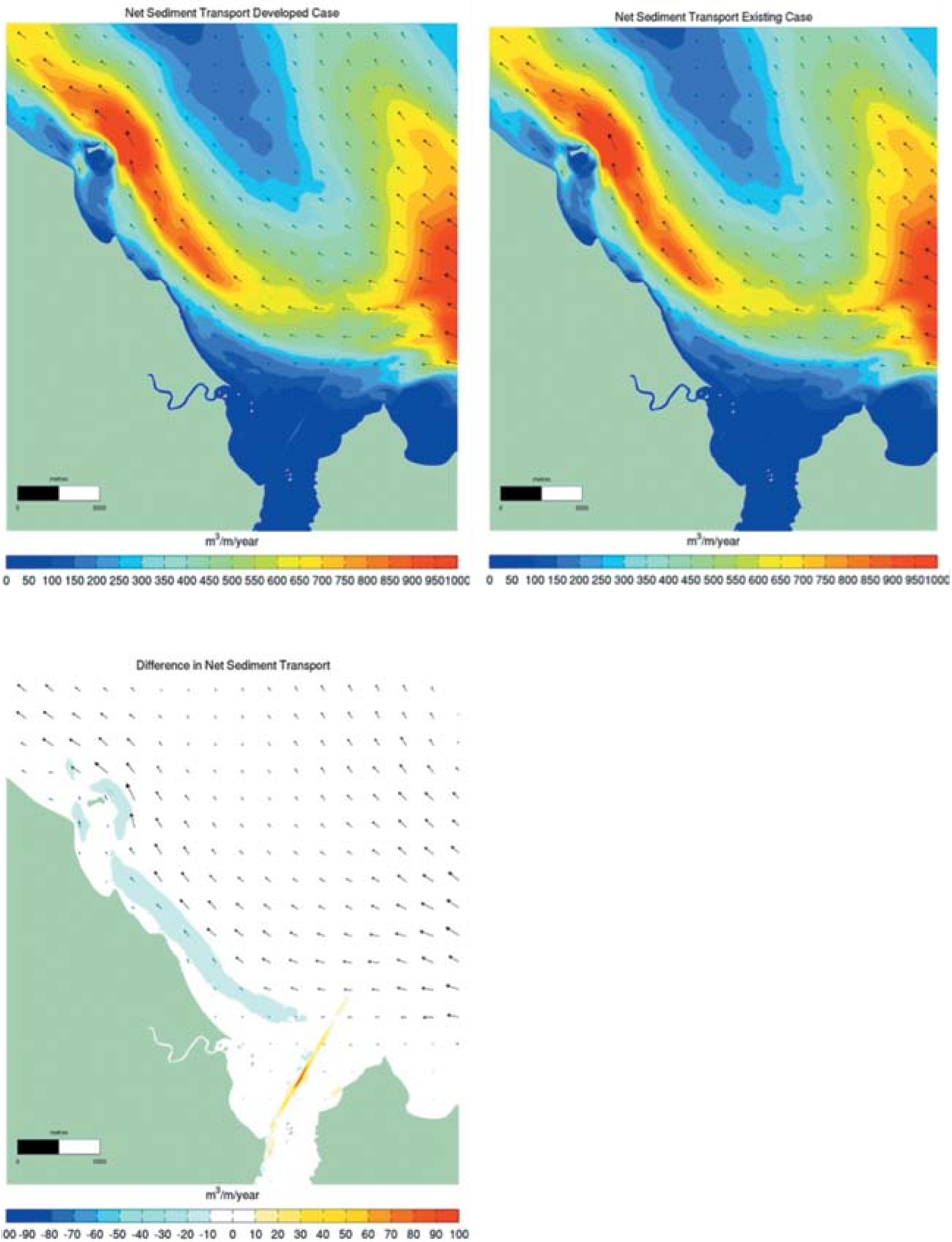
Based on the limited hydrodynamic impacts (**Section B3.5.1**) and wave impacts (**Section B3.5.2**) being restricted to the vicinity of the target dredge area, there are not expected to be any detectable impacts from the CSDP on the adjacent shorelines or littoral beach systems within the wider surrounds.

B3.5.3.2 Marine Sediment Transport

The predicted residual (net) sediment transport throughout the study area was shown earlier in **Figure B3.4.11.6e** and illustrated the net transport occurring shore-parallel in a north-westerly direction. Highest transport rates are predicted around Cape Grafton and offshore to depths approximately -8m AHD.

The base case, developed case net sediment transport and corresponding impact (difference) are shown in **Figure B3.5.3.2a**. It can be seen that the channel deepening and widening is predicted to intercept a relatively small quantity of the sediment load and therefore slightly reduce the net sediment transport to the northwest (corresponding to less than 5% change). This small reduction in fine cohesive sediment transport would not be expected to generate a perceptible morphological change either in the short or long term.

Figure B3.5.3.2a Modelled Net Sediment Transport (m³/m/year): Existing case *(top left)*; Developed case *(top right)* and Impacts *(bottom)*. Vectors indicate Direction; Contours indicate Magnitude.



B3.5.3.3 Channel Siltation

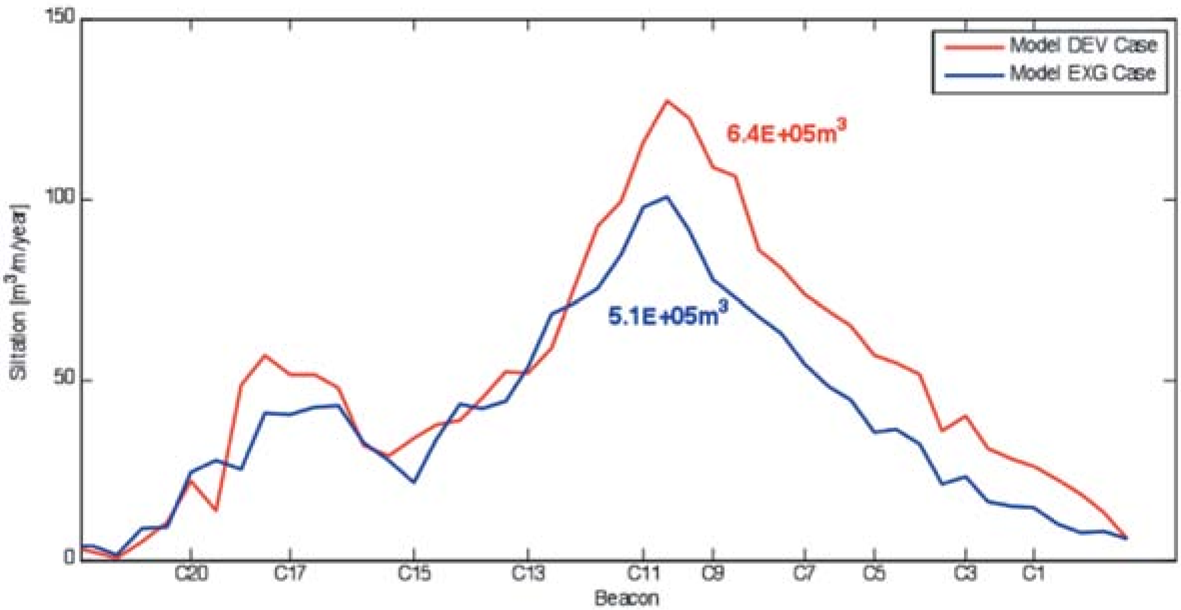
The purpose of the channel siltation impact assessment is to determine the likely percentage increase in siltation volume due to the developed case dredged channel configuration. The predicted percentage increase can then be more reliably applied to the historical siltation volumes (refer **Section B3.4.1.1**) to extrapolate the likely future maintenance dredging requirements.

The siltation impact assessment has been performed by undertaking base case and developed case simulations using the calibrated 3D HD and ST model. The developed case model bathymetry was adjusted within the channel footprint to account for the proposed channel deepening, widening and extending. In all other respects the base case and developed case models were identical. The developed case dredged channel footprint is approximately 58% larger than the existing area and is therefore expected to experience an increased volume of annual siltation requiring maintenance dredging.

The base and developed case simulations ran from the 19/02/2013 to the 27/06/2013, with net siltation calculations based on the period 04/03/2013 to 17/06/2013 to ensure that spring-neap cycle periods were equally sampled.

The base case and developed case siltation distributions are shown in **Figure B3.5.3.3a**. The developed case siltation rate and volume is predicted to be 25-30% higher than the base case. Applying this increase to the average historical siltation discussed in **Section B3.4.11**, the predicted annual average outer channel siltation volume is expected to increase to an *in-situ* volume of 410,000m^3 to 420,000m^3 (from 320,000m^3) using the upper value of the predicted percentage increase. The implications for future maintenance dredging are considered further in **Section B3.5.3.6**.

Figure B3.5.3.3a Modelled Existing Case and Developed Case Channel Siltation



B3.5.3.4 Dredge Sediment Deposition

The ST model was also used to derive sedimentation rates associated with dredge sediment dispersion and deposition. The assessment considered deposition during the base case capital dredging program, for a 12 month period following completion of the program and also for a "worst case" scenario.

The mixing of "dredge material" with the natural "ambient material" sediment fractions was included in the simulation. The change in sedimentation associated with the dredge sediments has been derived by subtracting the "ambient material" deposition from the "total" deposition which includes all ambient and dredge sediment fractions. This difference represents the influence the additional dredge sediments have on deposition rates. In accordance with GBRMPA recommendations the adopted sedimentation rate units are expressed in mg/cm^2/day.

Percentile exceedance analysis of the model results was performed using a moving 30 day period. This period was selected on the basis that it is representative of time-scales relevant to potential ecological effects to sensitive biota (see **Chapter B7, Marine Ecology**). Sedimentation plots are based on the following percentile values:

- 95th percentile = infrequent periods (occurring 5% of the time) of high sedimentation. This metric is used to identify infrequent periods of elevated sedimentation.
- 50th percentile plots = typical (median) sedimentation levels, which occur 50% of the time. This is relevant to determining typical sedimentation levels generated by re-suspension of dredge material.

The percentile plots in this assessment correspond to the most significant change in deposition over a 30 day period. The percentile values therefore represent the upper limit of impacts for the respective scenarios and correspond to exceedance durations of 36 hours (95th percentile) and 15 days (50th percentile) respectively for the 30 day window. It is important to note that a 36 hour period described by the 95th percentile is similar to the duration of typical, wind-generated turbidity and subsequent deposition events in the area.

The change in deposition associated with CSDP dredge material is presented for three scenarios:

- During the base case capital program (**Figure B3.5.3.4a**)
- Over the 12 months following completion of the capital program (**Figure B3.5.3.4b**)
- During a "worst case" period that corresponds to conditions experienced during Tropical Cyclone Yasi (**Figure B3.5.3.4c**)

It is important to note when interpreting these plots that different colour scales have been selected. A range of 10-100 mg/cm^2/day is provided for the 95th percentile plots and 1-10 mg/cm^2/day was selected for the 50th percentile plot. The assessment results indicate the following:

Base Case Capital Program

- During the base case capital program, deposition associated with CSDP dredging and placement activities occurs in the vicinity of the channel and at the DMPA. Outside of the DMPA perimeter, peak dredge material deposition rates are less than 80 mg/cm^2/day at the 95th (**Figure B3.5.3.4a** top). This corresponds to deposition of less than 1mm/day during the infrequent periods of elevated sedimentation. There are no known sensitive receptors within the predicted deposition zone
- Typical sedimentation levels during the dredging campaign, represented by the 50th percentile, are generally less than 10 mg/cm^2/day (**Figure B3.5.3.4a** bottom), corresponding to less than 0.1 mm/day within the predicted deposition zone. At the DMPA, the deposition zone aligns with the prevailing currents in a north-westerly to south-easterly direction. The additional dredge sediment deposition is considered a negligible impact in the context of the natural ambient material deposition rates.

12 months following Completion of the CSDP

- During the 12 months following completion of the CSDP capital dredging, the redistribution and deposition of dredge related sediments is only evident within the immediate vicinity of the shipping channel (**Figure B3.5.3.4b**). Re-suspension and deposition of dredge material from the DMPA is undetectable for the percentiles and ranges presented.

"Worst Case" Assessment

- The results of the "worst case" assessment suggest that minor re-suspension from the DMPA may occur during severe conditions associated with significant tropical cyclones (**Figure B3.5.3.4c**). For the simulated period that included Tropical Cyclone Yasi, dredge related material was predicted to deposit southeast of the DMPA due to the strong northerly wind and wave conditions that occurred in Cairns after the cyclone made landfall near Cardwell.
- At the "worst case" 95th percentile (i.e. over a 36 hour period), CSDP dredge sediment deposition rates of up to 40 mg/cm^2/day (~0.4mm/day) are predicted outside of the DMPA (**Figure B3.5.3.4c** top). Given the significant re-suspension and subsequent deposition of natural ambient sediment during extreme tropical cyclone events, the contribution of CSDP dredge sediments to the total deposition rate would be inconsequential.
- Very minor deposition of CSDP dredge sediments within the vicinity of the shipping channel is shown at the 95th and 50th percentiles (**Figure B3.5.3.4c**). Again, this material would be undetectable within the context of ambient re-suspension during an extreme tropical cyclone event.

Figure B3.5.3.4a Base Case Capital Program Dredge Change in Sediment Deposition Rate: 95th Percentile (top) and 50th Percentile (Bottom)

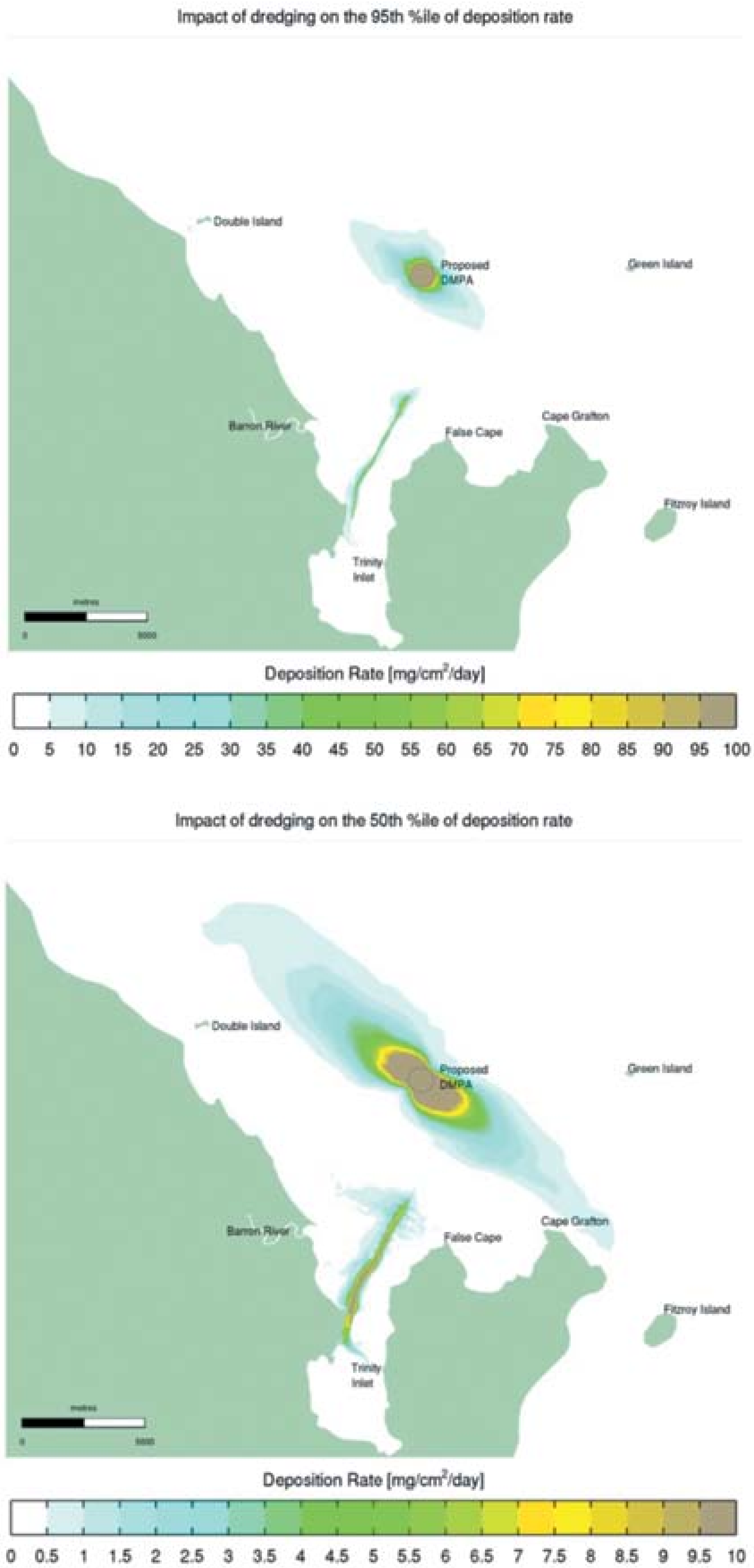


Figure B3.5.3.4b Base Case 12-month Re-suspension Change in Deposition Rate: 95th Percentile (top) and 50th Percentile (Bottom)

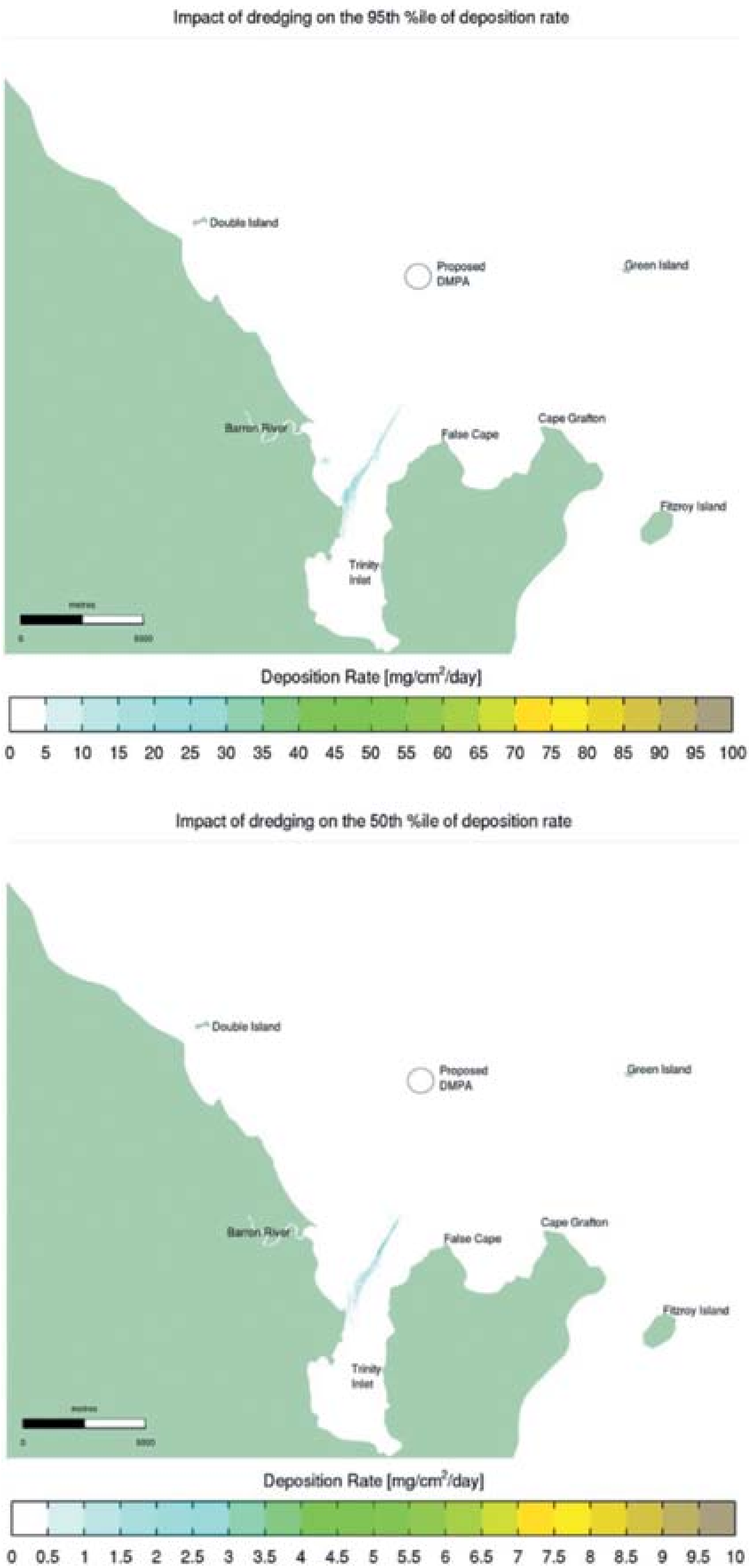
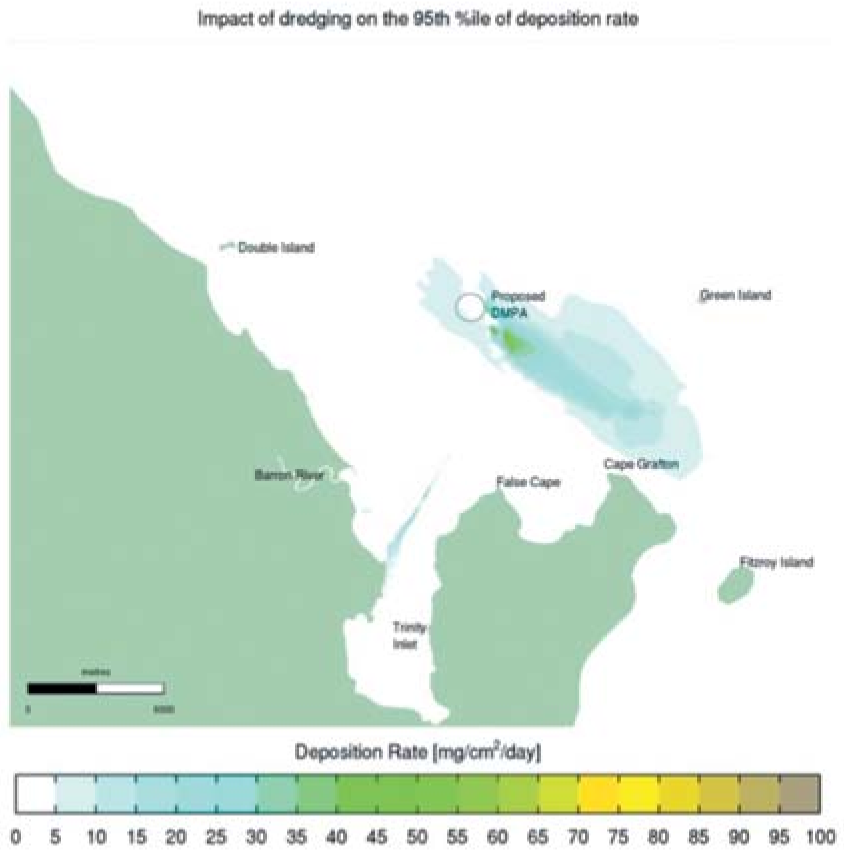
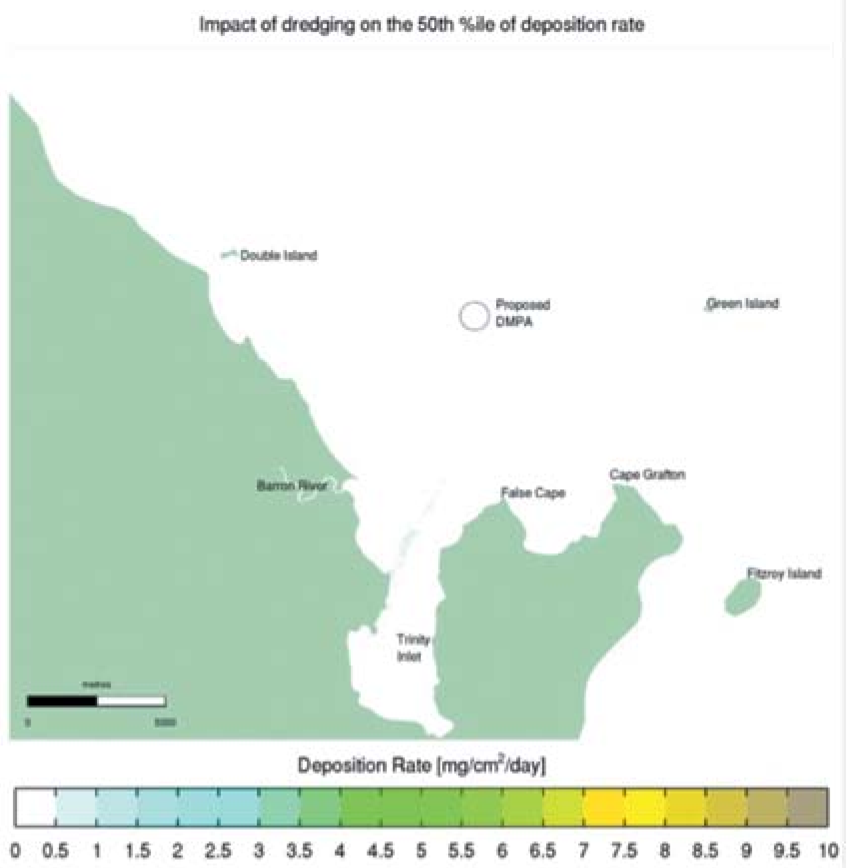


Figure B3.5.3.4c Worst Case Sediment Re-suspension Change in Deposition Rate: 95th Percentile (top) and 50th Percentile (Bottom)





B3.5.3.5 DMPA Dispersion

The quantity of material dispersed from the DMPA over a 12 month period following the completion of the capital dredge program was predicted using the ST model. This assessment only considers CSDP sediments and ignores any natural ambient material that may potentially move into or out of the DMPA perimeter. The quantity of CSDP sediments outside of the DMPA perimeter at the end of the 12 month period is relatively low, corresponding to less than 0.1% of the initial DMPA mass. These results are summarised in **Table B3.5.3.5a** and suggest a highly retentive DMPA location.

Table B3.5.3.5a Predicted Dispersion from the DMPA over a 12-month Period

Initial DMPA Mass ($x10^3$ tonnes)	DMPA Mass after 12-months ($x10^3$ tonnes)	Percentage Dispersed (%)
4338	4336	< 0.1%

The quantity of material dispersed from the DMPA during "worst case" conditions was also predicted using the TUFLOW FV model. For this assessment, re-suspension and dispersion associated with the conditions experienced during Tropical Cyclone Yasi was simulated. The quantity of material outside of the DMPA perimeter at the end of the "worst case" assessment remains relatively low, corresponding to approximately 1.1% of the initial DMPA mass. These results are summarised in **Table B3.5.3.5b**.

Table B3.5.3.5b Predicted Dispersion from the DMPA during "worst case" conditions

Initial DMPA Mass ($x10^3$ tonnes)	DMPA Mass after 12-months ($x10^3$ tonnes)	Percentage Dispersed (%)
4338	4290	1.1%

B3.5.3.6 Implications for Future Maintenance Dredging

As outlined above the widening and deepening of the channel is likely to result in an increase in annual maintenance dredging volume on the order of 80,000-100,000 m^3 per year. The existing annual maintenance dredging volume for the inner harbour (approximately 30,000 m^3 *in-situ* volume largely undertaken by grab bucket dredge *Willunga*) is not likely to change significantly as a result of CSDP as these areas do not accumulate sediment as rapidly as the outer channel.

Annual dredging at the Port of Cairns is likely to continue to be undertaken by the TSHD *Brisbane*, a similar but slightly smaller dredge vessel to that modelled as part of this CSDP. As such the frequency and duration of turbidity impacts from future maintenance are likely to be similar in nature to those presented in this EIS, albeit occurring over a much smaller duration each year which reduces the amount of material available for re-suspension.

As outlined previously in this EIS, Ports North has a 10 year permit to undertake maintenance dredging and associated at sea placement of maintenance dredging material at an approved dredge material placement site within the Great Barrier Reef Marine Park. If the CSDP proceeds, this maintenance permit will need renewing to reflect larger annual volumes required for placement at the new DMPA. In the context of this new disposal permit the following findings are relevant:

- It is proposed that placement of future maintenance material be in the new DMPA identified by the CSD project (e.g. Option 1A). This site has greater long term capacity than the current DMPA due to its depth and will likely provide adequate storage capacity for 20+ years. The existing DMPA would cease to be used following completion of the capital works and allowed to naturally rehabilitate similar to other disused sites in Trinity Bay
- As shown in the bathymetry, marine disposal sites in Trinity Bay have demonstrated a high degree of retentiveness of the dredge material placed within them over time despite the occurrence of extreme weather events. The new DMPA in water depths between 18 and 22 m has even greater retentive properties compared to the existing approved DMPA which is presently in water depths close to 11m. The material placed will stay at that location and consolidate over time similar to the behaviour shown by other DMPAs in Trinity Bay

- Current channel maintenance dredging campaigns typically occur during the months of July and August and generally take about 3-4 weeks to complete. The additional volume associated with the expanded channel will likely extend these campaigns to a period of 4-5 weeks. Chapter B5 (Marine Water Quality), discusses the water quality impacts from future maintenance dredging, noting the impacts on sensitive receptors from maintenance dredging has been assessed previously as being acceptable to regulatory agencies (as outlined in the 2005-2010 LTDSDMP and the Ports North 10 year LTDSDMP 2010-2020)
- Maintenance dredge material has similar, poor geotechnical properties to the capital dredge material (90 - 95% fine material) and has been demonstrated as part of the assessment of the Port's 10-year maintenance dredging and disposal permit that it is not a viable option to place the material on land. This reflects more recent statements within the State Party Report on the State of Conservation of the Great Barrier Reef World Heritage Area (Australia) (Australian Government 2014) which found that:
  - *'beneficial reuse and land disposal are unlikely to be viable strategies for overall management of dredge material in the long term. This is largely because much of the expected material, particularly from maintenance dredging is dominated by silts and clays'*
- As is currently the case, future maintenance dredging material must be tested periodically for compliance with the National Assessment Guidelines for Dredging. All material must be suitable for ocean disposal in terms of contamination levels before being placed at sea. The CSD project does not increase the risk of contamination of maintenance dredge sediments other than in the context of the larger channel resulting in a larger volume of sediment collected each year that needs to be removed from the channel to allow safe navigation. The potential for increased oil spills or leakages from the provision of fuel oil at the cruise berth presents a low probability risk of increasing contamination of sediments during the operational phase. These issues are discussed further in **Chapter B4, Marine Sediment Quality**
- As identified in **Chapter B7, Marine Ecology**, the benthic environment of the new DMPA does not contain habitats of significance to the Great Barrier Reef World Heritage Area or other matters of National Environmental Significance and the site itself is 10+ km away from other sensitive receptors such as nearshore seagrass and coral. In combination with the retentive properties of the site, the selected DMPA is considered the best environmental outcome for placement of maintenance material
- Placement of maintenance dredge material at the new DMPA, which is approximately 1 nautical mile in diameter with and area of 2.7 km^2, will occur in accordance with the existing practice of spreading the material evenly over the whole DMPA area. The result of this even spreading will result in a fill platform approximately 15cm per year from maintenance placement and allow rapid benthic recolonisation of the DMPA. This recolonisation process is further discussed in **Chapter B7, Marine Ecology**, noting surveys of the existing DMPA indicate that maintenance placement is not having a significant adverse impact on the benthic habitat in the long term (e.g. communities rapidly recover from temporary impacts of placement and are similar to adjoining benthic habitat areas that are not used for dredge placement).

B3.5.4 Impact Assessment Summary

The various coastal processes assessments have shown that impacts of the CSDP will not be of significance with respect to the adjacent shoreline areas. The impacts predicted using calibrated numerical models show relatively small zones of influence, typically within the immediate vicinity of the shipping channel and proposed DMPA. In reality, the magnitude of impact would not be detectable and is well within the natural, background conditions. As such, long term adverse impacts to coastal processes are highly unlikely.

The wave propagation modelling for this investigation indicates that there would be no changes in wave heights of any significance at adjacent shoreline areas associated with the proposed channel development. Under typical swell and sea state conditions, the absolute wave height levels along the adjacent shorelines within Trinity Bay are not affected.

With respect to potential impacts to the Northern Beaches, the findings of the DMPA dispersion assessments are consistent with previous studies (e.g. Carter et al., 2002) that suggest no evidence of placed dredge material reaching far field shoreline locations. The proposed DMPA location has been shown to be a highly retentive site under both prevailing and "worst case" conditions.

Specially, the modelling assessment results show that:

- Generally, impacts on tidal currents are highly localised and in the immediate vicinity of the target dredge area where some local realignment and modification of current speeds will occur
- There will be minor (unmeasurable) impact to currents and tidal flows in Trinity Bay and Trinity Inlet
- There will be no detectable increase to storm tide vulnerability to adjacent areas
- There will be minor (unmeasurable) modification to wave propagation in the vicinity of the developed channel area and no detectable impact to wave conditions at far field areas
- There will be an increase of approximately 20-30% to the annual channel siltation and maintenance dredge requirements
- Very minor dispersion from the proposed DMPA will be parallel to and distant from the coastline (consistent with previous studies relating to the existing DMPA)
- There will be no detectable impact to sediment transport pathways and beach processes.

The coastal processes impact assessments are summarised in **Table B3.5.4a** together with the anticipated risk and potential mitigation measures (where relevant). Based on the assessments, all risks to coastal processes and dredging related water quality that have been identified can be reduced to a low or medium residual risk through the application of controls inherent of the CSDP design.

Table B3.5.4a Coastal Processes Impact Assessment Summary

Coastal Processes	Initial assessment with standard mitigation (i.e. statutory compliance) in place				Residual Assessment with additional mitigation in place (i.e. those actions recommended as part of the impact assessment)			
Primary Impacting Processes	**Statutory Mitigation Measures Required**	**Significance of Impact**	**Likelihood of Impact**	**Risk Rating**	**Additional Mitigation Measures Proposed**	**Significance of Impact**	**Likelihood of Impact**	**Residual Risk Rating**
Modification to currents in the vicinity of the target dredge area	Minor impacts in vicinity of developed channel footprint; no detectable impacts to surrounding areas	Negligible	Likely	Negligible	NA	Negligible	Likely	Negligible
Detectable changes to tidal flows and water levels within Trinity Bay and Trinity Inlet	Less than 0.2% change to tidal prism within Trinity Bay and Trinity Inlet	Minor	Unlikely	Low	NA	Minor	Unlikely	Low
Increased vulnerability to storm tide flooding	No detectable increase to storm tide inundation vulnerability	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Modification to wave propagation in the vicinity of the target dredge area	Minor changes to reflection/refraction in vicinity of developed channel footprint; less than 5% change to significant wave height	Negligible	Likely	Negligible	NA	Negligible	Likely	Negligible
Detectable changes to wave conditions within Trinity Bay and Trinity Inlet	No detectable impact to wave height, period or direction to surrounding areas	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Change to shipping channel annual siltation rate and maintenance dredging requirements	Increase of approximately 25% to annual siltation and maintenance dredging requirements	Minor	Likely	Medium	NA	Minor	Likely	Medium
Change to sediment transport pathways and beach processes	No detectable impact to sediment transport and beach processes	Moderate	Highly Unlikely	Low	NA	Moderate	Highly Unlikely	Low
Long term fate of placed dredge material	Minor re-suspension during worst case scenario; no impact to known sensitive habitats	Minor	Possible	Low	Locate DMPA in deeper water to improve retentiveness	Minor	Unlikely	Low

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