Cairns Shipping Development Project

Ports North

VOLUME 2

Draft : Environmental Impact Statement

Chapter B5 Marine Water Quality

B5.1 Introduction

The Cairns Shipping Development Project (the project) is a capital dredging project in Trinity Inlet and Trinity Bay to increase the capacity of the Port of Cairns for tourism and shipping. Approximately 4.4 M m^3 of material is proposed to be dredged. The project has the potential to influence water quality within Trinity Inlet and Trinity Bay during both the construction phase and operational phases. Impacts on water quality could result from capital dredging of the existing shipping channel into Cairns port, the channel bend, swing basins and inner port. Additionally, the placement of dredge material at the dredge material placement area (DMPA) could also have water quality impacts. These influences are potentially both short term (i.e. construction) and long term (i.e. maintenance dredging and operation).

Terms of reference (TOR) for the project have been set by the Queensland Government (2012) with provisions to address marine water quality, potential impacts, mitigation and monitoring in Section 5.3.2 of the TOR. Additionally, the EIS guidelines for the project have been set by the Australian Government (2012) with provisions to address the existing environment, potential impacts, mitigation and monitoring in Section 5.9 through 5.14 of the EIS guidelines.

This chapter addresses environmental issues and impacts to marine water quality associated with the construction and operation of the project. This chapter describes the following:

- The baseline water quality of the existing marine environment in the study area
- Potential impacts on the marine water quality from:
  - Construction related – primarily capital dredging and placement activities, and also construction of wharf infrastructure
  - Operation of the port facilities focusing on accommodating an increased number of larger cruise vessels at Trinity Inlet wharves, maintenance dredging of the entrance channel, and placement of maintenance dredge material
- Options for managing and mitigating identified impacts.

It is noted that potential water quality impacts on the marine environment associated with stormwater runoff or spills from the land-based component of the project are addressed in **Chapter B6, Water Resources**.

B5.2 Applicable Legislation, Policies and Guidelines

The indicators and water quality objectives and guidelines for assessing the impact of water quality upon the environmental values (EVs) are determined (described in order of precedence) from the following legislation, policies and guidelines.

B5.2.1 Environmental Protection Act 1994 & Environmental Protection (Water) Policy 2009

The ***Queensland Environmental Protection Act 1994*** is the principal legislative basis for environmental protection within the context of ecologically sustainable development in Queensland. To achieve this aim with regards to water quality, the Act provides the ***Environmental Protection (Water) Policy 2009*** (EPP Water) and the EPP Water is the principal legislative basis for water quality management in Queensland. The EPP Water includes a process for:

- Identifying environmental values (EVs) of waterways, including both aquatic ecosystems values and human use values
- Establishing corresponding water quality objectives (WQOs) to protect identified EVs.

The EVs and WQOs for Trinity Inlet and Trinity Bay (Basin No. 111) were set by the Department of Environment and Heritage Protection (DEHP; formerly DERM) July 2010. The plan, shown in **Figure B5.3a**, covers lowland freshwater streams and the marine and estuarine environments from the tidal limits of Trinity Inlet (e.g Simmonds and Smith's Creek) to the waters of Trinity Bay (i.e. from the entrance of the Barron River to False Cape).

The EPP Water WQOs provide benchmarks for water quality through annual median values. That is annual median from monitoring data should be compared to these values.

B5.2.2 Queensland Water Quality Guidelines (2009)

The Queensland Water Quality Guidelines 2009 (QWQG) (DERM, 2009) are intended to address the need for local guidelines as identified in the ANZECC/ARMCANZ (2000) guidelines by:

- Providing guideline values (numbers) that are tailored to Queensland regions and water types
- Providing a process/framework for deriving and applying local guidelines for waters in Queensland.

The QWQG provide a mechanism for recognising and protecting local Queensland waters and are not mandatory legislative standards or WQO's. WQOs are generally reserved for the waters' schedule in the EPP Water.

The QWQG values applicable to the Trinity Inlet and Trinity Bay locality are that of the Wet Tropics region for a 'slightly to moderately' disturbed water for those constituents and waterway types the EPP Water does not address.

B5.2.3 Water Quality Guidelines for the Great Barrier Reef Marine Park

The Water Quality Guidelines for the Great Barrier Reef Marine Park (WQGGBRMP) specifically describe the concentrations and trigger values for sediment, nutrients and pesticides that have been established as necessary for the protection and maintenance of marine species and ecosystem health of the Great Barrier Reef. The guidelines address the ANZECC/ARMCANZ (2000) processes of defining environmental values and defining water quality objectives and support the following initiatives listed below:

- The Australian Government's Reef Rescue Plan, targeting improved farm management practices and supporting water quality monitoring programs
- The Australian Government's Reef Water Quality Protection Plan
- The Australian Government's Coastal Catchment Initiative (CCI)
- The Australian Government's National Water Quality Management Strategy (NWQMS).

Given the initiatives above, the guidelines ultimately provide environmentally-based values for water quality contaminants, based upon a compilation of currently-available scientific information, which, if breached, will trigger management actions, and are not for use as single point compliance triggers as part of a dredging project.

The trigger values for sediments and nutrients provided within WQGGBRMP for an enclosed coastal water body (i.e. that of Trinity Inlet and Trinity Bay) are adapted from the QWQG to facilitate a complementary system between Queensland and Australian Government water quality guidelines in the GBRMP. As the WQGGBRMP are comparable to the QWQG, reference to water quality guidelines is based on the QWQG where appropriate.

B5.2.4 ANZECC/ARMCANZ (2000) Guidelines for Fresh and Marine Water Quality

The Australian and New Zealand Environment and Conservation Council/Agriculture and Resource Management Council of Australia and New Zealand (ANZECC/ARMCANZ) Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC/ARMCANZ 2000) guidelines can be used where regional guidelines (QWQG) are not adequate or available, for example, when assessing toxicants such as metals and metalloids.

The main objective of the recent ANZECC/ARMCANZ (2000) water quality guidelines is to provide an authoritative guide for setting water quality objectives required to sustain current, or likely future, environmental values for natural and semi-natural water resources in Australia and New Zealand. The guidelines are intended to provide Government, industry, consultants and community groups with a sound set of tools for assessing and managing ambient water quality, according to designated environmental values. The guidelines similar to the QWQG were not intended to be applied as mandatory standards but do provide guidelines for recognising and protecting water quality.

With respect to toxicants (heavy metals and pesticides) in marine waters, the ANZECC/ARMCANZ (2000) guidelines provide four levels of protection for different ecosystems (80 percent, 90 percent, 95 percent and 99 percent). For Trinity Inlet and Trinity Bay which is considered to be 'slightly to moderately disturbed' the 95 percent protection is commonly applied, and as recommended by ANZECC/ARMCANZ (2000), the 99 percent level is applied for certain toxicants (e.g, cadmium) to protect vulnerable biota or to mitigate bioaccumulation.

B5.3 Description of Environmental Values, Water Quality Objectives and Guidelines

Provided in **Table B5.3a** is a summary of the relevant environmental values (EVs) as presented in the EPP Water Schedule 1 of Trinity Inlet and Trinity Bay. The WQOs and guidelines defined by the documents in Section 1.1 are in turn provided in **Table B5.3b**. Waterway types, as per the EPP Water, are presented in **Figure B5.3a**. The EVs and water quality objectives and guidelines presented are used to assist in the evaluation of existing (baseline) water quality conditions of Trinity Inlet and Trinity Bay and as an indication of the potential impact from the project.

With reference to the WQOs and guidelines summarised in **Table B5.3b** and as noted in **Section B5.2.2**, the EPP Water objectives provide the quantitative measure of performance for the EVs where applicable followed by the WQGGBRMP (2010) and the ANZECC/ARMCANZ (2000) in order of precedence. Compliance with the most generally stringent aquatic ecosystem values will ensure achievement of all EV outcomes for Trinity Inlet and Trinity Bay.

In contrast to the EPP Water WQOs, the ANZECC/ARMCANZ (2000) toxicant trigger values (TTV) for metals/metalloids are for instantaneous comparison of data. Metals/metalloids are assessed in terms of their dissolved concentrations rather than total concentrations.

Table B5.3a Trinity Inlet and Trinity Bay Environmental Values

Environmental values	Trinity Inlet and Trinity Bay – Marine & Estuarine
Educational and Scientific Use	✔
Aquatic Ecosystems	✔
Seagrass[a]	✔
Aquaculture	✔
Human Consumer	✔
Oystering[b]	✔
Primary Recreation	✔
Secondary Recreation	✔
Visual Recreation	✔
Cultural and Spiritual Values	✔

[a] Seagrass is a component of the aquatic ecosystem EV.

[b] Oystering is a component of the human consumer EV.

Table B5.3b Trinity Inlet and Trinity Bay Water Quality Objectives and Guidelines

Parameter	Units	Waterways Type: Open Coastal	Waterways Type: Enclosed Coastal	Waterways Type: Mid Estuary	Applicable Guideline
Ammonia N	µg/L	2	15	15	EPP Water (2009) - Annual median values
Chlorophyll a	µg/L	0.45	2	3	
Dissolved oxygen	% of sat	95-105	No more than 10% decrease in minimal diurnal concentration		
Filterable reactive phosphorus (FRP)	µg/L	4	7	7	
Organic N	µg/L	135	200	200	
Oxidised N	µg/L	2	20	30	
Particulate N	µg/L	20	--	--	
Particulate phosphorous	µg/L	2.8	--	--	
pH	pH units	8.15 - 8.40	7.1 - 8.2	6.5 - 8.4	
Secchi depth	m	10	> 1.2m (20th percentile)		
Temperature		--	< +2 °C Increase		
Total nitrogen	µg/L	140	250	250	
Total phosphorus	µg/L	20	20	20	
Total suspended solids	mg/L	2	Where background is < 15mg/L, no increase > 10mg/L for extended periods.		
			Where background is > 15mg/L, no increase > 25mg/L for extended periods.		
Turbidity	NTU	1	10[a]	10[a]	
Sedimentation		Daily Average = 3 mg/cm²/day			WQGGBRMP (2010)
		Daily Maximum = 15mg/cm²/day			
Faecal Coliform	CFU/100mL	Median count no greater than 150 CFU/100mL in bathing season 80% of samples less than 600CFU/100mL; min 5 samples			ANZECC/ARMCANZ (2000) Recreational WQ Guidelines

Aluminium	µg/L	0.5[b]	ANZECC/ARMCANZ (2000) Toxicant Trigger Values
Arsenic	µg/L	50.0[c]	
Cadmium	µg/L	0.7[d]	
Chromium	µg/L	4.4	
Cobalt	µg/L	1.0	
Copper	µg/L	1.3	
Iron	µg/L	300[b]	
Lead	µg/L	4.4	
Manganese	µg/L	80.0[b]	
Mercury (inorganic)	µg/L	0.1[d]	
Nickel	µg/L	7.0[d]	
Selenium	µg/L	3.0[b]	
Silver	µg/L	1.4	
Tributyltin (TBT) - expressed as Sn	µg/L	0.006	
Zinc	µg/L	15.0	
Ammonia	µg/L	460[e]	
Nitrate	µg/L	700[b]	
Cyanide	µg/L	4	
Diuron	µg/L	0.9	WQGGBRMP (2010)[d]
Simazine	µg/L	0.2	
Atrazine	µg/L	0.6	
Hexazinone	µg/L	1.2[b]	
Ametryn	µg/L	0.5	
Chlorpyrifos	µg/L	0.0005	
Endosulfan	µg/L	0.005	
DDE	µg/L	0.0005[b]	
Tebuthiuron	µg/L	0.02b	

[a] Queensland Water Quality Guidelines (2009). Department of Environment and Resource Management, Queensland Government.

[b] Marine TTV of low reliability; indicative guideline only

[c] Based on more stringent recreational guideline value

[d] Based on the 99 percent protection level to protect against chronic toxicity to related species and bioaccumulation

[e] New ammonia TTV based on Batley and Simpson (2009)

Figure B5.3a Trinity Inlet and Trinity Bay Water Way Types

Legend

- Mid-Estuary
- Lower Estuary Enclosed Coastal
- Open Coastal

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ARUP

BMT WBM

Job Title: Cairns Shipping Development Project Environmental Impact Statement

Map Title: Trinity Inlet and Bay Water Way Types

Kilometers: 0, 2, 4

Scale at A4	Map Status
1 : 95,110	Final

Coordinate System: GDA 1994 MGA Zone 55

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

Job No	Figure No
230377-00	B5.3a

B5.4 Existing Environment

This section provides a summary of the general water quality conditions and available water quality data in the project study area below the tidal limit. The study area for marine water quality includes Trinity Inlet and the coastal waters of Trinity Bay extending east to Cape Grafton and north to Double Island (refer to Figure B5.4.4a). Previous studies, monitoring campaigns and literature were used to characterise the existing water quality and determine baseline levels for impact assessment. In this sense (and where possible), the water quality components within this baseline assessment were aimed at identifying the plausible linkages (i.e. tides, currents, rainfall, etc) of the existing water quality regime, based on present knowledge.

This baseline assessment has provided water quality results and information on heavy metals, turbidity, suspended sediment, dissolved oxygen, nutrients and oil in water. Where appropriate this assessment has compared baseline results with applicable guideline values.

B5.4.1 Overview

The Port of Cairns and the shipping channel are located in Trinity Inlet and Trinity Bay. The Great Barrier Reef is approximately 25-30 km offshore to the northeast. There are some freshwater inflows that drain into Cairns harbour, and Trinity Inlet is fed by numerous freshwater creeks which drain small catchments, including Smith's Creek, Skeleton Creek, Redbank Creek, and also Chinaman's Creek and Fearnley St Drain, which contribute urban and industrial inputs. The Barron River feeds into the north western region of Trinity Bay.

The Barron River catchment is 2,150km^2, (Barron and Haynes 2009) approximately the size of the Calliope River in Gladstone and the Ross River in Townsville (Milliman and Farnsworth 2011). The catchments draining directly to Trinity Inlet are approximately 340 km^2 in total area (Barron and Haynes 2009). While the combined catchments are 46 percent natural forest, 29 percent of the land is used for grazing and 13 percent for crops including sugarcane, and seven percent urban. Sugarcane crops comprise approximately 26 percent of the Trinity Inlet catchment land use.

Trinity Inlet and Trinity Bay are naturally turbid environments (**Figure B5.4.1a**), especially following periods of high rainfall and sustained winds and currents which resuspend seabed sediments. As a result, naturally occurring turbid plumes are a regular feature of the marine environment. An example of a turbid plume is shown in **Figure B5.4.1b**, which shows a turbid plume in Trinity Inlet resulting from freshwater discharge from Hills Creek (East Trinity).

Water quality is an important environmental asset in the study area and surrounds due to the presence of a number of ecological receptors that are sensitive to water quality conditions (**Chapter B7, Marine Ecology**). These sensitive receptors include seagrass meadows that are located throughout Trinity Inlet and Trinity Bay, as well as fringing coral communities near Cape Grafton (east), Double Island (northwest) and offshore reefs (northeast). The historical and current conditions of these ecological assets are discussed in **Chapter B7, Marine Ecology**.

Figure B5.4.1a Naturally Turbid Marine Environment of Trinity Inlet and Trinity Bay

Figure B5.4.1b Naturally Occurring Turbid Plumes in Trinity Inlet resulting from Freshwater Discharge from Hills Creek, East Trinity

B5.4.1.1 Sediment and Pollutant Sources

Sediment and nutrient fluxes into Trinity Inlet and Trinity Bay continuously occur due to tidal flushing and riverine discharge of catchment related runoff associated with (sometimes cyclonic) rainfall events between November and May (Barron and Haynes 2009). The plumes can extend into the Great Barrier Reef lagoon varying according to size and dynamics of the flood event (GBRMPA 2001). Catchment inflows and urban stormwater runoff also introduce metals and organic pollutants, such as pesticides, into the surrounding waterways (Mitchell et al 2006).

Hateley et al (2009) estimated through modelling that the Barron River delivers approximately 44,000 tonnes of sediment per year (t/yr) to Trinity Bay, while Trinity Inlet catchments deliver 19,000 t/yr. However as indicated in Coastal Process Chapter B3 (refer table B3.4.11a), modelled results appear to be a significant under-estimate of the actual Barron River annual sediment loads which have been recorded through physical measurements of between 163,000 t/yr and 396,000t/yr for the period of 2007-2011. Of total nitrogen and phosphorus, Hateley *et al* (2009) predicted loads of 1,400 and 230 t/yr, respectively, are delivered to Trinity Inlet and Trinity Bay from the Barron and Trinity catchments. A photo of the Barron River discharging into Trinity Bay is shown in **Figure 5.4.1.1a**.

Anthropogenic sources of sediment and turbidity include urban runoff and dredging activities. The key water quality issue related to dredging activities is the generation of turbid plumes. Additional sources of pollutants within Trinity Inlet and Trinity Bay and surrounds include:

- Two sewage treatment plants, the Southern STP (19.4 ML/day) and the Edmonton STP (6.7 ML/day) discharge to Trinity Inlet and provide a constant source of nitrogen and phosphorus to that waterway (Cairns Regional Council [CRC] 2013)
- If not appropriately managed, boating and shipyard activities have potential to release petroleum-based pollutants, anti-fouling leachates, litter and some organic waste (Mitchell et al 2006)
- Urban stormwater flows that discharge into the port area via constructed drains that may contribute gross pollutants, along with dissolved and particulate contaminants.

Figure B5.4.1.1a Barron River discharging into Trinity Bay

B5.4.1.2 Seasonality

Sediment transport within Trinity Bay is primarily affected by seasonal wind regimes, diurnal currents, and tropical cyclones (Carter *et al* 2002). Southeast trade winds in the winter and north and northeast winds during the summer are also accompanied by a daily easterly coastal breeze. These processes and movements cause bed re-suspension of mud and result in high background turbidity (Carter *et al* 2002). These forces are also strong enough to create currents (>0.20 cm/s) that can mobilise sediment particles as coarse as sand at the seabed.

During typical weather conditions, under which south-easterly winds prevail, sediments generated from the Barron River settle out uniformly coarse-to-fine sediments relative to the distance from the entrance. Variable summer winds from the north and northeast are seen to result in counter clockwise circulation of sediment transport to the east and south with fine and some coarse sediments depositing within Trinity Inlet and as far east as False Cape and Cape Grafton (Carter *et al* 2002).

Because of these divisions of seasonal wind and rain regimes, the data used for this baseline characterisation were divided into two distinct seasons, where practical. Based on the seasonal occurrences of the wind regimes and rainfall data, the seasonal division will be as follows:

- Wet season will consist of the months of November to April. Monsoonal troughs, cyclones and a majority of the median annual rainfall (87 percent) occurs during these months (Cairns Airport; BoM 2013; Carter *et al* 2002; Devlin *et al* 2012)
- Dry season will consist of the months of May through October. Subtropical ridge formation with southeast trade winds are predominant through these months (BoM 2013).

These ocean/coastal and sediment transport processes are more thoroughly described in **Chapter B3, Coastal Processes**.

B5.4.2 Data Sources

The key existing studies identified as most applicable in characterising baseline water quality are discussed below. The locations of these monitoring sites per each study are presented in **Figure B5.4.4a**.

- Cairns Shipping Development (CSD) Project EIS, BMT WBM Coastal Data Collection (February 2013-February 2014) – This data set comprises a significant portion of the main body of information from which baseline conditions, particularly suspended sediment and turbidity, have been established. Overall, this data set consists of 12 months collection at some locations, with some sites discontinued after six months. For February 2013 through August 2013, these data were collected at three sites along the channel and two in the region of the DMPA. For September 2013 through February 2014, data were collected at one location within the shipping channel and one at the DMPA (Figure B5.4.4a). These data include:

- Static seabed water level, current, wave, turbidity, temperature and conductivity measurements
- Water quality grab samples for Total Suspended Sediments (TSS) (at various depths), metals (surface and bottom) and nutrients (surface and bottom). These samples were collected in both wet and dry seasons, and during spring and neap tides
- Current, water level, turbidity temperature and conductivity transects.

- Further information in regard to the Coastal Data Collection program is provided in **Appendix D3, Coastal Data Collection Report**
- CSD Project EIS, BMT WBM Water Quality Monitoring Program (July 2013 to July 2014) – This additional water quality data was collected in support of the project, and intended to provide information to the EIS at six additional sites not covered in the Coastal Data Collection (Figure B5.4.4a). This data set consists of 12 months of continuous turbidity and some physico-chemical measurements, along with grab samples of total and dissolved metals, nutrients and TSS taken during both wet and dry seasons and during spring and neap tides. The monitoring sites were chosen in consultation with State and Federal Government agencies, and were chosen because:
    - They are located at sensitive receptors where potential impacts (above background) could occur from dredging and placement
    - They allow for development of site specific water quality trigger values as part of the Dredge Management Plan (e.g locally derived values for determining acceptable impacts from turbidity on water quality)
    - They are appropriately located for compliance monitoring during capital dredging

Additionally, routine profiling of four deep water sites located between the DMPA and the offshore reef areas was undertaken during equipment servicing trips. Further information in regard to the Water Quality Monitoring Program is provided in **Appendix D3, Coastal Data Collection Report**.

- Ports North (Formerly the Cairns Port Authority, CPA; 1995–2007 then Ports North 2007-2013) data – Water quality monitoring program extending back to 1995 for some constituents, represents more than 17 years of data. These data were primarily collected within Trinity Inlet; however, there were some older data that characterise water quality within the shipping channel to its current extents (Figure B5.4.4a). These data do not represent continuous monitoring (as do some of the coastal data collection and water quality monitoring data), however, the period of records for this data is extensive so as to capture seasonal and more long-term climatic influences
- James Cook University (JCU; 2013-2014) – Monitoring of photosynthetically active radiation (PAR) since February 2013 (ongoing) by James Cook University at four intertidal sensitive receptor (seagrass) locations within Trinity Bay. Additionally, two sub-tidal locations have been monitored, one at the DMPA between February 2013 and February 2014, and one at water quality monitoring site 3 adjacent to the channel (Trinity Bay) between October 2013 and July 2014 (**Figure B5.4.4a**)
- Rainforest and Reef Research Centre (RRRC; 1995-2012) – Data which include marine water quality measurements collected from 1995 to present; however, there were some significant periods during which it was not collected. It is noted these data were not undertaken in a comprehensive seasonal monitoring program; rather they are representative of opportunistic monitoring of plume water quality in association with large catchment inflows from cyclones. Additionally, these data have been synthesised into regions of flood plume types which define regions of frequency and level of pollutant exposure.

It should be noted that monitoring data collected during times of dredging (including maintenance dredging undertaken between 21 July 2013 and 17August 2013) were quarantined from the data sets because they represent conditions monitored during dredging operations and would not represent background conditions. This quarantined data represents approximately eight percent of the data set.

B5.4.3 Water Quality Data Divisions

The water quality monitoring locations for the previously listed programs and studies are presented in **Figure B5.4.4a**. The data were collated and consolidated by sampling location. Sampling locations were grouped into six principal areas (**Figure B5.4.4a**) with a few sub-regions delineated by both geographical features and the pertinent waterway types and applicable water quality objectives. The delineated areas include:

- Region 1 - Trinity Inlet:
  - Middle estuary
  - Lower estuary.
- Region 2 – Inner Cairns Harbour:
  - Enclosed coastal
  - Open ocean.
- Region 3 - Open ocean, outer Cairns harbour, including False Cape
- Region 4 - Open ocean, DMPA
- Region 5 - Northern Beaches
- Region 6 - Far eastern harbour, which includes a conservation park zone and the Cape Grafton WQ monitoring location.

It is noted that some regions (1 and 2) are divided strictly along the lines where applicable water quality objectives and geographical features distinguish one from another (i.e. Trinity Inlet and inner Trinity Bay). Beyond those regions, however, these features are less strictly applied and are based on the locations of the monitoring regions and general geographic features. These regions were adopted to characterise baseline conditions specifically where needed. They are general so as to provide a sufficient amount of spatial resolution to the data without being overly specific.

Water quality data were divided into six general groups of parameters:

- Physico-chemical.
- TSS and turbidity
- Photosynthetically Active Radiation (PAR)
- Metals
- Nutrients
- Oil and grease.

Due to the spatial, seasonal and temporal coverage of the previously listed data sets, not all sites and regions could be represented for each parameter. **Table B5.4.3a** presents the primary data source(s) used to characterise background for each parameter ground and for each region.

Table B5.4.3a Water Quality Data Primary Source Matrix

Region	Physico - Chemical	Turbidity - TSS	PAR	Metals	Nutrients	Oil and Grease
1a	3	3	no data	3	3	3
1b	3	1, 2 & 3	no data	3	3	3
2a	1	1, 2 & 3	4	no data	3	no data
2b	1	1, 2 & 3	4	2	3	no data
3	1	1, 2 & 3	no data	2	3	no data
4	1	1	4	no data	no data	no data
5	2	2	no data	2	2	no data
6	2	2	no data	2	2	no data

1 - CSD Project EIS, Coastal Data Collection (wet and dry season)

2 - CSD Project EIS, WQ Monitoring (wet and dry season)

3 – Ports North WQ data (1995-2013)

4 - James Cook University (2014) - PAR data

B5.4.4 Suitability of Baseline Data

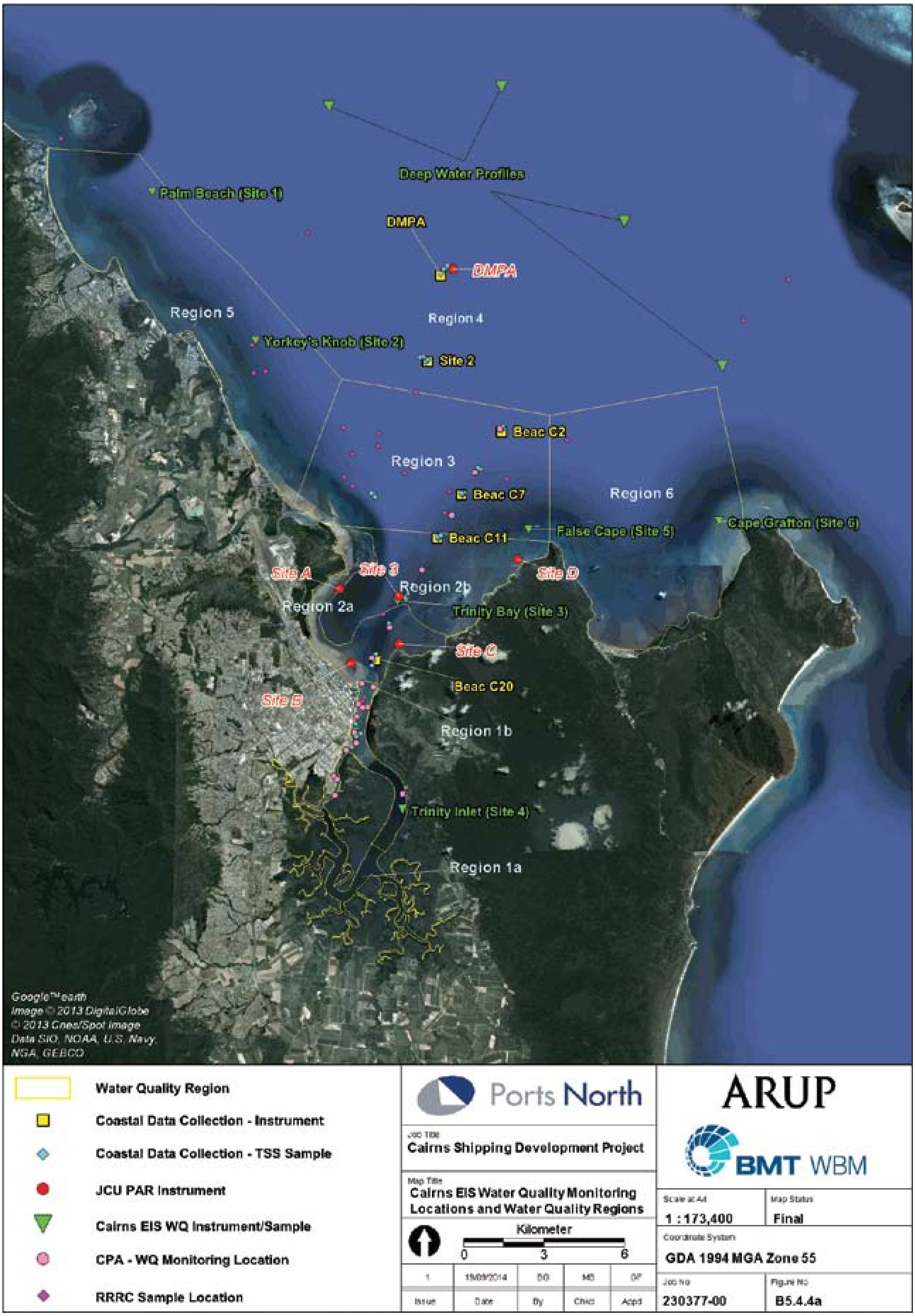
Under the Queensland TOR, water quality data requirements must account for seasonal (i.e. wet and dry seasons) and tidal variation. The EIS Guidelines also outline the need for collection of water quality data at sensitive receptor sites (such as seagrass and coral communities) that could be affected by the dredging and placement.

The baseline data sets are sufficient to meet the TOR and EIS Guidelines because:

- The Coastal Data Collection provides an uninterrupted 12-month coastal and water quality data set for model calibration purposes and assist to capture any storm events and/or freshwater flows during the 2013/14 wet season
- The Water Quality Monitoring Program provides 12 months (July 2013 to July 2014) of continuous turbidity measurements at sensitive receptors to use as part of baseline characterisation, impact assessment, and the development of trigger values
- The other (secondary) data sets are used for constituents which are not included in the primary data sets (e.g oil and grease), or to provide historical, seasonal, and climatic context to the primary data sets.

It should be noted the Queensland and Federal Governments were consulted in the development of the baseline monitoring program for the project.

Figure B5.4.4a Cairns Shipping Development Project EIS Water Quality Monitoring Locations and Water Quality Regions

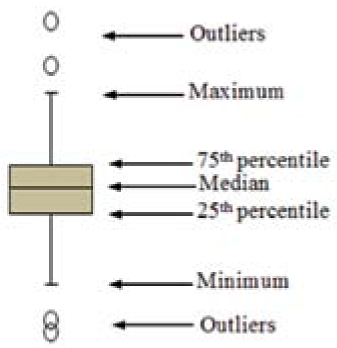


B5.4.5 General Physico-Chemical Characteristics

Physico-chemical parameters that comprise the baseline characterisation for water quality within Trinity Inlet and Trinity Bay and surrounds are:

- Salinity
- Temperature
- pH
- Dissolved oxygen (DO) expressed as a percentage of saturated DO.

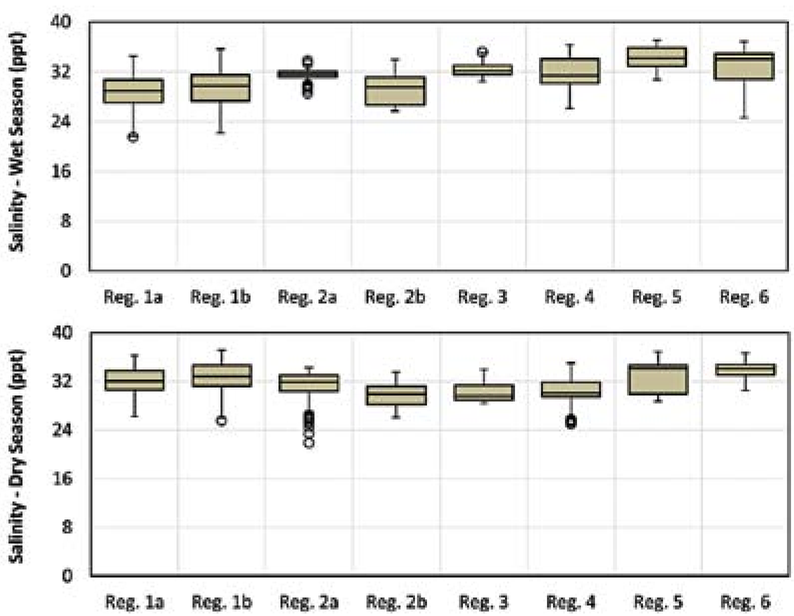
The figures in the subsections below present box and whisker plots for each of these parameters. These box and whisker plots present a convenient way of graphically depicting groups of numerical data through their five-number summaries: the smallest observation (sample minimum), lower quartile (Q1 or 25th percentile), median (Q2 or 50th percentile), upper quartile (Q3 or 75th percentile), and largest observation (sample maximum). A boxplot may also indicate which observations, if any, might be considered outliers. Boxplots display differences between populations without making any assumptions of the underlying statistical distribution: they are non-parametric. The spacing between the different parts of the box helps indicate the degree of dispersion (spread) and skewness in the data, and identify outliers.



B5.4.5.1 Salinity

Seasonal salinity is typically lower during the wet season closer to Trinity Inlet, likely because of the influence of freshwater inflows. For the wet season, salinity increases farther from Trinity Inlet. Region 1 is represented by the Ports North data, Regions 2 through 4 by the Coastal Data Collection and Regions 5 and 6 by the Water Quality Monitoring Program.

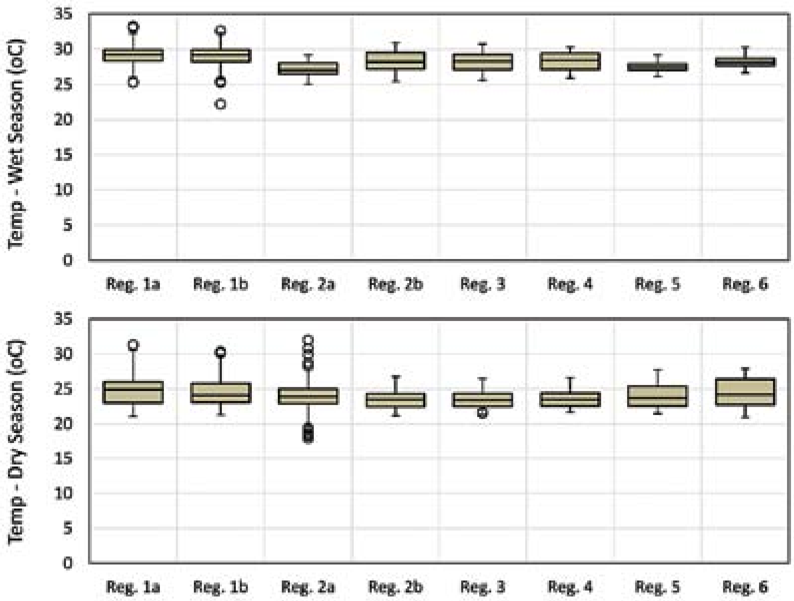
Figure B5.4.5.1a Seasonal Salinity Box and Whisker Plots



B5.4.5.2 Temperature

Water temperature remained relatively constant throughout the area, slightly decreasing toward the open ocean, especially during the dry season. Dry season temperatures were approximately 4-5°C less from site to site.

Figure B5.4.5.2a Seasonal Temperature Box and Whisker Plots

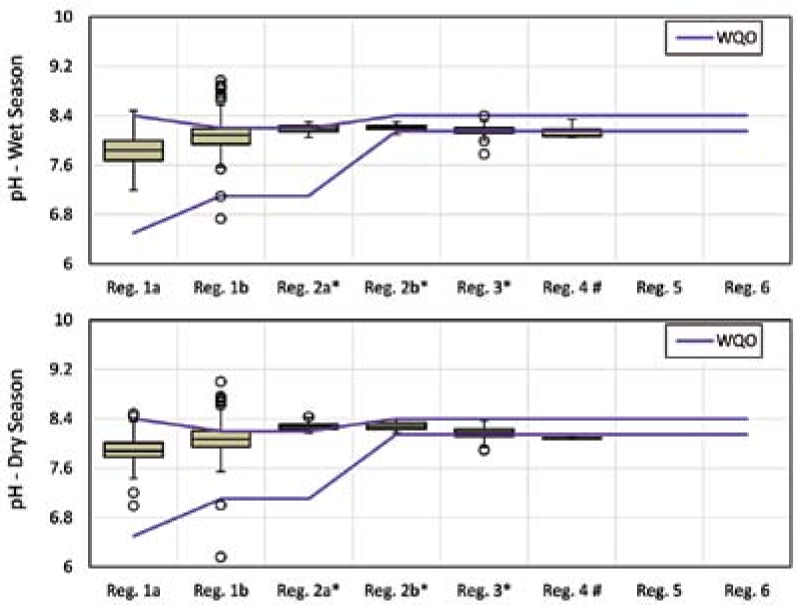


B5.4.5.3 pH

Trinity Inlet and Trinity Bay pH levels increased with increased connection with the open ocean. This is likely due to the influence of more acidic conditions of catchment flows and acid sulphate soils (Mitchell et al 2006) and because of the basic nature of oceanic water. Of particular interest with these data is the wide variability of pH within region 1b. These data are indicative of both inlet and open ocean, however, there are values observed at the sites of that location that are likely due to anthropogenic causes, including the influence of acid sulfate soils (ASS), as this behaviour is not replicated within any of the other regions. Nevertheless pH was generally compliant with the WQO with the exception of region 2a during the dry season, where the median pH value is slightly elevated above the WQO. Analysis of the spatial and temporal trends of the data did not reveal an obvious pattern or cause for this.

It should be noted the WQO for pH are different for some regions because they are within different waterway types (e.g., enclosed coastal versus mid estuary).

Figure B5.4.5.3a Seasonal pH Box and Whisker Plots

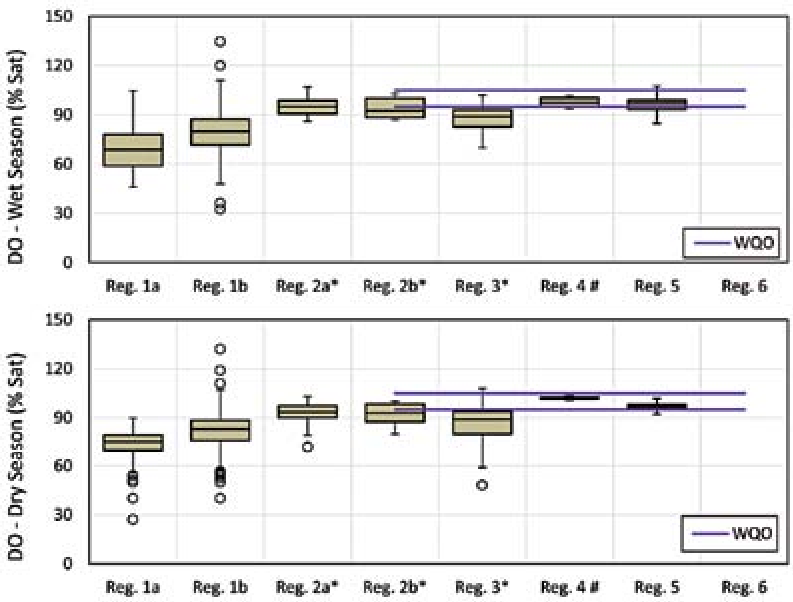


B5.4.5.4 Dissolved Oxygen

Dissolved oxygen (DO) typically increased with improved connection to the open ocean. Even with increased DO in Trinity Bay (Regions 2b and 3), DO concentrations were less than the minimum DO WQO. Low DO in Trinity Inlet (Regions 1a and 1b) was likely due to chemical oxygen demand associated with metals mobilisation from acid sulphate soils (Mitchell *et al* 2006), organic nutrient loading (Worley Parsons 2010) and limited tidal flushing. In a manner similar to pH, DO variability in region 1b was greater than that observed within the other regions. Analysis of the spatial and temporal trends of the data did not reveal an obvious pattern or cause for this.

It should be noted the WQOs for these figures do not extend across all regions because there is no applicable numeric WQO for those regions (see **Table B5.3b**). For DO within the enclosed coastal and mid-estuary regions, the WQO is assessed in terms of the change in DO levels.

Figure B5.4.5.4a Seasonal Dissolved Oxygen Box and Whisker Plots



* pH data from PortsNorth(1995-2013) data used. Limited Coastal Data Collection or EIS pH data available

Deep Water Profiling data used for Region 4

B5.4.6 Turbidity and Total Suspended Sediment (TSS)

TSS and turbidity have been studied extensively in Trinity Inlet and Trinity Bay. TSS and turbidity is of particular relevance to the project due to capital dredging and on-going maintenance dredging required in the development area and the potential impact upon sensitive ecological habitats (outlined in further detail in **Chapter B7, Marine Ecology**).

B5.4.6.1 Historical Background and Seasonal Effects on Turbidity

There is anecdotal evidence that turbidity and TSS within Trinity Inlet and Trinity Bay has changed over the last few decades. Over the past 100 years, much of the forest, coastal vegetation and wetlands in this region have been modified to allow urban, industrial and agricultural development. Coastal rivers now increasingly bring eroded sediment to settle as mud in the estuaries, coastal shallows and on inshore reefs (Mitchel et al. 2006).

Trinity Inlet and Trinity Bay frequently experience naturally high suspended sediment concentrations (20-200mg/L) driven primarily by south-east trade winds during the dry season, north and north-east winds (15-25 knots) and tropical cyclones during the wet season (Carter et al 2002). During the dry season, the wind, current and wave climates drive seabed mud re-suspension. Some currents are sufficient (greater than 0.2 m/s) to move sediment as coarse as sand (Carter *et al* 2002).

During the wet season, sediments from the Barron River are deposited at various locations within the bay depending on the sediment particle size. In particular, coarse sediment grain sizes tend to settle out near the Barron River entrance, shoreline channels or along the beaches. Finer sediment particles settle out within mangroves or within the centre of Trinity Bay (Carter *et al* 2002).

Figure B5.4.6.1a shows the effects of currents and wind on sediments in the vicinity of Trinity Bay. Wind and current measurements taken at Green Island (north-east of Cairns) were plotted against TSS concentrations at three locations along the northern beaches from Double Island to south of Yorkeys Knob. In particular, TSS appears to be strongly correlated to currents along with wind speed and direction. In these instances (22 and 29 August) sustained south-east winds and associated south-easterly currents resulted in TSS concentrations greater than 1000 mg/L at Site 1 south of Yorkeys Knob (Wolanski and Spagnol 2000).

Figure B5.4.6.1b also shows the effects that wind speed and direction can have on turbidity in Trinity Bay, especially in areas exposed to these winds. In this figure, a portion of the turbidity data from Palm Cove Beach (Site 1) has been plotted against wind speed and wind direction data. This shows that during periods of stronger south-east winds, there was generally an associated spike in turbidity at Palm Cove Beach. In areas more sheltered from these winds, such as Trinity Inlet, turbidity is less susceptible to wind direction and more influenced by stronger currents during spring tides. This is illustrated in Figure B5.4.6.1b which shows turbidity spikes in Trinity Inlet which are generally associated with spring tide phases.

Figure B5.4.6.1a Wind, Current and Turbidity Measurements near Northern Beaches (Wolanski and Spagnol 2000)

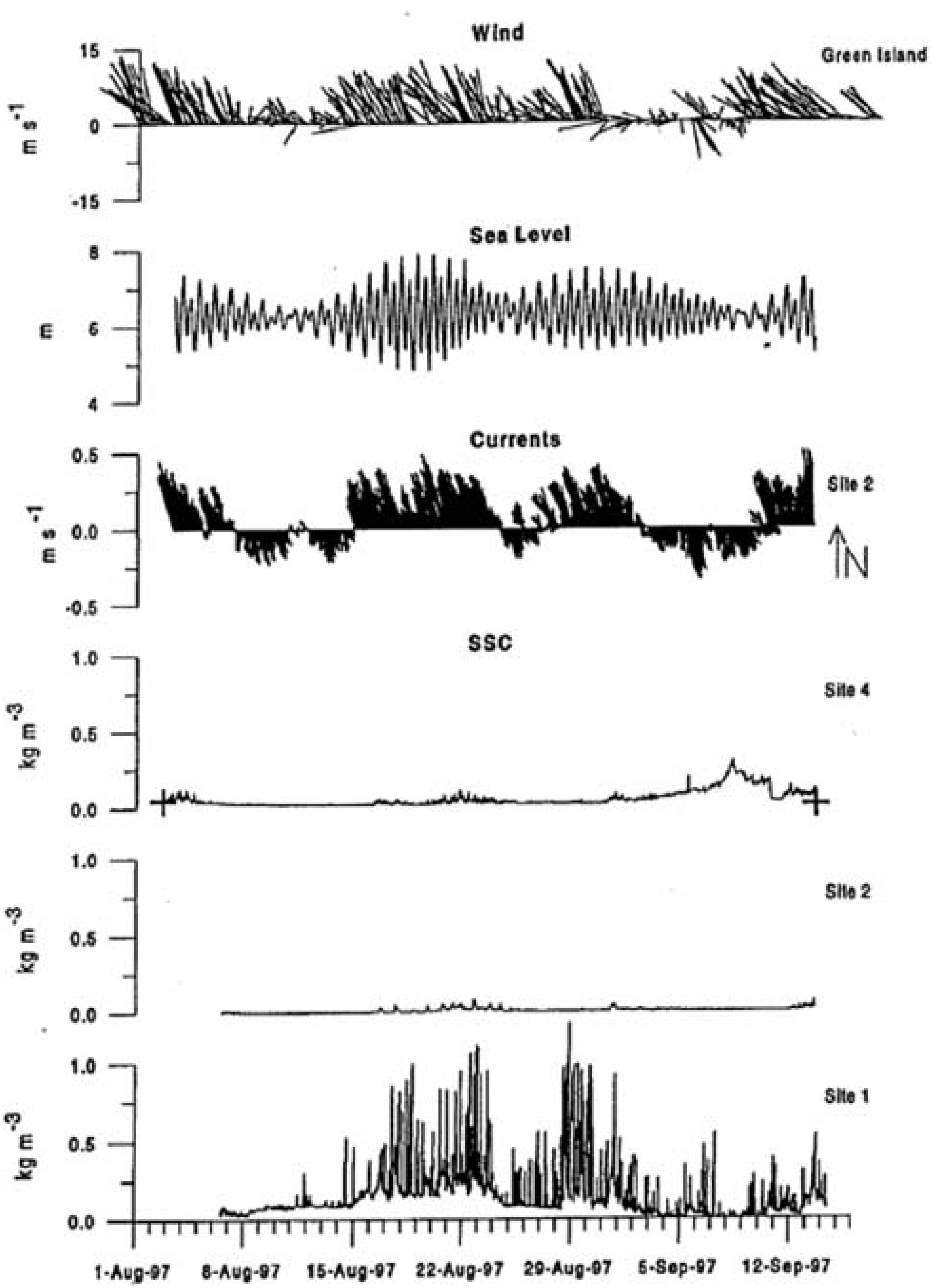
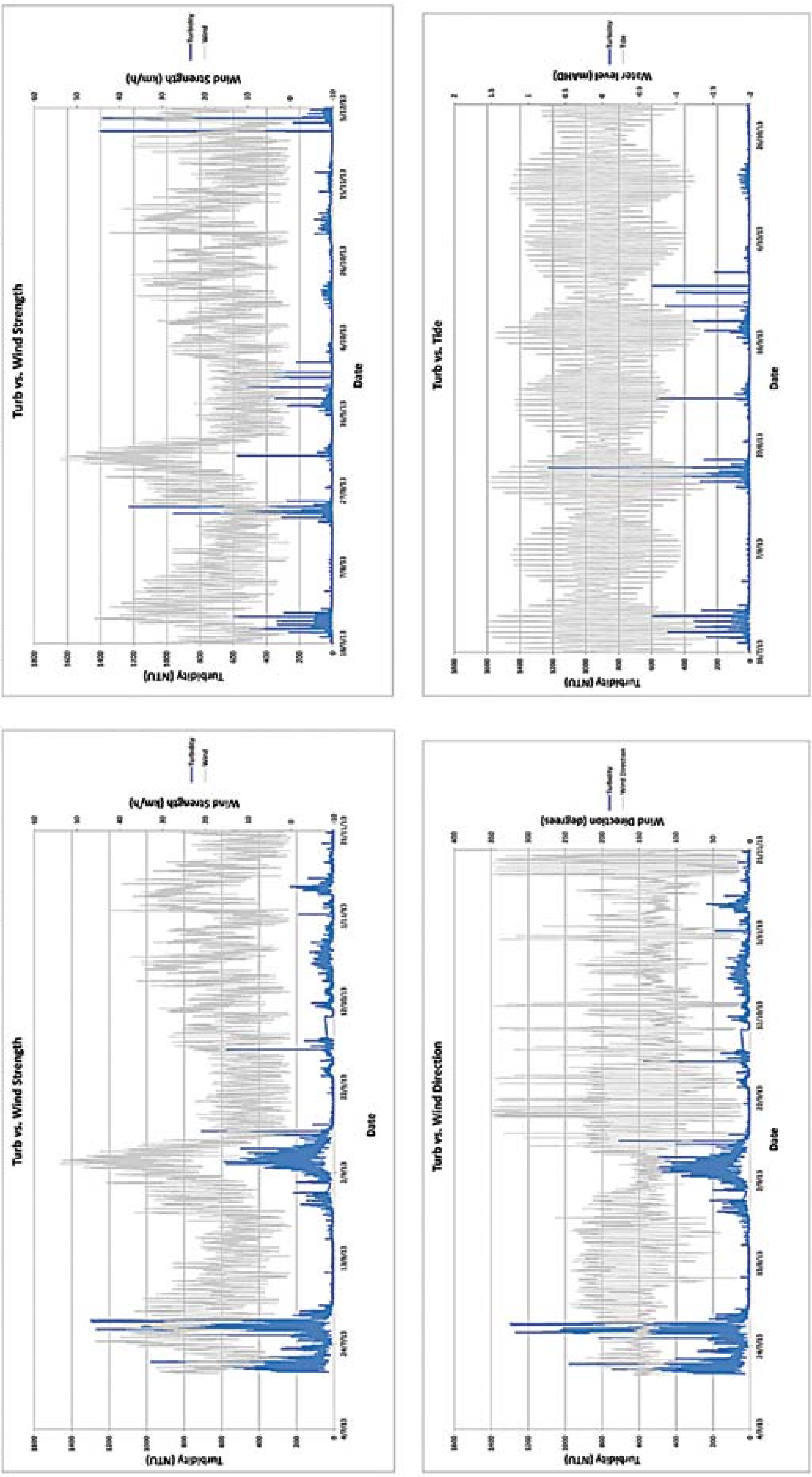


Figure B5.4.6.1b Turbidity at Northern Beaches (left column) and Trinity Inlet (right column) from Cairns EIS Water Quality Monitoring Program – Correlated with Wind and Tidal Data

Palm Cove Beach (Site 1) | Trinity Inlet (Site 4)



B5.4.6.2 Previous Studies

Barron and Haynes (2009) have estimated background TSS concentrations at 4.09 mg/L within six km of the shore and 1.43 mg/L from 6-24km.

Davis *et al (1998)* conducted wet season (November 1994 to December 1994) sampling at three locations near the entrance of Trinity Inlet and one at the DMPA. Their findings demonstrated high TSS concentrations at:

- Marlin Jetty (Trinity Inlet) – 35 mg/L with spikes of up to 1,200 mg/L associated with tidal currents (spring). Neaps tide currents generated lower increase of approximately 50mg/L
- Mud flats adjacent to the entrance of Trinity Inlet – very high TSS concentrations throughout the monitoring period from 800 mg/L to greater than 2,500 mg/L
- Shipping channel at the entrance – generally very high background concentrations (350-400 mg/L). It is suspected that these measurements reflect a mobilised mud layer near the sea bed at this location
- DMPA – high background TSS at approximately 400 mg/L. The peak TSS concentrations usually coincided with periods occurring after the fastest current (at the DMPA) were observed rather than at the same time.

Connell Wagner (1991) concluded that north-easterly winds (summer) tended to produce the highest turbidity within Trinity Inlet, with concentrations of 70 NTU. East and south-easterly winds were observed to generate lower turbidity of 30 to 40 NTU (Connell Wagner 1991). GHD (2000) found that turbidity within Trinity Inlet was influenced by catchment and urban stormwater, but also from re-suspension of material in Trinity Bay and transported during flood tides.

More regional studies have indicated lower inshore ambient TSS concentrations at 1.2 to 1.7 mg/L (Furnas *et al* 2011). These concentrations were not associated with cyclonic riverine floods which were typically significantly higher (Furnas *et al* 2011).

B5.4.6.3 Turbidity

The primary sources of turbidity data used in the characterisation of baseline conditions are from the Project specific Coastal Data Collection and the Water Quality Monitoring Program. Turbidity data for both sources of data are summarised in **Figure B5.4.6.3a**. **Figure B5.4.6.3b** presents turbidity data collected as part of the Ports North monitoring program. These data were collected from 2001 to 2013 at locations within Trinity Inlet only. **Table B5.4.6.3a** shows the regional statistical information for turbidity divided into seasons for the Coastal Data Collection and Water Quality Monitoring Program. **Table B5.4.6.3b** shows the same statistical measures for the Ports North monitoring program.

The baseline turbidity data collected as part of the 12-month Coastal Data Collection and Water Quality Monitoring Program was used to develop threshold values for impact assessment (as well as trigger values for the Dredge Management Plan). Further information on how this data was analysed and used for impact assessment is included in **Section B5.5.2**.

General analysis of the data indicates the following observations:

- The Coastal Data Collection and Water Quality Monitoring programs showed there was no significant difference between wet season and dry season turbidity values. Some areas, such as Trinity Inlet, False Cape and Cape Grafton had higher turbidity during the wet season. This is likely due to these areas being more sheltered from predominant south-east winds and therefore more influenced by freshwater flows. Other areas, such as Yorkeys Knob and Palm Cove Beach (Region 5), had higher turbidity during the dry season as these areas are more exposed to sustained south-easterly winds during the winter.
- During the wet and dry seasons, turbidity levels generally increased from the Trinity Inlet out to near shore areas (False Cape, Cape Grafton and Northern Beaches). Turbidity was relatively low (<10 NTU) at offshore areas (region 4) during both seasons. The highest median turbidity was at False Cape during the wet season.
- All monitoring locations demonstrated median turbidity levels in excess of the WQO for both seasons, with the exception of Trinity Inlet (Region 1b) during the dry season
- The Ports North turbidity data show similar turbidity levels to those observed in the Coastal Data Collection and Water Quality Monitoring programs.

Figure B5.4.6.3a Coastal Data Collection WQ Data (2013-2014) and WQ Monitoring Program (2013-2014) Turbidity Box and Whiskers, Wet Season (Top) and Dry Season (Bottom)

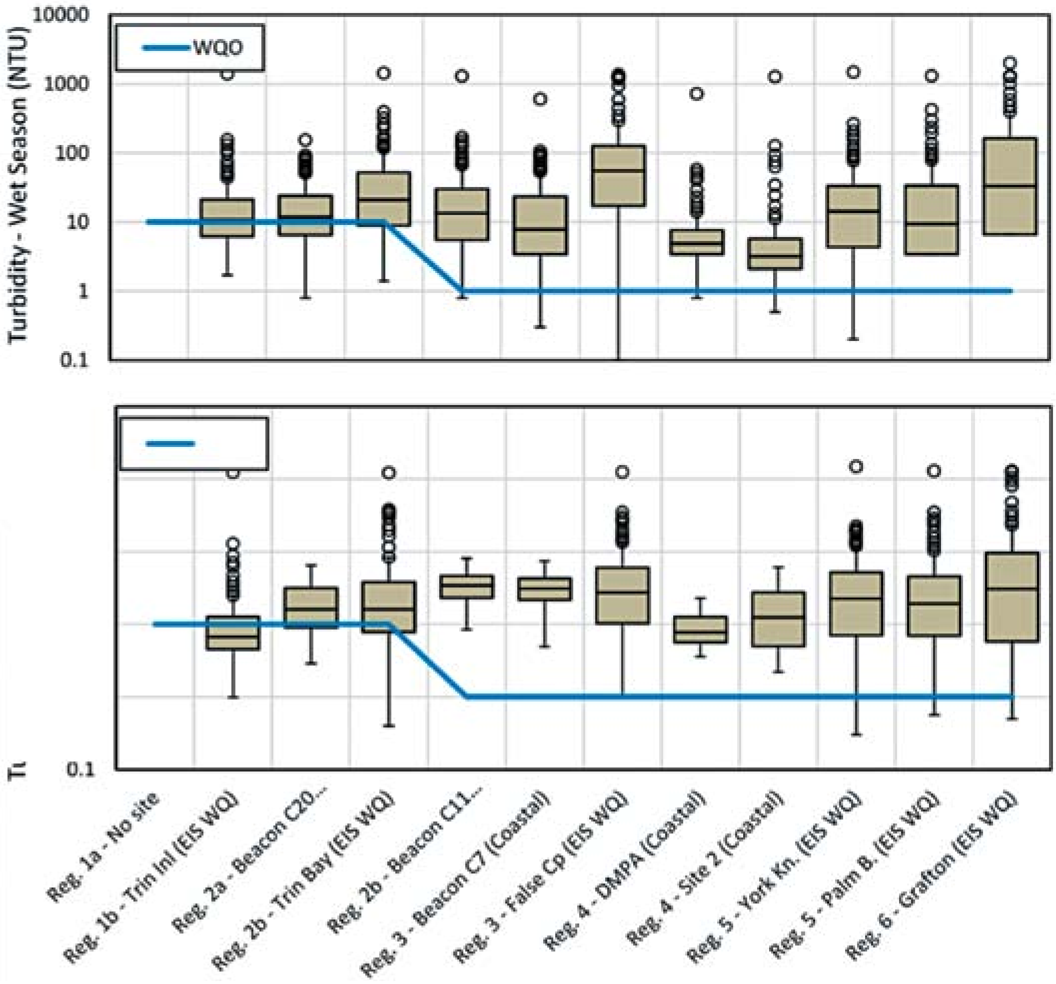


Figure B5.4.6.3b Cairns Port Authority WQ Data (2001-2013) Turbidity Box and Whiskers

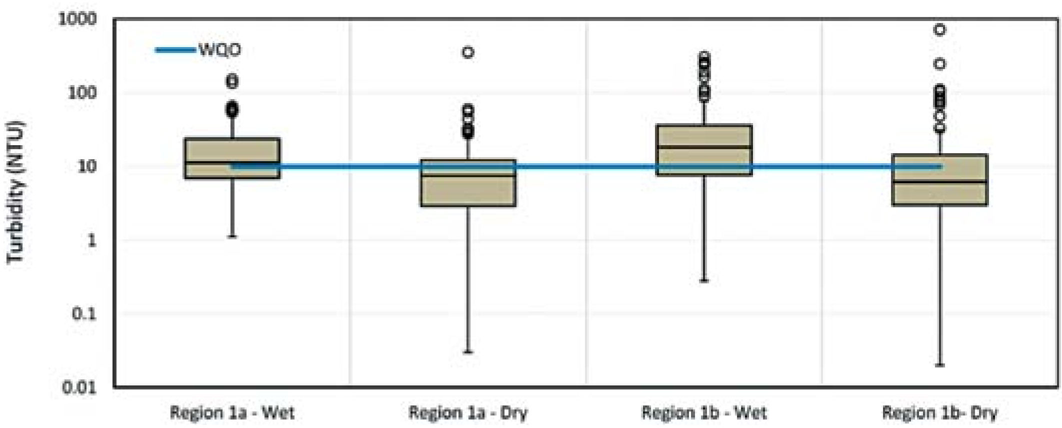


Table B5.4.6.3a Coastal Data Collection WQ Data (2013-2014) and WQ Monitoring Program (2013-2014) Turbidity (NTU) Statistics

Season	Region	n	Mean	Min	Percentile				Max
					20th	50th	80th	95th	
						10			
	WQO					--			
	1a	--	--	--	--	11	--	--	--
	1b	23300	23	2	6	12	27	74	1387
	2a	5115	19	1	6	1	30	59	153
Wet	WQO					21			
	2b	33476	41	1	7	55	60	124	1423
	3	21296	144	0	11	3	161	815	1355
	4	35770	9	1	2	9	7	31	1264
	5	33471	31	0	3	33	40	96	1305
	6	33478	189	0	4	10	277	1212	1984
	WQO								
	1a	--	--	--	--	--	--	--	--
	1b	21804	15	1	4	7	15	50	1284
	2a	27041	26	0	6	12	32	93	298
Dry	WQO					1			
	2b	36281	42	0	7	16	48	199	1390
	3	32840	56	1	8	28	72	173	1332
	4	52488	14	1	3	6	19	45	1286
	5	19848	40	1	6	19	54	138	1282
	6	19848	100	0	4	31	123	390	1971

Italicized values highlighted in red represent exceedances of the WQO; applied to the median only.

Table B5.4.6.3b Ports North (2001-2013) Turbidity (NTU) Statistics

Season	Region	n	Mean	Min	Percentile				Max
					20th	50th	80th	95th	
	WQO					10			
Wet	1a	96	19	1	6	11	30	57	150
	1b	806	31	0	6	18	41	88	306
	WQO					10			
Dry	1a	86	14	0	2	7	13	32	350
	1b	684	16	0	3	6	17	75	712

Italicized values highlighted in red represent exceedances of the WQO; applied to the median only.

B5.4.6.4 Total Suspended Sediments (TSS)

TSS was monitored during the Coastal Data Collection events, for both wet and dry seasons. This data formed the primary basis of characterisation for TSS where applicable[1].

Gaps in these data include region 1a (mid-estuary in Trinity Inlet) and regions 5 and 6. To supplement these data, the CPA monitoring program sampled for TSS between 1995 and 1997 within Trinity Inlet and Trinity Bay to the end of the channel. Additionally, the Water Quality Monitoring Program included TSS sampling which has also been summarised here.

Figure B5.4.6.4a presents the Coastal Data Collection TSS concentrations for each region, and **Figure B5.4.6.4b** presents the CPA TSS concentrations. Statistical summaries of each data source are provided in **Table B5.4.6.4a** for the Coastal Data Collection and **Table B5.4.6.4b** for the CPA data. Again it is noted that the WQOs in these figures does not extend to all regions because the WQO is not a static numerical value for those regions.

Table B5.4.6.4c presents the RRRC data for the regions for which data were sampled in the wet seasonal. Data coverage for TSS data extends from 1996 to 1999 only. Finally, **Table B5.4.6.4d** presents the Water Quality Monitoring Program TSS grab samples.

On a regional level, Devlin ***et al*** (2012) have mapped flood plume area within the GBR region based on load contributions and frequency of flooding using physical measurements and satellite imagery. This mapping and analysis are based on 10 years of flooding data. This analysis produced three types of areas of plumes:

- Primary plume waters – characterised by high TSS concentrations
- Secondary plume waters – characterised by high phytoplankton production
- Tertiary plume waters – characterised by elevated dissolved and detrital matter.

The spatial distribution of these areas relative to the frequency of these plume water types has been assessed by Devlin *et al* (2012) for Trinity Inlet and Trinity Bay. These plumes are shown in **Figure B5.4.6.4c**. Note the high frequency of primary plume waters within inner Trinity Inlet dissipates to low frequency approximately at the end of the shipping channel, prior to the DMPA.

Within the Wet Tropics, the estimated mean TSS concentration was 23.3 mg/L for primary areas, 15.0 mg/L in secondary areas, and 8.3 mg/L in tertiary areas (Devlin et al 2012).

General analysis of the data indicates the following observations:

- The wet and dry season data for the Coastal Data Collection demonstrated a similar pattern of high median TSS concentrations in Trinity Inlet and decreasing with increasing distance from the entrance of Trinity Inlet. TSS concentrations for each region demonstrated similar ranges between wet and dry seasons
- Region 4 (offshore area) was the only area that demonstrated compliance with the TSS WQO from the Coastal Data Collection (the WQO for Trinity Inlet and Inner Trinity Bay is not shown as it is specified in terms of increases in TSS over background levels)
- Similar to the Coastal Data Collection, the CPA data demonstrated high TSS in Trinity Inlet in the wet season (25-35 mg/L), however, median dry season TSS concentrations were less than 10 mg/L. Within Trinity Bay, median TSS values increased farther away from the Trinity Inlet entrance. In contrast to the trend demonstrated by the Coastal Data Collection, typical CPA TSS concentrations were higher in the outer bay for both seasons
- The CPA TSS samples extended three full years, and likely demonstrated typical seasonal variation in TSS geographically, inclusive of catchment and wind influences
- Median CPA TSS concentrations within the Bay are typically greater than the WQO for open coastal waters, though only slightly so for some regions
- Median RRRC TSS concentrations are within the ranges similar to the other studies.

[1] TSS samples were collected for both wet and dry conditions over two or three days during each monitoring

Figure B5.4.6.4a Coastal Data Collection WQ Data (2013) TSS Box and Whiskers, Wet Season *(Top)* **and Dry Season** *(Bottom)*

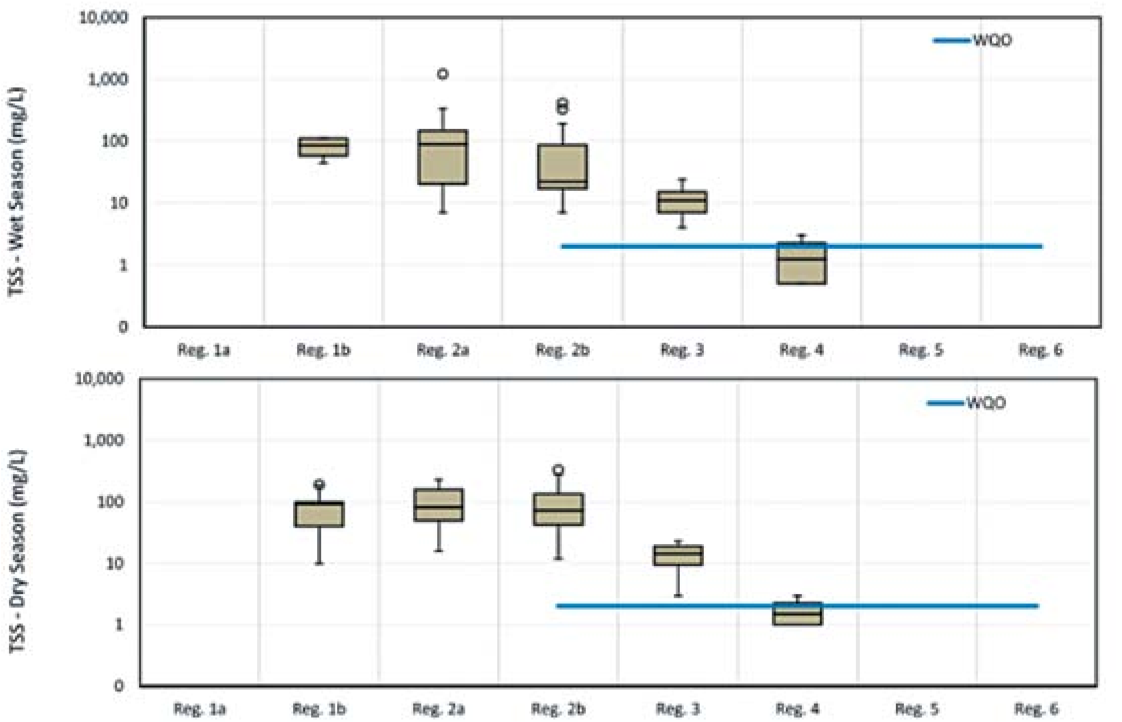


Figure B5.4.6.4b Cairns Port Authority WQ Data (1995-1997) TSS Box and Whiskers

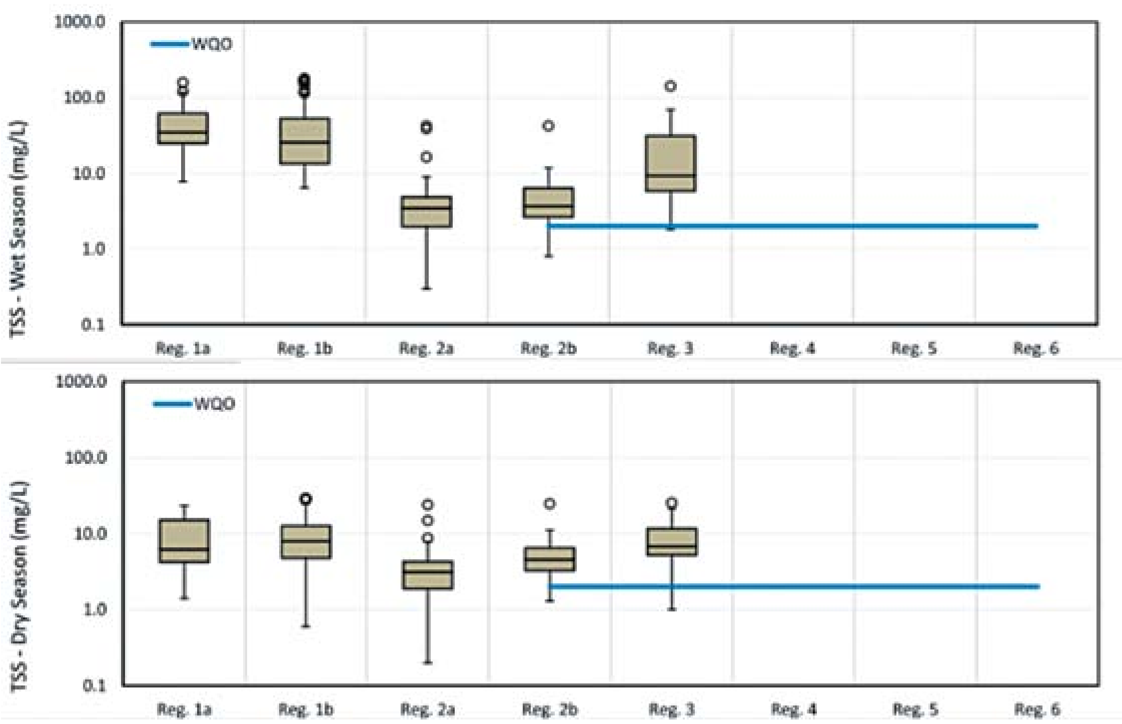


Table B5.4.6.4a Coastal Data Collection WQ Data (2013) TSS (mg/L) Statistics

Season	Region	n	Mean	Min	Percentile 20th	Percentile 50th	Percentile 80th	Percentile 95th	Max
	WQO					na			
	1a	--	--	--	--	--	--	--	--
	1b	8	82	44	54	86	110	110	110
	2a	10	192	7	12	89	160	747	1220
Wet	WQO					2			
	2b	18	707	7	16	24	112	2058	11400
	3	7	12	4	6	11	17	22	24
	4	4	2	1	1	1	2	3	3
	5	--	--	--	--	--	--	--	--
	6	--	--	--	--	--	--	--	--
	WQO					na			
	1a	--	--	--	--	--	--	--	--
	1b	10	83	10	24	94	102	154	190
	2a	7	107	16	33	83	190	224	230
Dry	WQO					2			
	2b	15	94	12	36	74	140	197	330
	3	10	14	3	8	15	19	22	23
	4	4	2	1	1	2	2	3	3
	5	--	--	--	--	--	--	--	--
	6	--	--	--	--	--	--	--	--

Table B5.4.6.4b Coastal Data Collection WQ Data (2013) TSS (mg/L) Statistics

Season	Region	n	Mean	Min	Percentile 20th	Percentile 50th	Percentile 80th	Percentile 95th	Max
	WQO					na			
	1a	25	51	8	22	35	73	118	158
	1b	91	41	6	11	26	65	135	178
	2a	20	7	0	2	3	5	39	42
Wet	WQO					2			
	2b	10	8	1	2	4	7	26	42
	3	30	22	2	6	9	36	58	141
	4	--	--	--	--	--	--	--	--
	5	--	--	--	--	--	--	--	--
	6	--	--	--	--	--	--	--	--
	WQO					na			
	1a	39	9	1	4	6	16	19	23
	1b	103	9	1	4	8	13	19	29
	2a	24	4	0	2	3	5	14	24
Dry	WQO					2			
	2b	12	6	1	3	5	7	15	25
	3	36	9	1	4	7	13	19	26
	4	--	--	--	--	--	--	--	--
	5	--	--	--	--	--	--	--	--
	6	--	--	--	--	--	--	--	--

Italicized values highlighted in red represent exceedances of the WQO; applied to the median, only.

Table B5.4.6.4c RRRC Data (1995-2013) TSS (mg/L) Statistics

Season	Region	n	Mean	Min	Percentile				Max
					20th	50th	80th	95th	
Wet	WQO					na			
	1a	--	--	--	--	--	--	--	--
	1b	3	34	20	--	30	--	--	53
	2a	1	31	--	--	--	--	--	--
	WQO					2			
	2b	1	24	--	--	--	--	--	--
	3	21	15	2	9	13	16	43	46
	4	10	4	1	2	3	6	9	11
	5	6	11	2	2	11	13	22	25
	6	1	10	--	--	--	--	--	--

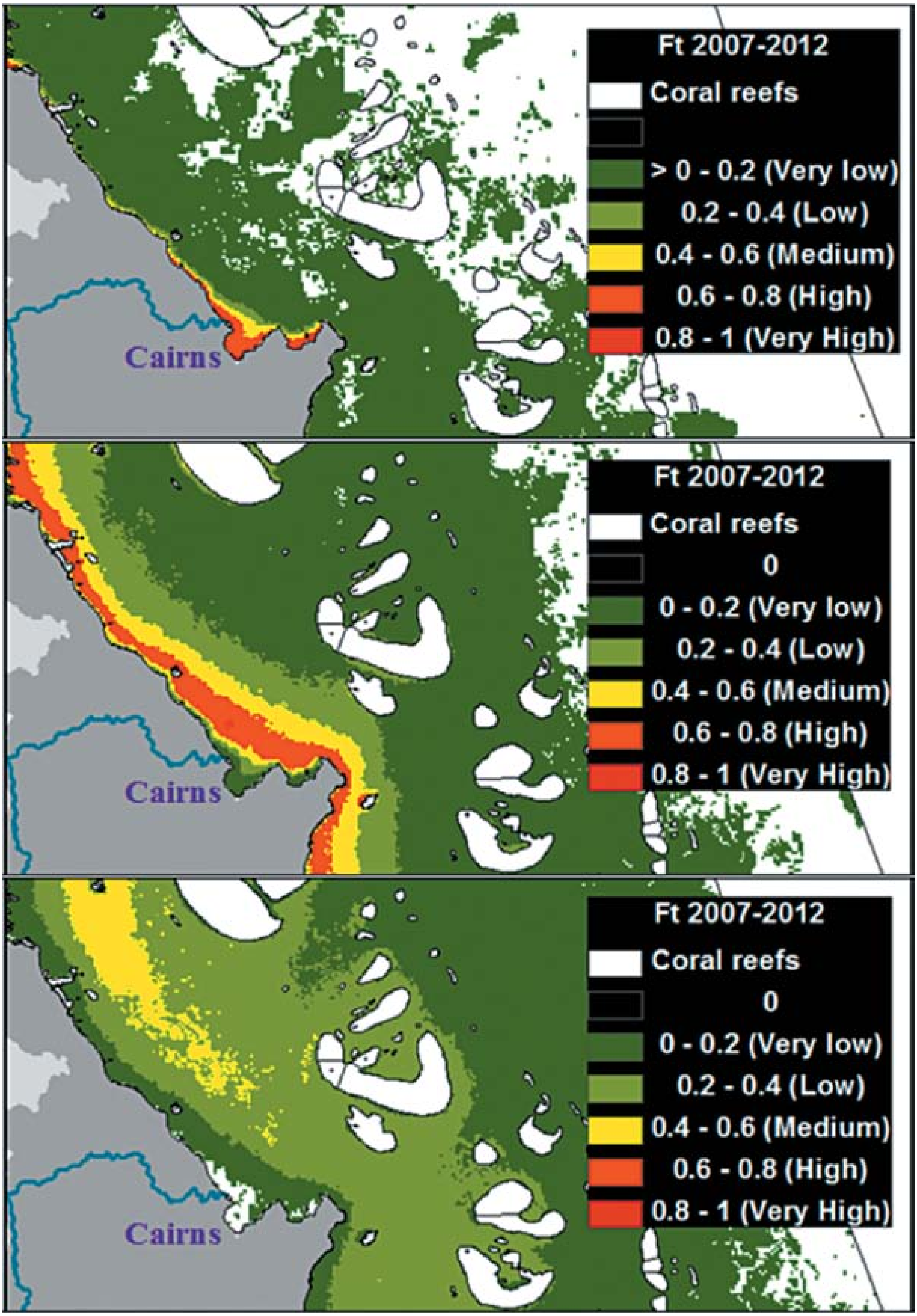
Italicized values highlighted in red represent exceedances of the WQO; applied to the median, only.

Table B5.4.6.4d Water Quality Monitoring Program (2013) TSS (mg/L) Statistics

Season	Region	TSS Upper	TSS Lower
Dry	WQO	na	
	1a	--	--
	1b	<2	2
	2a	--	--
	WQO	2	
	2b	4	4
	3	26	40
	4	--	--
	5 (Palm Beach)	<2	4
	5 (Yorkey's Knob)	6	31
	6	14	35

Italicized values highlighted in red represent exceedances of the WQO.

Figure B5.4.6.4c Flood Plume Type and Frequency: Primary (Top), Secondary (Middle) and Tertiary (Bottom)



B5.4.6.5 Turbidity-TSS Correlation

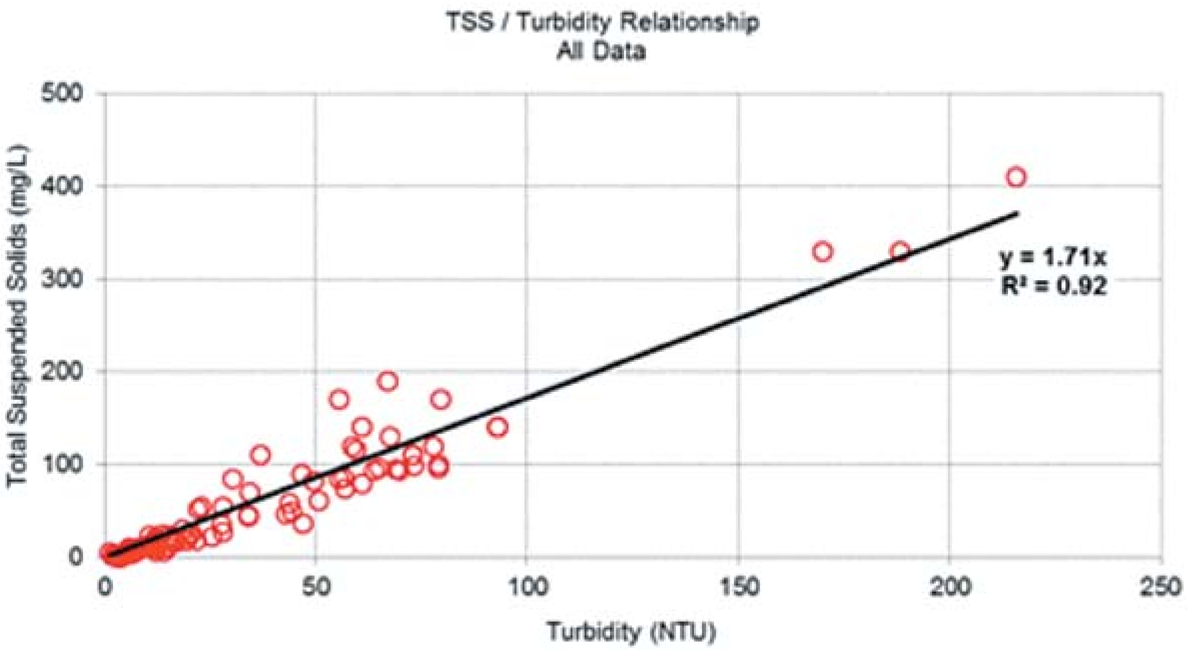
TSS is an important parameter of concern with regard to water quality as it is what is typically measured and monitored to determine compliance with water quality objectives.

Turbidity, however, is the general parameter often used as a surrogate for TSS because it is easier and more cost-efficient to monitor. Therefore, there is the need to establish a relationship between turbidity and TSS such that the conversion of turbidity data to TSS concentrations can be made without the need to monitor for TSS.

Previously, Connell Wagner (1991) had undertaken this task for Trinity Inlet and Trinity Bay and surrounds in their Dredge and Dump Monitoring Report (Connell Wagner 1991). That study determined a relationship of 1.5 mg/L of TSS per 1 NTU of turbidity.

The Coastal Data Collection TSS data collection was conducted in concert with the collection of transect data for currents, waves, conductivity, temperature and turbidity. TSS samples were collected at the same time, location and depth as the turbidity measurements, allowing for the correlation between TSS and turbidity for nearly identical parcels water. **Figure B5.4.6.5a** shows the linear correlation between TSS and turbidity for the study area. This relationship is based on the analysis of 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 relationship established using this method is 1.71 mg/L of TSS per 1 NTU of turbidity. The derivation of this relationship is further described in **Chapter B3, Coastal Processes**.

Figure B5.4.6.5a TSS – Turbidity Correlation



B5.4.7 Deep Water Profiling

Deep water profiling was undertaken during each servicing trip throughout the 12-month Water Quality Monitoring Program. These profiling sites, generally located between the DMPA and offshore reef areas, are shown in **Figure B5.4.4a**. The aim of including these deep water profiling sites was to provide further information in terms of the baseline offshore water quality.

The deep water profiling involved using a water quality instrument to log readings of turbidity, pH and dissolved oxygen (DO) through the water column from surface to seabed. A summary of this data is presented in **Table B5.4.7a**.

Table B5.4.7a Summary of Deep Water (Offshore) Profiling Data

Deep Water Profiling Site	Water Depth	Average Turbidity (NTU)	Average pH	Average DO (% sat)
Deep 1	Surface (0.3m)	0.3	8.2	100.0
	Middle (~10m)	0.3	8.2	99.1
	Bottom (~18m)	0.9	8.2	98.5
Deep 2	Surface (0.3m)	1.6	8.2	99.5
	Middle (~10m)	1.0	8.2	99.3
	Bottom (~24m)	0.4	8.2	98.5
Deep 3	Surface (0.3m)	0.6	8.2	98.8
	Middle (~10m)	0.2	8.2	99.3
	Bottom (~25m)	0.7	8.2	97.9
Deep 4	Surface (0.3m)	0.5	8.2	99.1
	Middle (~10m)	0.3	8.2	99.0
	Bottom (~25m)	1.1	8.2	97.0
Average	0.7	8.2	98.8	

B5.4.8 Photosynthetically Active Radiation (PAR)

Photosynthetically active radiation (PAR) is a measure of the amount of light available for photosynthetic processes of the benthic marine community (e.g seagrasses). PAR reaching the sea floor is impacted by the water depth and the amount of suspended material in the water column that leads to light attenuation. Previous studies of light within Trinity Inlet determined that light attenuation increased farther up in the estuary, and hence a decrease in PAR (Dennison and O'Donohue 1994). The greatest attenuation of light (decrease of PAR) occurred within the smaller tributaries within the estuary. This typically corresponded to higher chlorophyll-a concentrations and productivity rates (Dennison and O'Donohue 1994). The amount of PAR that reaches the sea floor is also directly affected by water depth as the total amount of light that arrives at the water surface is attenuated as it passes through the water column.

James Cook University (JCU) conducted 12 months of benthic PAR monitoring (2013-2014) (Jarvis ***et al.*** 2014) at selected locations to form a baseline of light regime in areas of current or previous seagrass areas. This is the first time that JCU has collected PAR data in the Cairns area, and the use of this baseline data to derive local seagrass tolerance limits is still under development.

The JCU PAR locations are shown in **Figure B5.4.4a**, and include three intertidal PAR monitoring sites and three subtidal monitoring sites.

B5.4.8.1 PAR and Turbidity

Two of the JCU subtidal PAR monitoring sites also had turbidity loggers recording measurements at the same locations. These two sites, and associated monitoring period, are as follows:

- Existing DMPA – monitoring period February 2013 to January 2014
- Next to outer channel in Trinity Bay (Site 3) – monitoring period October 2013 to June 2014.

It should be noted that during the monitoring period, no seagrass was evident at either of the above subtidal monitoring sites (Jarvis ***et al.*** 2014). The main purpose of the two subtidal sites measuring PAR and turbidity was to investigate whether a relationship between PAR and turbidity could be observed from the data obtained.

The data from these two subtidal PAR monitoring sites was analysed to determine the total daily benthic PAR ($mol/m^2/day$). At these sites, turbidity and depth was recorded as part of the Coastal Data Collection (existing DMPA) and the Water Quality Monitoring Program (Site 3). Using this data, a preliminary light attenuation coefficient (Kd) was able to be calculated. This coefficient takes into account water depth and surface irradiance to provide an indication of attenuation of light per metre of water. This can then be correlated with turbidity data without these other variables (i.e. water depth and surface irradiance) affecting the relationship. Light attenuation (Kd) was calculated using the following formula derived from Anthony *et al.* (2004):

$$Kd = \ln\left(\frac{E(s)}{E(z)}\right)/z$$

In this equation, E(s) is the PAR at the water surface and E(z) is the PAR at a depth of z.

For this preliminary calculation, surface irradiance (PAR) data was sourced from the nearest Australian Institute of Marine Science (AIMS) marine weather monitoring station at Agincourt Reef approximately 100km north of Cairns. It is noted that this location is not ideal, and further PAR monitoring (benthic and surface) would need to be undertaken prior to commencement of dredging to further refine the light attenuation relationship.

Daily fluctuation in benthic PAR at the two subtidal sites was assessed by plotting the time series of total daily benthic PAR and the two-week running average for both sites. A two-week running average was chosen as recent studies in Gladstone for the key intertidal seagrass *Zostera muelleri* (capricorni) found that a two-week average of daily light was a critical time window to support seagrass growth (Chartrand *et al.* 2012). This data is presented in **Figure B5.4.8.1a** and **Figure B5.4.8.1b**, which also includes average daily benthic PAR for each site. These figures illustrate that while the average daily benthic PAR levels are low at both sites, benthic PAR fluctuates widely and at times seagrass at these sites could receive significantly greater light levels, especially during the growing season (July – December).

Figure B5.4.8.1a Total Daily PAR (top) and Two Week Running Mean of Total Daily PAR (bottom) for Site 3

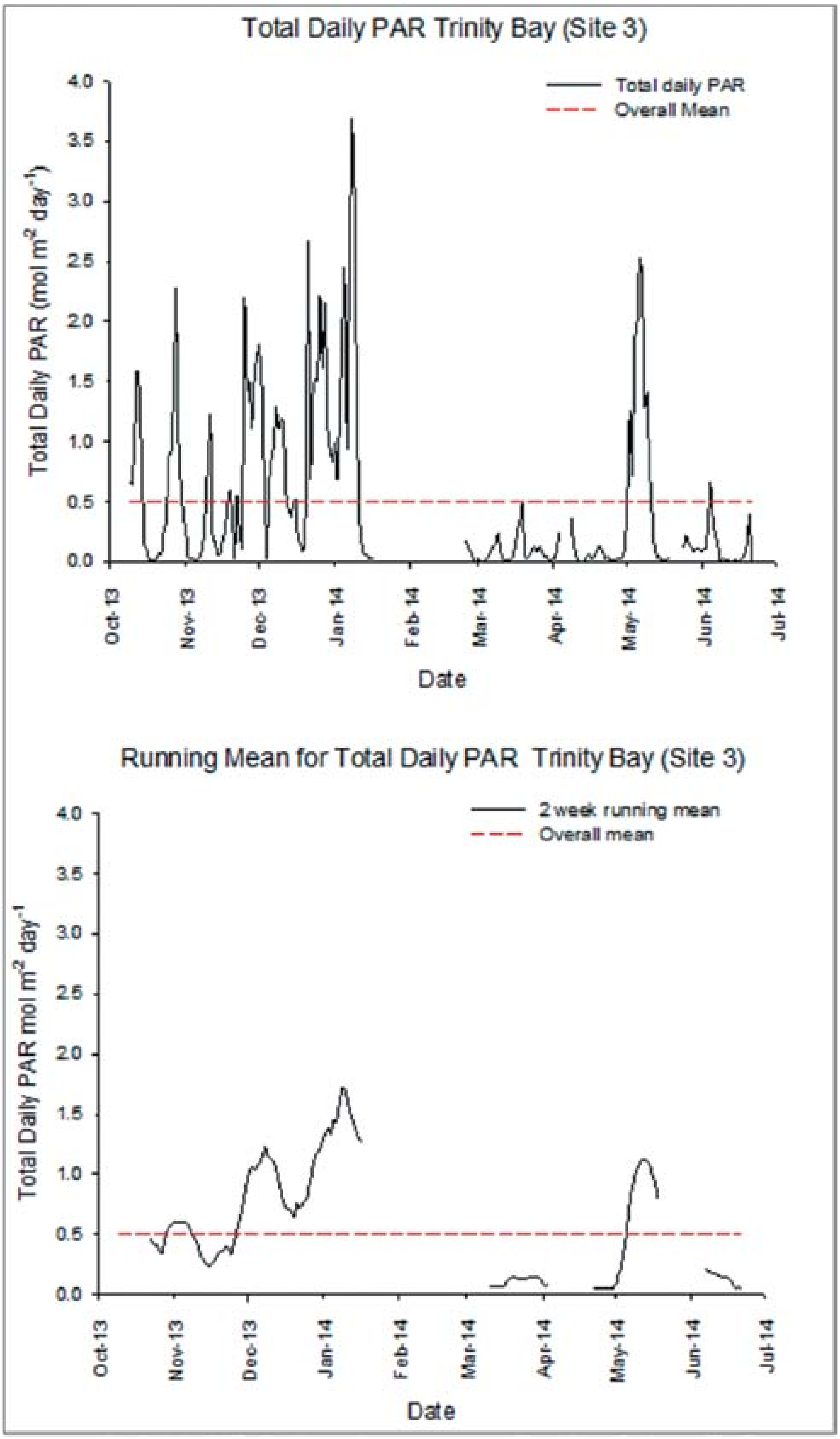
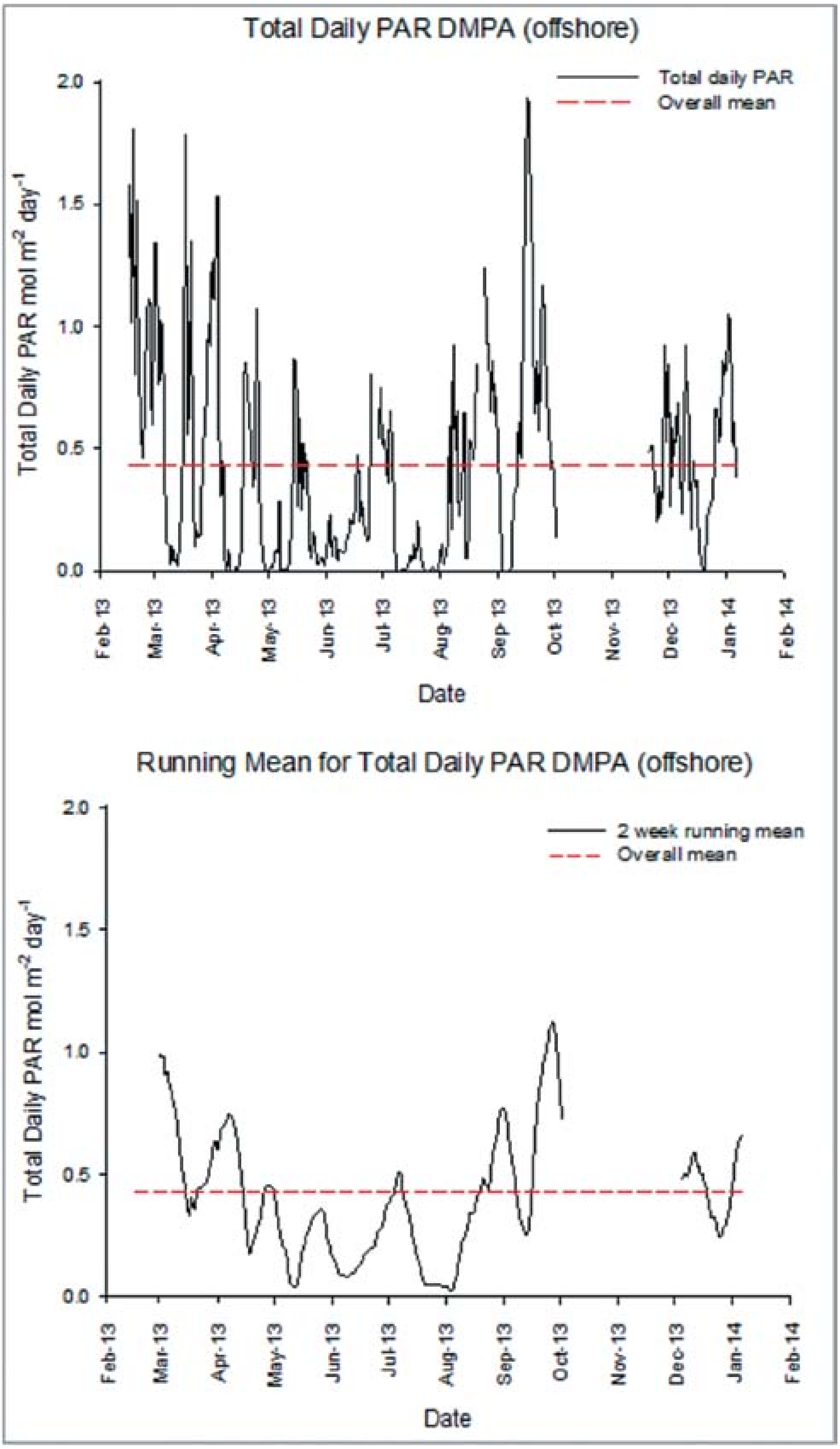


Figure B5.4.8.1b Total Daily PAR (top) and Two-Week Running Mean of Total Daily PAR (bottom) for DMPA site

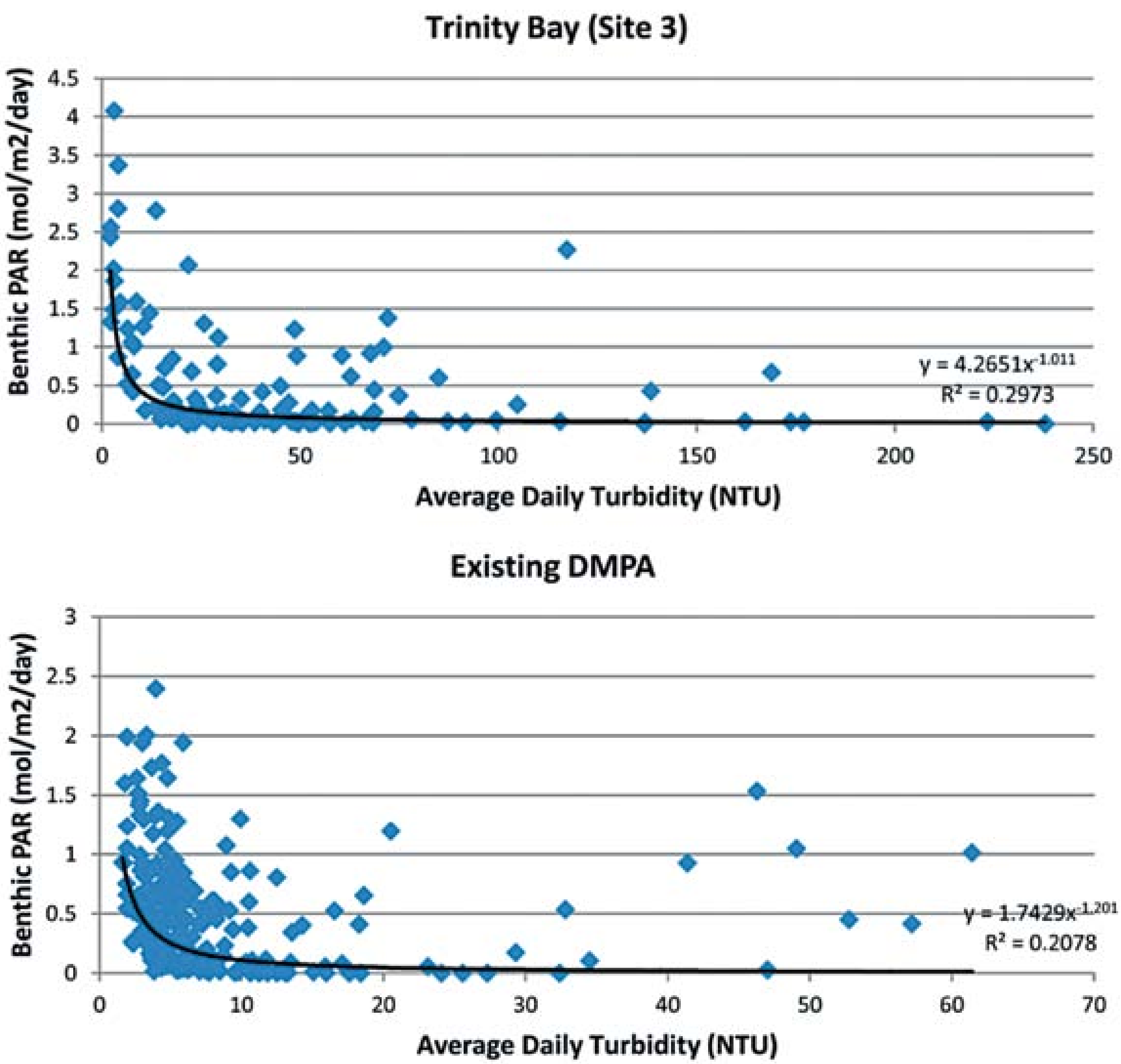


The data indicates that average total daily PAR reaching the sea bed at the Trinity Bay site was 0.43 mol/m^2/day and the DMPA site was 0.50 mol/m^2/day. **Figure B5.4.8.1a** and **Figure B5.4.8.1b** indicate that PAR levels ranged from 0.00 – 1.94 mol/m^2/day at the near shore site (Site 3) and from 0.00 – 3.69 mol/m^2/day for the offshore site (DMPA). This is within the range of benthic PAR previously measured at Abbot Point in subtidal seagrass meadows dominated by *Halophila* (0.28 – 4.5 mol/m^2/day) (Jarvis *et al.* 2014). Jarvis *et al.* (2014) noted that this range of benthic PAR is well below the likely light requirements for *Zostera* (at least 4.5 mol/m^2/day) and *Halodule* (5.2 mol/m^2/day). **Figure B5.4.8.1a** and **Figure B5.4.8.1b** indicate that the two week rolling average of benthic PAR during the seagrass growing season (July-December) fluctuate greatly and may still be capable of maintaining *Halophila* meadows at certain times of the year which can survive in light with less than six percent surface irradiance (Udy and Levy 2002).

The average daily turbidity data was plotted against the total daily benthic PAR for each subtidal monitoring site (**Figure B5.4.8.1c**). This figure shows that benthic PAR values peaked at about 4 mol/m^2/day at Trinity Bay (~4m water depth) and about 2.5 mol/m^2/day at the existing DMPA (~14m water depth). **Figure B5.4.8.1c** also shows that benthic PAR was generally extinguished when turbidity was approximately 100 NTU at Trinity Bay, and approximately 20 NTU at the existing DMPA. The difference in turbidity when light extinguishment occurs is related to the water depth at each site.

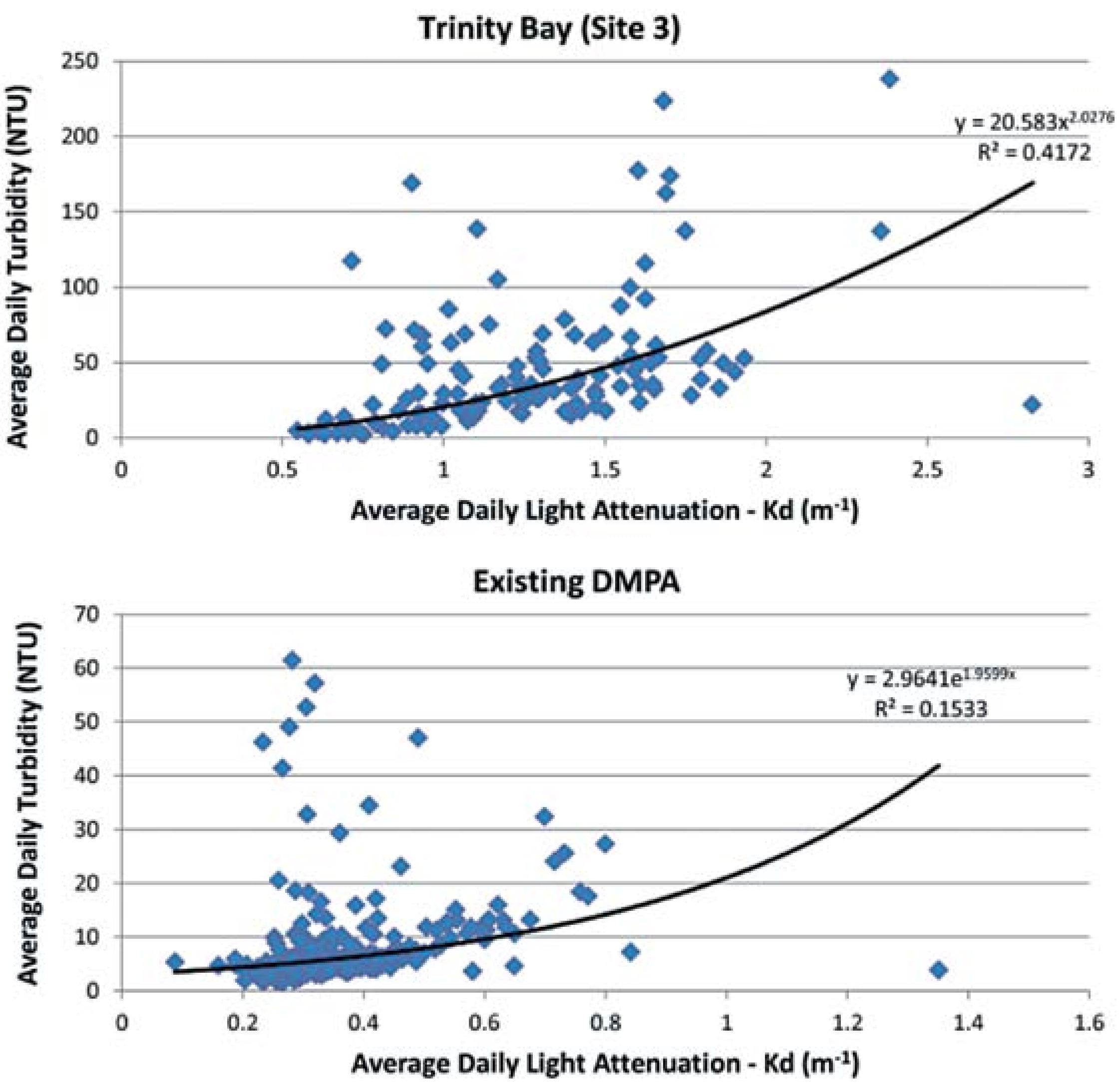
It is important to note that **Figure B5.4.8.1c** shows a relatively poor relationship between benthic PAR and turbidity data, with a low level of correlation (R^2 of 0.2). Further turbidity and PAR monitoring prior to commencement of dredging could be used in an attempt to strengthen this relationship.

Figure B5.4.8.1c Benthic PAR (mol/m2/day) and Average Daily Turbidity (NTU) for Trinity Bay (top) and Existing DMPA (bottom)



To further understand the relationship between turbidity and PAR, and to aid in a preliminary conversion of turbidity to PAR in any depth of water (**Section B5.5.2**), light attenuation data (per metre of water) for each monitoring site were plotted against average daily turbidity (**Figure B5.4.8.1d**). As shown in **Figure B5.4.8.1d**, both sites show a general trend of increasing light attenuation with increasing turbidity. As mentioned previously, the correlation of light attenuation to turbidity data is relatively poor (R^2 of 0.1 and 0.4), and could not be reliably used without further PAR monitoring and analysis. Nevertheless, this relatively poor correlation is used to undertake a preliminary conversion of turbidity to PAR to test impact assessment thresholds in subsequent sections of this chapter (**Section B5.5.2**).

Figure B5.4.8.1d Turbidity and Light Attenuation (Kd) Relationship at Trinity Bay (top) and Existing DMPA (bottom)

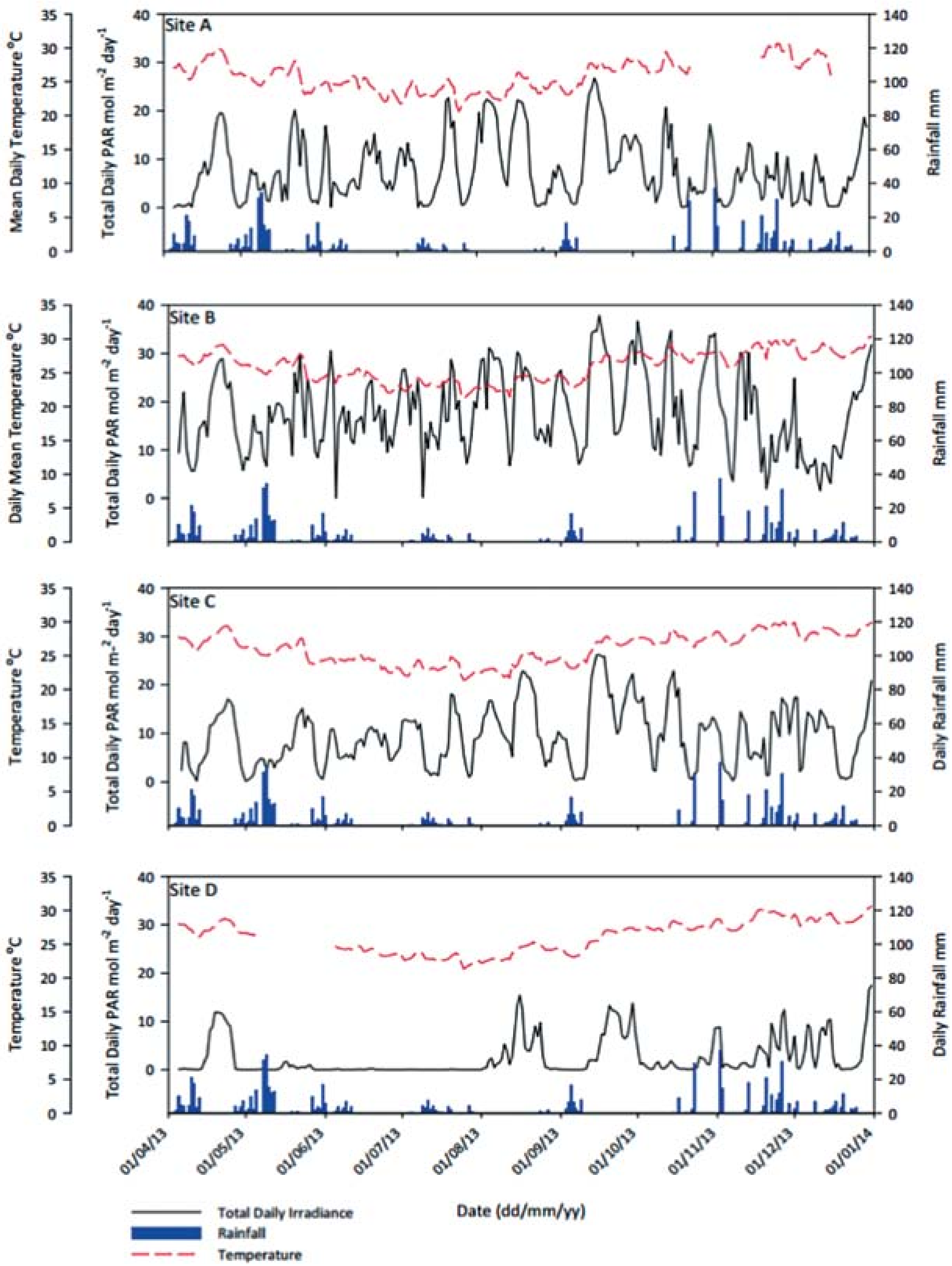


B5.4.8.2 Other PAR Monitoring Sites

JCU also monitored PAR at three intertidal sites (Sites A, B and C) and one other subtidal site (Site D) between April 2013 and December 2013 (refer to **Figure B5.4.4a** for locations of these sites). The data collected from these four sites, sourced from Jarvis et al. (2014), is presented in **Figure B5.4.8.2a**.

In regard to this PAR data, Jarvis *et al.* (2014) noted that light levels (mol/m^2/day) were consistently greater at site B on the intertidal bank at the southern end of the Esplanade and lowest for the subtidal site D at False Cape. Light levels were similar between the other two intertidal sites A and C. Light showed a limited seasonal effect with light decreasing slightly in the wet season (December-May) compared to the dry season (June-November) seasons. Site D near False Cape is a completely subtidal site so lower light levels are to be expected.

Figure B5.4.8.2a Total daily PAR (mol/m²/day), mean daily temperature (° C), and total daily rainfall (mm) for JCU monitoring sites (April to December 2013) (Jarvis *et al.* 2014)



B5.4.9 Metals/Metalloids

Monitoring of total metals/metalloids in the surface water, primarily within Trinity Inlet, is undertaken by Ports North as part of their routine monitoring campaign. The available monitoring data in Trinity Inlet (region 1) are summarised in **Table B5.4.9a** below, with the ANZECC/ARMCANZ (2000) Toxicity Trigger Value (TTV) provided for comparison purposes. It should be noted that the TTV is relevant to the dissolved fraction of metals, however, the Ports North data only includes total metals.

Grab samples of metals were collected during the Water Quality Monitoring campaign as part of opportunistic water quality monitoring at the locations where instruments were deployed. These metals samples included both dissolved and total concentrations. The samples were collected within the upper and lower portion of the water column.

The ANZECC/ARMCANZ (2000) guidelines state that for toxicants in water (such as metals/metalloids), the 95th percentile of monitoring data should be compared to the TTV. As such, **Table B5.4.9b** and **Table B5.4.9c** present the 95th percentile dissolved and total metals concentrations, respectively, at the monitoring locations.

The Ports North data indicate the 95th percentile cadmium, copper, chromium, zinc and tributyltin exceed the TTVs (as well as the 80th percentile values), however, it is noted these metals concentrations are given in total concentrations rather than the dissolved fractions.

Assessment of data from the Water Quality Monitoring Program indicates that 95th percentile aluminium, and copper concentrations exceeded the TTV for all monitoring locations. Two sites also had slight exceedances of zinc. Concentrations of metals/metalloids were relatively similar throughout the water column (i.e. upper and low samples were similar), indicating the water column is generally well mixed in the study area.

Table B5.4.9a Ports North (2001-2013) Total Metals (µg/L) Data Statistics

Region	Statistic	As	Cd	Cu	Cr	Pb	Zn	TBT [a]
		ANZECC TTV						
		50	0.7	1.3	4.4	4.4	15	6
Regional 1a	Count	13	7	27	9	7	47	7
	LOR > TTV [b]	3	6	5	2	6	0	0
	No. > TTV [c]	0	2	13	4	0	7	0
	80th %-ile	10.6	1.6	3.0	12.2	1.0	4.8	2.5
	95th %-ile	15.2	2.0	16.3	14.6	1.0	30.8	2.5
Regional 1b	Count	81	50	243	62	50	317	83
	LOR > TTV [b]	18	25	18	6	26	0	0
	No. > TTV [c]	3	16	125	22	0	32	19
	80th %-ile	17.0	2.0	3.0	20.0	1.0	4.0	8.0
	95th %-ile	20.0	2.0	10.0	21.0	1.0	25.0	26.3

Italicized values highlighted in red represent exceedances of the TTV

[a] Tributyltin, measured as nanograms of tin per millilitre of water

[b] Number of samples not detected above the Limit of Reporting (LOR), with an LOR greater than the TTV. These values were omitted

[c] Number of samples detected above the TTV

Table B5.4.9b Water Quality Monitoring Program (2013) – 95th Percentile Dissolved Metals (µg/L)

Region	Site	Depth	Al	As	C d	Cr	Cu	Fe	Pb	Mn	Ni	Ag	Zn	Hg
			Limit of Reporting (LOR)											
			20	5	0.7	2	1	20	1	5	3	1	5	0.1
			ANZECC TTV											
			0.5	50	0.7	4.4	1.3	300	4.4	80	7	1.4	15	0.1
1b	Trinity Inlet	Upper	*27.35*	2.26	0.31	1.43	*3.93*	11.70	0.47	55.65	1.40	0.46	*16.55*	0.0003
		Lower	*15.40*	2.34	0.32	1.00	*3.20*	9.66	0.46	22.80	1.43	0.48	12.27	0.0005
2b	Trinity Bay	Upper	*33.15*	2.32	0.31	1.43	*3.33*	10.00	0.43	4.97	1.37	0.46	13.61	0.0001
		Lower	*33.60*	2.32	0.31	1.43	*2.99*	10.85	0.46	4.71	1.37	0.46	9.13	0.0001
3	False Cape	Upper	*36.45*	2.40	0.31	1.43	*2.81*	10.00	0.43	2.93	1.38	0.46	14.10	0.0001
		Lower	*34.05*	2.38	0.31	1.43	*6.05*	32.95	0.43	3.35	1.42	0.46	11.50	0.0001
5	Palm Beach	Upper	*32.95*	2.32	0.31	1.43	*2.55*	54.20	0.44	2.84	1.39	0.46	12.64	0.0001
		Lower	*30.85*	2.38	0.31	1.43	*2.30*	10.85	0.44	3.01	1.37	0.46	*18.30*	0.0001
5	Yorkeys Knob	Upper	*31.75*	2.32	0.31	1.43	*3.01*	10.00	0.43	3.65	1.37	0.46	10.31	0.0001
		Lower	*33.85*	2.32	0.31	1.43	*2.30*	10.00	0.45	2.76	1.37	0.46	13.55	0.0001
6	Cape Grafton	Upper	*37.55*	2.40	0.33	1.43	*3.07*	10.00	0.44	4.03	1.43	0.46	14.25	0.0001
		Lower	*36.40*	2.38	0.31	1.43	*1.84*	10.00	0.43	3.86	1.42	0.46	2.50	0.0001

Italicized values highlighted in red represent exceedances of the Toxicity Trigger Value (TTV).

LOR is the lowest level able to be detected by the laboratory.

Note: To analyse the data, values below the LOR were assumed to be half the LOR value as per ANZECC/ARMCANZ (2000). For some samples, the LOR was raised due to matrix interference, while for others the LOR was lowered on request to lab.

Table B5.4.9C Water Quality Monitoring Program – 95th Percentile Total Metals (µg/L)

Region	Site	Depth	Al	As	Cd	Cr	Cu	Fe	Pb	Mn	Ni	Ag	Zn	Hg
			Limit of Reporting (LOR)											
			20	5	0.7	2	1	20	1	5	3	1	5	0.1
1b	Trinity Inlet	Upper	773	2.29	0.31	1.43	9.94	632	0.72	62.15	1.44	0.46	17.55	0.0001
		Lower	149	2.38	0.32	1.00	10.14	135	1.64	25.80	1.47	0.48	16.85	0.0001
2b	Trinity Bay	Upper	211	2.44	0.31	1.43	3.68	235	0.53	37.65	1.46	0.46	15.98	0.0001
		Lower	299	2.59	0.31	1.43	4.02	320	0.49	31.15	1.46	0.46	17.80	0.0001
3	False Cap e	Upper	177	2.47	0.31	1.43	3.01	156	0.46	11.25	1.42	0.46	34.93	0.0001
		Lower	833	2.47	0.31	2.61	4.26	685	1.52	37.80	1.49	0.46	19.50	0.0001
5	Palm Beach	Upper	150	2.43	0.31	1.43	3.98	146	0.50	7.30	1.41	0.46	15.40	0.0001
		Lower	176	2.44	0.31	1.43	3.39	165	2.64	8.13	1.42	0.46	15.25	0.0008
5	Yorkey s Knob	Upper	158	2.43	0.31	1.43	9.71	110	0.53	12.25	1.46	0.46	12.70	0.0001
		Lower	626	2.44	0.31	2.95	4.22	535	2.75	38.50	1.49	0.46	15.25	0.0001
6	Cape Grafton	Upper	955	2.43	0.31	3.29	6.01	788	1.20	52.65	1.43	0.46	15.07	0.0001
		Lower	386	2.44	0.31	3.12	2.43	365	1.48	18.80	1.44	0.46	16.44	0.0001

B5.4.10 Nutrients and Chlorophyll

Ports North routinely monitors Trinity Inlet for total nitrogen and phosphorus, ammonia and chlorophyll a. **Table B5.4.10a** summarises the Ports North nutrient and chlorophyll statistical concentrations in the region for which data were collected (Region 1). Ammonia has both a scheduled water quality objective under the EPP (Water) 2009 and a Toxicity Trigger Value (TTV) under ANZECC/ARMCANZ (2000) guidelines. In **Table B5.4.10a**, the ammonia TTV (0.46 mg/L) was not included, as even the maximum ammonia concentrations for the region did not exceed this value.

Grab samples of metals were collected during the Water Quality Monitoring campaign as part of opportunistic water quality monitoring at the locations where instruments were deployed. These samples included ammonia, nitrate and nitrite, and phosphates, as well as total nutrient concentrations. The samples were collected within the upper and lower portion of the water column, during both wet and dry seasons over spring and neap tides. **Table B5.4.10b** presents the median nutrient concentrations for the sampled locations.

Nutrient data from Dennison and O'Donohue (1994) showed median ammonia concentrations (0.05mg/L) similar to the median ammonia concentrations of Ports Northdata (0.06 and 0.08 mg/L for both subregions in Region 1). Median ammonia concentrations from the Water Quality Monitoring data were a lot lower than previously recorded, with median concentrations of 0.0015 mg/L. As a value of half the LOR was used in the analysis of this data, this median concentration represents a value of half the LOR (0.003 mg/L). All other nutrient data from the Water Quality Monitoring campaign were either at or below the WQOs.

Overall, the Ports North data show that Trinity Inlet has experienced high levels of phosphorus and ammonia in the past. Both nutrients demonstrate exceedances of the WQO. Higher nutrient concentrations are thought to be the result of intensive agricultural land use in the upstream catchments (Environment North 2005) and from sewage treatment plant discharge within the estuary (WorleyParsons 2010).

On a regional level, Devlin ***et al*** (2012) estimate that 90 percent of the nutrients entering the GBR lagoon are from terrestrial sources associated with catchment runoff. Within the Wet Tropics these nutrients are generally from fertilised agriculture (Devlin et al 2012).

Table B5.4.10a Ports North (2001-2013) Nutrient and Chlorophyll a Data Statistics

Parameter	Region	*n*	Mean	Min	Percentile				Max
					20th	50th	80th	95th	
Total Nitrogen (mg/L)	*WQO*					***0.25***			
	1a	47	0.25	0.05	0.13	0.19	0.27	0.49	1.50
	WQO					***0.25***			
	1b	95	0.24	0.05	0.10	0.16	0.25	0.50	4.60
Total Phosphorus (mg/L)	*WQO*					***0.02***			
	1a	32	0.06	0.01	0.03	*0.05*	0.07	0.13	0.18
	WQO					***0.02***			
	1b	54	0.19	0.01	0.02	*0.045*	0.08	0.20	7.2
Ammonia (mg/L)	*WQO*					***0.015***			
	1a	11	0.09	0.05	0.05	*0.06*	0.12	0.165	0.19
	WQO					***0.015***			
	1b	11	0.11	0.05	0.05	*0.08*	0.14	0.23	0.31
Chlorophyll *a* (µg/L)	*WQO*					***3***			
	1a	34	4.8	1	2	3	6	13.8	21
	WQO					***2***			
	1b	236	3.1	1	2	*3*	4	6	28

Italicized values highlighted in red represent exceedances of the WQO

Table B5.4.10b Water Quality Monitoring Program (2013) – Median (50%ile) Nutrient (mg/L) Concentrations

Region	Site	Depth	Ammonia	NOx	Total N	Ortho-P	Total P
			Limit of Reporting (LOR)				
			0.003	0.002	0.05	0.002	0.005
1b	Trinity Inlet	WQO (*TTV*)	0.015 (*0.46*)	0.02[a] (*0.7*)	0.25	0.007	0.02
		Upper	0.0015	0.001	0.15	0.001	0.016
		Lower	0.0015	0.002	0.14	0.002	0.016
2b	Trinity Bay	WQO (*TTV*)	0.002 (*0.46*)	0.002[a] (*0.7*)	0.14	0.004	0.02
		Upper	0.0015	0.002	0.10	0.001	0.011
		Lower	0.0015	0.001	0.14	0.001	0.016
3	False Cape	Upper	0.0015	0.001	0.09	0.001	0.011
		Lower	0.0015	0.001	0.11	0.001	0.015
4	Palm Beach	Upper	0.0015	0.001	0.09	0.001	0.010
		Lower	0.0015	0.001	0.08	0.001	0.010
5	Yorkeys Knob	Upper	0.0015	0.001	0.08	0.002	0.011
		Lower	0.0015	0.001	0.09	0.002	0.010
6	Cape Grafton	Upper	0.0015	0.001	0.09	0.001	0.010
		Lower	0.0015	0.001	0.08	0.002	0.011

Italicized values highlighted in red represent exceedances of the WQO

LOR is the lowest level able to be detected by the laboratory.

Note: To analyse the data, values below the LOR were assumed to be half the LOR value as per ANZECC/ ARMCANZ (2000)

[a] WQO is for combined nitrate and nitrite (oxidised nitrogen)

[b] LOR is greater than the WQO

B5.4.11 Oil and Hydrocarbons

The only oil and grease data available for this baseline characterisation is the Ports North monitoring data for Trinity Inlet. These data were collected from 1995 to 1997. **Table B5.4.11a** presents the statistical measures of the oil and grease data from this dataset.

For Ports North oil and grease monitoring data, many samples were not detected at concentrations greater than the LORs and therefore reported as 0. The actual LOR at the time of the analysis was not ascertained for this baseline characterisation. Therefore, the statistical values of the data have been summarised based only on the detected samples and the number of samples not detected for oil and grease are reported in **Table B5.411a** as ND (not detected).

Overall, the levels of oil and grease detected in Trinity Inlet are likely due to boating activities, coupled with the limited flushing capacity of the estuary.

Total petroleum hydrocarbons (TPH) were monitored during the same time period as oil and grease in the Ports North program, however, none were detected in the two-year monitoring period.

Table B5.4.11a Ports North (1995-1997) Oil and Grease (mg/L) Data Statistics

Region	*n* (ND[a])	Mean	Min	Percentile 20th	50th	80th	95th	Max
WQO					--[b]			
1a	32 (18)	0.86	0.1	0.2	0.4	1.62	2.28	2.6
1b	47 (24)	0.93	0.1	0.2	0.5	1.88	2.37	3.7

[a] ND - not detected at a concentration greater than the level or reporting, which is unknown

[b] Narrative oil and grease WQO: Oil and petrochemical should not be noticeable as a visible film on the water

B5.4.12 Pesticides

Pesticides are typically generated from agriculturally intensive land use, including forestry and orchards. Agriculture comprises approximately 13percent of the Barron River and Trinity Inlet catchments (Mitchell *et al* 2006). Pesticide measurements within Trinity Inlet and Trinity Bay are limited. Kapernick *et al* (2006) monitored for range of pesticides including diuron, atrazine, simazine, and hexazinone at the Barron River entrance and Fitzroy Island (east of Cape Grafton) for both wet and dry seasons. **Table B5.4.12a** presents the pesticide measurements at these two sites.

For diuron, simazine, atrazine, hexazinone, amtryn, and tebethiuron a total of nine samples at Fitzroy Island were collected over both wet and dry seasons, however, specific numbers per season were not provided. For the same constituents, one sample was collected at the Barron River entrance during the wet season. For chlorpyrifos, endosulfan and DDE, seven samples were collected over wet and dry seasons at Fitzroy Island and two samples were collected at the Barron River entrance over the wet season.

None of the samples were measured in excess of the Draft WQGGRBMPA (2010) trigger values.

Table B5.4.12a Kapernick et al (2006) Pesticide (μg/L) Data Statistics

Season	Pesticide	ANZECC TTV[a]	Fitzroy Island			Barron River Entrance		
			Mean	Min	Max	Mean	Min	Max
Dry	Diuron	0.9	0.0025	0.0004	0.004		--	
	Simazine	0.2	0.00009	< 0.001	0.0005		--	
	Atrazine	0.6	< 0.001	< 0.001	< 0.001		--	
	Hexazinone	1.2	< 0.001	< 0.001	< 0.001		--	
	Ametryn	0.5	< 0.001	< 0.001	< 0.001		--	
	Tebuthiuron	0.02		--			--	
	Chlorpyrifos	0.0005	< 0.00003	< 0.00003	< 0.00003		--	
	Endosulfan	0.005	< 0.0006	< 0.0006	< 0.0006		--	
	DDE	0.0005	< 0.00005	< 0.00005	< 0.00005		--	
Wet	Diuron	0.9	0.0028	0.0009	0.0058		0.0019[b]	
	Simazine	0.2	< 0.001	< 0.001	< 0.001		0.008[b]	
	Atrazine	0.6	0.00061	< 0.001	0.0016		0.0032[b]	
	Hexazinone	1.2	0.00062	< 0.001	0.0016		0.001[b]	
	Ametryn	0.5	< 0.001	< 0.001	< 0.001		< 0.001[b]	
	Tebuthiuron			--			< 0.001[b]	
	Chlorpyrifos	0.0005	< 0.00003	< 0.00003	< 0.00003	< 0.00003	< 0.00003	< 0.00003
	Endosulfan	0.005	< 0.0006	< 0.0006	< 0.0006	< 0.001	< 0.001	< 0.001
	DDE	0.0005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005	< 0.00005

[a] For slightly to moderately disturbed waters

[b] Based on one measurement

B5.4.13 Bacteria

Bacteria (faecal coliform) was measured routinely within Trinity Inlet by Ports North from 2001 to 2013. **Table B5.4.13a** presents the statistical measure of faecal coliform data from this dataset.

The median organism counts for wet and dry seasons of both regions were less than the ANZECC/ARMCANZ (2000) recreational water quality guideline for the bathing season.

Table B5.4.13a Ports North (2001-2013) Faecal Coliform (CFU/100mL) Data Statistics

Season	Region	*n*	Mean	Min	Percentile				Max
					20th	50th	80th	95th	
	WQO					***150***			
Wet	1a	25	176	< 1	14	39	160	363	2600
	1b	181	150	< 1	5	19	110	411	5900
Dry	1a	25	126	2	38	59	184	458	560
	1b	171	85	< 1	6	18	59	300	5200

B5.4.14 Perfluorinated Compounds (PFCs)

Perfluorinated compounds (PFCs) are chemical compounds often used as a component of aqueous film-forming foams (AFFFs) used for firefighting. These compounds are characterised as persistent in the environment with the potential to bio-accumulate or biomagnify. A spill of AFFFs (Tridol S3) occurred in January 2013 at a commercial premises on Draper Street in Cairns. The spill consisted of approximately 1000 L of Tridol S3 concentrate and 60,000 L of water that was discharged to the onsite stormwater system draining to Trinity Inlet close to Wharf 11/Navy Base. Approximately 21,000 L of the total volume was pumped and disposed via a trade waste contractor, resulting in an estimated 40,000 L of diluted foam being potentially discharged to Trinity Inlet.

Monitoring was undertaken by DEHP, and PFCs were detected at the discharge site just after the event. Subsequent modelling and validation sampling in April 2013 recorded PFCs at low levels, although it was noted that some of the PFCs could have originated from other sources (southern sewage treatment plant, based on chemical fingerprinting). Based on this monitoring, it was concluded that PFCs occurred at levels that represented a low risk to human health and recreational fishing, but had the potential for low level bioaccumulation and biomagnification.

Further sediment quality testing was subsequently undertaken by Ports North in April and July 2013 to verify possible extent of PFC's in sediments proposed for maintenance dredging, however, results indicated an absence of broad scale contamination and that the spill presented a low risk (also refer to **Chapter B4, Marine Sediment Quality**).

B5.4.15 Key Findings

The above sections provide an assessment of the existing baseline water quality within the study area. The key findings in regard to baseline water quality conditions can be summarised as follows:

- Dissolved oxygen levels were lower than the acceptable range for regions with a specific WQO (open coastal regions). In the remaining regions (without a specific WQO), which are defined by acceptable changes to the background DO concentrations, DO was typically low - likely from oxygen demand from other pollutants (e.g sewage effluent) within Trinity Inlet
- Median turbidity levels typically exceeded the WQOs, with median turbidity levels ranging from approximately five to 50 NTU for all regions and seasons. Peak turbidity levels range from 150 to 1,900 NTU. Ports North data for Trinity Inlet demonstrated similar turbidity values to those of the Coastal Data Collection and Water Quality Monitoring Program data for those regions
- Median TSS concentrations collected during the Coastal Data Collection in Trinity Inlet and Trinity Bay were elevated (80-95 mg/L in Trinity Inlet and 10-75 mg/L in Trinity Bay). In contrast, median TSS concentrations from the Ports North data (collected over a longer period) showed lower TSS levels in Trinity Inlet and Trinity Bay
- Seasonal assessments of TSS and turbidity for the study area as a whole do not reveal any significant variation between wet and dry season. However, there appears to be some correlation between exposure to south-easterly winds and increased turbidity for some sites (e.g Northern Beaches). Turbidity in other more protected areas (e.g Trinity Inlet, False Cape) appears to be more likely influenced by freshwater inflows during the wet season.

- Ports North data indicated that some total metals/metalloids, including tributyltin, cadmium, copper, chromium and zinc exceeded the TTV for the 95th percentile value in Region 1. The Water Quality Monitoring Program indicated some exceedances of dissolved aluminium, copper, and zinc
- Ports North data indicated elevated nutrient levels in Region 1 relative to the EPP Water WQOs for total phosphorus and ammonia, the likely source of which is STPs. In contrast, the Water Quality Monitoring Program indicated low levels of nitrogen and phosphorus.

Overall, while there are some exceedances of water quality guideline values in the study area, this is not unexpected of a marine environment located adjacent to an urban/industrialised area. The range of anthropogenic sources that influence inshore marine areas such as Trinity Inlet are common along the Queensland coast.

In regard to turbidity, the near shore areas of Trinity Bay are naturally turbid environments, especially following periods of high rainfall and sustained winds and currents. However, this is to be expected in near shore areas such as Trinity Bay with shallow water depths and muddy benthic sediments which are susceptible to re-suspension. In deeper waters further offshore, the turbidity is relatively low due to less re-suspension of bottom sediments.

B5.5 Assessment of Potential Impacts

B5.5.1 Overview

This section outlines the potential impacts the project may have on the marine water quality. This section describes:

- Potential impacts on the ambient water quality from the construction and operation of the port facilities
- Options for managing and mitigating identified impacts during both construction and operation.

In this section, potential impacts are discussed in terms of the construction and operational stages, as follows:

- Construction stage – primarily focusing on capital dredging and placement activities
- Operational stage ¬ operation of the port facilities, maintenance dredging of the inner port and entrance channel, and placement of maintenance dredge material.

A risk-based approach has been used to assess water quality impacts, and is based on the consideration of the following:

- Significance of Impact – made up of assessment of the intensity, scale (geographic extent), duration of water quality impacts and sensitivity of environmental receptors to the impact (as prescribed in the EPP Water). **Table B5.5.1a** is a summary of the categories used to define impact significance
- Likelihood of Impact – which assesses the probability of the impact occurring. **Table B5.5.1b** 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 table (**Table B5.5.1c**) adopted is generated from the Significance and Likelihood scores, based on the overall matrix presented in Part A.

Table B5.5.1a Categories Used to Define Significance of Impact (Water Quality)

Impact Significance	Description for Water Quality (includes magnitude, duration, and sensitivity of receiving values)
Very High	Permanent change in the ecosystem for Trinity Inlet and Trinity Bay and surrounds resulting from changes to water quality due to direct impacts of the construction or operational phases of the project and associated activities. Generally corresponds to the 'Zone of High Impact' in terms of dredge-related turbidity as per **Section B5.5.2** below.
High	Water quality in Trinity Inlet and Trinity Bay and surrounds is permanently altered due to direct impacts of the construction or operational phases of the project and associated activities such that the scheduled Environmental Values and Water Quality Objectives are no longer achievable if currently being achieved, or are prevented from being achieved in the future if currently not being achieved. Generally corresponds to the 'Zone of High Impact' in terms of dredge-related turbidity as per **Section B5.5.2** below.

Impact Significance	Description for Water Quality (includes magnitude, duration, and sensitivity of receiving values)
Moderate	Water quality in Trinity Inlet and Trinity Bay and surrounds is temporarily altered due to direct and indirect impacts of the construction phase of the project and associated activities such that the scheduled Environmental Values and Water Quality Guidelines are no longer achievable if currently being achieved, or are prevented from being achieved in the future if currently not being achieved. Generally corresponds to the 'Zone of Low to Moderate Impact' in terms of dredge-related turbidity as per **Section B5.5.2** below.
Minor	Water quality in Trinity Inlet and Trinity Bay and surrounds is temporarily impacted such that mitigation measures prevent changes to water quality over an annual period, though short-term exceedances may occur during construction activities. Generally corresponds to the 'Zone of Low to Moderate' Impact in terms of dredge-related turbidity as per **Section B5.5.2** below.
Negligible	No detectable impacts on the water quality in Trinity Inlet and Trinity Bay and surrounds through the use of effective mitigation measures during the construction and operational phases and no perceptible change to long-term water quality through altered flow regimes or other hydrologic changes resulting from the project. Generally corresponds to the 'Zone of Influence' in terms of dredge-related turbidity as per **Section B5.5.2** below.
Beneficial	Existing water quality is improved in Trinity Inlet and Trinity Bay and surrounds due to altered flow regimes, hydrological changes or operational phase mitigation measures.

Table B5.5.1b Categories used to Define Likelihood of Impact (Water Quality)

Likelihood	Categories
Highly Unlikely/Rare	Highly unlikely to occur but theoretically possible.
Unlikely	May occur during construction/life of the project but probability well <50percent; unlikely but not negligible.
Possible	Less likely than not but still appreciable; probability of about 50percent.%.
Likely	Likely to occur during construction or during a 12 month timeframe; probability >50percent.
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 B5.5.1c 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 B5.5.1d 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

B5.5.2 Impact Assessment Methods and Threshold Values

The typical approach to assessing the predicted impacts from construction and operations works is to assess compliance against water quality guideline values (such as the EPP Water). This method allows a direct comparison of the likely compliance with established guidelines to ensure protection and/or enhancement of environmental values for the waters of concern.

As the capital dredging works are anticipated to occur over a span of 21-34 weeks (depending on the dredge plant used and not including mobilisation and demobilisation), impacts over this sub-annual scale cannot be meaningfully compared for compliance against annual median water quality guidelines. Specifically, calculation of an annual median from only 21-34 weeks of impact would result in underestimation of potential impacts.

Given this, three levels of assessment were undertaken to support assessment of the potential impacts from the dredging works. Firstly, median concentrations for the dredging campaign were assessed against water quality guideline values. Although it is acknowledged (as above) that this approach is not strictly precise, it does provide a high level 'screening' type assessment tool to allow rapid identification of potential impacts, worthy of subsequent rigorous assessment.

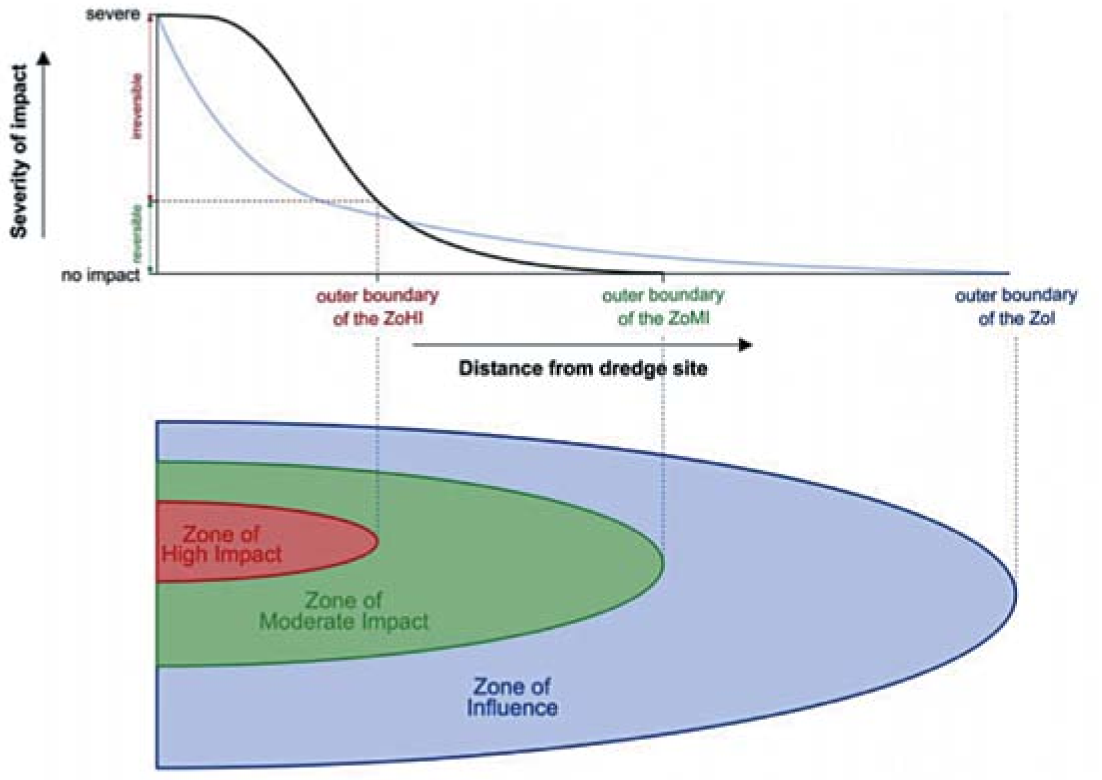
Secondly, percentile exceedance plots of dredging related turbidity are presented. These percentile plots are direct outputs from the modelling, and provide an indication of excess turbidity from dredging activities (these plots are discussed further in Section B5.5.3). Additionally, time series plots of modelled turbidity at particular locations are presented. These plots are separated out into ambient turbidity natural re-suspension and dredge-related turbidity for the modelling period. This was undertaken to aid in the assessment of impacts at particular locations by identifying the proportion of turbidity originating naturally and from dredging works.

Thirdly, project-specific threshold values were developed to assess potential impacts to marine water quality and ecologically sensitive areas (refer to **Chapter B7, Marine Ecology**). These impact predictions are presented as 'zones of impact' as per the Commonwealth EIS Guidelines and GBRMPA Modelling Guidelines, and are derived using the percentile exceedance plots described above. The zones of impact, which are generally based on dredging environmental assessment guidelines produced by the WA EPA (2011), include the following:

- Zone of High Impact = water quality impacts resulting in predicted mortality of ecological receptors with recovery time greater than 24 months.
- Zone of Low to Moderate Impact = water quality impacts resulting in predicted sub-lethal impacts to ecological receptors and/or mortality with recovery between 6 months (lower end of range) to 24 months (upper end of range).
- Zone of Influence = extent of detectable plume, but no predicted ecological impacts.

A concept design of the zones of impact (sourced from WA EPA 2011) are shown in **Figure B5.5.2a**.

Figure B5.5.2a Concept Design of Impact Zones (WA EPA 2011)



To determine the threshold values to delineate the zones of impact, a combination of water quality (turbidity) and biological tolerances methods was used. This entailed using baseline water quality monitoring data to set initial threshold values. These values were then compared to biological tolerances from literature values as a 'reality check' to confirm that the threshold values are biologically meaningful.

B5.5.2.1 12-Month Baseline Water Quality Data

As described in Section B5.4.2, continuous turbidity data (and other parameters) were collected over a 12-month period (July 2013 to July 2014) at six sites generally representing sensitive ecological receptor locations. The locations of these sites are shown in **Figure B5.4.4a** and include:

- Palm Cove Beach (Site1) – generally representing corals at Double Island
- Yorkeys Knob (Site 2) – generally representing Northern Beaches
- Trinity Bay (Site 3) – generally representing historical subtidal seagrass areas
- Trinity Inlet (Site 4) – generally representing remnant seagrass in Trinity Inlet
- False Cape (Site 5) – generally representing historic seagrass areas near False Cape
- Cape Grafton (Site 6) – generally representing corals in Mission Bay.

Additionally, 12-month monitoring of turbidity was undertaken as part of the Coastal Data Collection program (**Section B5.4.2**) from February 2013 to February 2014 near the existing DMPA.

The 12-month monitoring data set underwent a quality control process whereby periods of data were quarantined to ensure the data represented baseline conditions. Periods of data were quarantined if the following occurred during the monitoring period:

- Obvious signs of sensor bio-fouling
- Equipment failure
- Periods of dredging
- Any unusually large rainfall events (i.e. larger than one in five year recurrence interval).

Overall the data quality was reasonably good, with approximately 10 percent quarantined due to bio-fouling and periods of equipment failure. The majority of this quarantined data was due to equipment failure at three sites in December 2013. Further to this, a period of maintenance dredging between 21 July 2013 and 17 July 2013 was quarantined from the data, representing a further eight percent of the collected data. As there were no unusually large rainfall events which occurred during the monitoring period, data did not need to be quarantined in this regard. Therefore, approximately 18 percent of the data was quarantined in total (i.e. 82 percent of collected data was retained as good quality baseline data).

After the quality control process was complete, the 12-month monitoring data set included approximately 50,000 turbidity data points at each monitoring site across the wet and dry season.

Further information in regard to the 12-month baseline water quality monitoring program is provided in **Appendix D3, Coastal Data Collection Report**.

B5.5.2.2 Impact Assessment Threshold Values

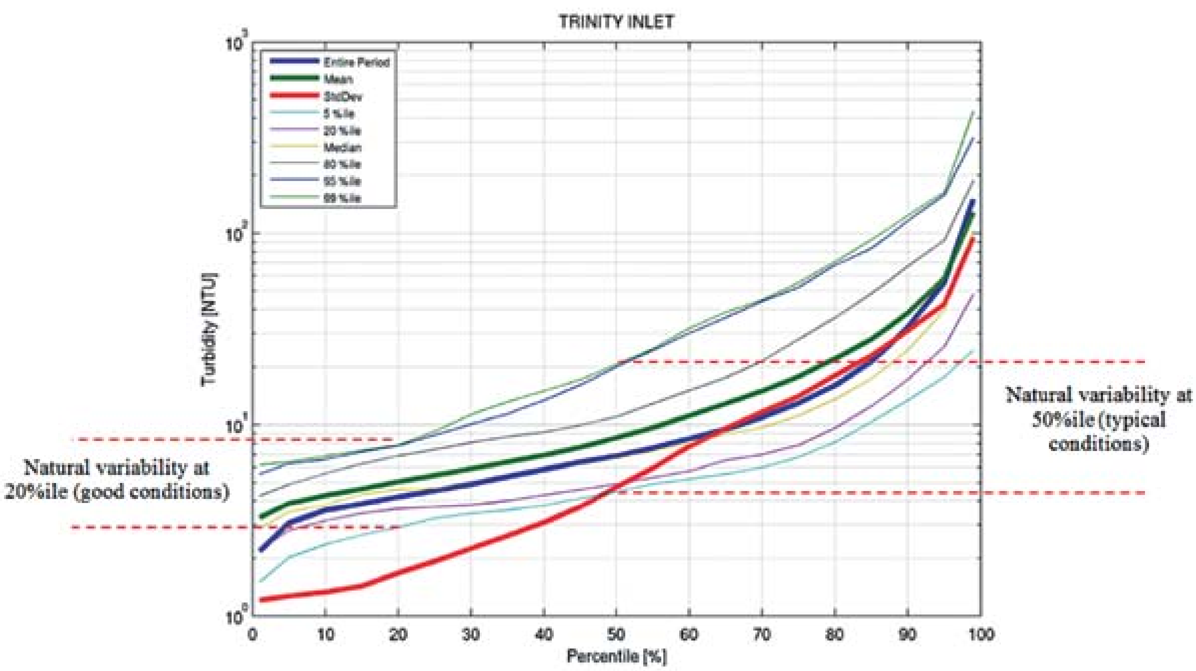
As the long-term data shows variability in turbidity among sites during the same time period, site-specific impact assessment thresholds were deemed more appropriate than a 'one size fits all' approach. To determine initial impact assessment threshold values, the 12-month baseline water quality monitoring data set was analysed and percentile curves were produced. These percentile curves provide an indication of magnitude of turbidity and combined duration/ frequency metrics for a range of conditions.

The 12-month baseline data was analysed over a moving 30-day window to give a range of percentile values over different periods. The 30-day window period is somewhat arbitrary but in a physical hydrodynamic context represents the approximate duration of two consecutive spring-neap tidal cycles. The 30-day moving window analysis was undertaken by moving the 30 day window by 10-day increments over the entire monitoring period (approximately 34 different 30-day periods). This method provides an indication of natural variability around each percentile value and provides context for excess turbidity from dredging.

As an example, **Figure B5.5.2.2a** shows the percentile curves for data collected at Trinity Inlet. This shows the natural variability measured around the median (50th percentile) and other percentile values. The x-axis in **Figure B5.5.2.2a** represents the different percentile values extracted from the moving 30-day window analysis moving from frequently exceeded on the left to rarely exceeded on the right. The different curves are statistics representing the variability of the percentile analysis results across the different 30-day periods (making up the 12-month baseline monitoring period). The lower curve represents the least turbid conditions experienced across the 12-month period while the upper limit is conversely the most turbid conditions. The solid green line is the mean of the different 30-day window conditions.

Percentile curves for all monitoring sites are included in **Appendix B5a**, located at the end of this chapter, and summary statistics of the monitoring data is included in **Appendix B5b**, located at the end of this chapter.

Figure B5.5.2.2a Example Summary Analysis of Baseline Data for Site 4 at Trinity Inlet



Threshold values were derived from these percentile curves based on the natural variability around the 50th percentile (average conditions), 20th percentile (good conditions – low wind and waves) and the 80th percentile (poor conditions – moderate to high wind and waves). Therefore, this method considers both acute and chronic impacts.

A description of the threshold values for the three zones of impact and how they relate to the natural variability is provided in **Table B5.5.2.2a**. The approach used to determine the threshold level for the 'zone of low to moderate impact' (i.e. when water quality extends beyond natural variation and impacts to ecological receptors may begin to occur) involve using one standard deviation from the natural background mean at each percentile (i.e. 20^{th}, 50^{th} and 80^{th} percentiles). This is a similar approach developed by Orpin et al. (2004) to assess impacts from construction-related turbidity increases in Townsville. Orpin ***et al.*** (2004) suggested using one standard deviation from ambient conditions as a possible conservative upper limit of an acceptable increase in turbidity. Orpin ***et al.*** (2004) noted that the standard deviation of natural turbidity levels was considered to be a reasonable and convenient envelope within which an allowable construction-related increase could occur. If construction-related turbidity (such as from dredging) remained within one standard deviation, Orpin ***et al.*** (2004) suggested it would not be detectable over and above the natural variability.

Extending this method out, threshold levels for the 'zone of high impact' were determined using three standard deviations from the mean.

The 'zone of influence' was defined as the probable maximum extent of detectable plumes due to the proposed dredging. Turbid plumes were conservatively assumed to become detectable once they were 10percent above background conditions. Therefore, to determine the extent of this zone, the following method was used:

- Modelled dredging-related turbidity was compared to modelled ambient turbidity level, and areas where dredging-related turbidity was greater than 10 percent above modelled ambient turbidity for more than five percent of the time were designated as the 'zone of influence'
- As 10 percent of ambient turbidity could result in very low turbidity values (especially in offshore waters), any value below one NTU was considered as being below detectable limits and disregarded from the output of the above analysis.

Descriptions of the zones of impact and how they relate to water quality (turbidity) thresholds are included in **Table B5.5.2.2a**. Also included in this table are biological tolerance values for seagrass provided by James Cook University (JCU). Only biological tolerances for seagrass are included as corals are too variable among species and sites to define at this stage. The purpose of these biological tolerances is to test the impact zone predictions developed using water quality (turbidity) thresholds, and are not intended to be used for light-based thresholds. Locally relevant and tested light thresholds for seagrass would need to be developed following further monitoring before the dredging campaign.

Table B5.5.2.2a Description of Impact Assessment Threshold Values

Zone of Impact	Water Quality (Turbidity)	Biological Tolerances (Seagrass)
Zone of High Impact	Excess turbidity causes total turbidity to go beyond natural variation. Threshold value = excess turbidity greater than three standard deviations from the natural background mean.	LR[#] for *Zostera* (4.5-12 mol/m^2/day rolling two week average) is not met for more than six weeks. LR for *Halophila ovalis* (2.8-4.4 mol/m^2/day)[##] not met during the growing season (July-December) for more than 21 days. Resulting in total loss of seagrass and no recovery within one year (reliant on new recruitment).

Zone of Impact	Water Quality (Turbidity)	Biological Tolerances (Seagrass)
Zone of Low to Moderate Impact	Excess turbidity may push total turbidity beyond natural variation. Threshold value = excess turbidity greater than one standard deviation from the natural background mean.	LR for ***Zostera*** (4.5-12 mol/m^2/day rolling two week average) is not met for one week (low impact) to six weeks (moderate impact) LR for ***Halophila ovalis*** (2.8-4.4 mol/m^2/day) not met for one week (low impact) to three weeks (moderate impact) during the growing season (July-December). Resulting in declines in seagrass but some recovery within one month likely for moderate impacts; management action can avoid declines in seagrass cover for low impacts.
Zone of Influence	Extent of detectable plumes. Dredging related turbidity exceeds 10 per of the ambient turbidity level for more than 5percent of the time.	Light does not fall below the LR for ***Halophila ovalis*** (2.8-4.4 mol/m^2/day) for more than seven consecutive days. Light does not fall below the LR for ***Zostera*** (4.5-12 mol/m^2/day) for more than seven consecutive days.

Notes:

[#] LR = Light Requirement

[##] Collier et al 2009 lab experiments found significant loss of H ovalis after 14 days below LR and based on lab experiments determined a light requirement of 4.4 mol/m^2/day. JCU work in Gladstone also noted declines of ***Halophila ovalis*** in shaded treatments within two weeks

The output from the analysis of data was turbidity (NTU) impact assessment threshold values for each impact zone at each monitoring site. These values represent turbidity above background levels, and are included in **Table B5.5.2.2b**. It should be noted that with the use of these impact threshold values, an assumption has to be made in regard to what constitutes 'background turbidity'. For the purposes of this impact assessment, background turbidity is assumed to be the mean turbidity of background data at each percentile (i.e. 20 percentile mean, 50 percentile mean and 80 percentile mean – refer to **Figure B5.5.2.2a**).

Important to note is that the threshold values presented in **Table B5.5.2.2b** have been used for impact assessment purposes only, and are not proposed as trigger values during dredging. Turbidity trigger values during dredging will be developed following further monitoring before the dredging campaign, as per **Chapter C2, Dredge Management Plan**.

Table B5.5.2.2b Turbidity Threshold Values (Above Background) for Impact Assessment Purposes

Impact Zone	Description	Method	Percentile	Descriptor	Palm Cove	Yorkeys Knob	Trinity Bay	Trinity Inlet	False Cape	Cape Grafton	DMPA
					Turbidity Threshold Values (NTU) - *above background*						
Zone of High Impact	Excess turbidity definitely pushes total turbidity beyond natural variation.	3 x standard deviations from 20%ile mean.	20 percentile	Exceeded 80percent of the time.	33	24	30	6	36	30	3
		3 x standard deviations from 50%ile mean.	50 percentile	Exceeded 50 percent of the time.	48	39	66	15	75	123	6
		3 x standard deviations from 80%ile mean.	80 percentile	Exceeded 20 percent of the time.	69	75	183	54	399	327	15
Zone of Low to Moderate Impact	Excess turbidity may push total turbidity beyond natural variation.	One standard deviation from 20%ile mean.	20 percentile	Exceeded 80 percent of the time.	11	8	10	2	12	10	1
		One standard deviation from 50%ile mean.	50 percentile	Exceeded 50 percent of the time.	16	13	22	5	25	41	2
		One standard deviation from 80%ile mean.	80 percentile	Exceeded 20 percent of the time.	23	25	61	18	133	109	5
Zone of Influence	Full extent of detectable plumes (including re-suspension).	Dredging related turbidity exceeds 10percent of background turbidity.	95 percentile	Exceeded more than 5 percent of the time.	10 percent above background conditions (minimum value one NTU)						

To test whether the zones of impact developed using turbidity thresholds in **Table B5.5.2.2b** are biologically meaningful, the turbidity thresholds were added to actual PAR monitoring data (April-December 2013) for three intertidal sites known to previously contain seagrass and monitored by JCU. Their locations are shown in **Figure B5.4.4a** and include the following:

- Site A – Ellie Point
- Site B – Esplanade
- Site C – Bessie Point.

The aim of this analysis was to assess the amount of PAR available to these seagrass areas if additional turbidity as per the turbidity impact thresholds was added to the measured PAR data. The aim was to simulate a hypothetical scenario whereby a dredge would be operating with turbid plumes being created at these threshold values (note that in reality, a dredge would not be operating for this entire period). An outcome of this analysis, for example, should be that PAR available to seagrass after adding the low to moderate turbidity threshold (22 NTU) should only result in predicted low to moderate impacts and not high impacts (i.e. seagrass mortality).

To undertake this analysis, it was necessary to use the preliminary turbidity/PAR relationship described in **Section B5.4.8** to convert between PAR and turbidity. As mentioned in previous sections, the relationship between the currently available turbidity and PAR data is relatively weak, and therefore the conversions presented in this section should be considered as indicative only at this stage. Further turbidity and PAR monitoring prior to commencement of dredging could be used in an attempt to strengthen this relationship.

The threshold values applicable to the intertidal seagrass areas include those for Trinity Bay (**Table B5.5.2.2b**). The 50^{th} percentile values were used as this allowed a relatively simple addition of excess turbidity to the time series PAR data.

Two week rolling averages of the derived PAR data for each of the three monitoring sites are presented in **Figure B5.5.2.2b**, which also shows baseline monitoring data (actual recorded data). As there are no defined threshold values for the zone of influence (10 percent above background), this zone is not shown on the graphs. However, it can be assumed that light levels in the zone of influence would be somewhere between the baseline and the low to moderate threshold.

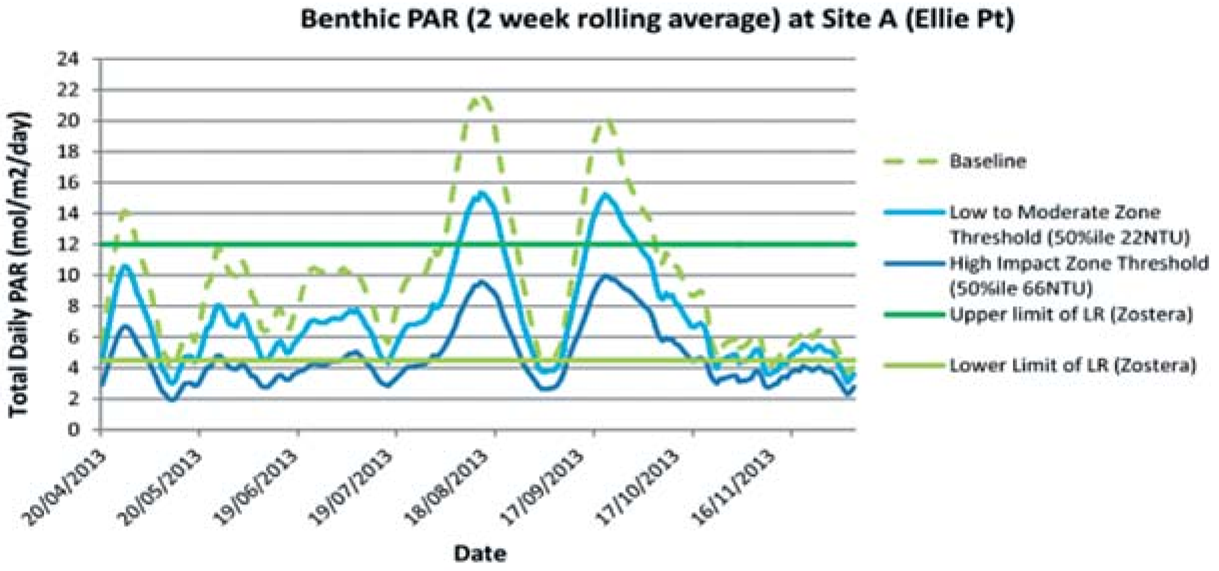
As *Zostera* is the seagrass species found in the intertidal areas, the results were compared to the biological tolerances for Zostera in **Table B5.5.2.2a**. The results indicate that:

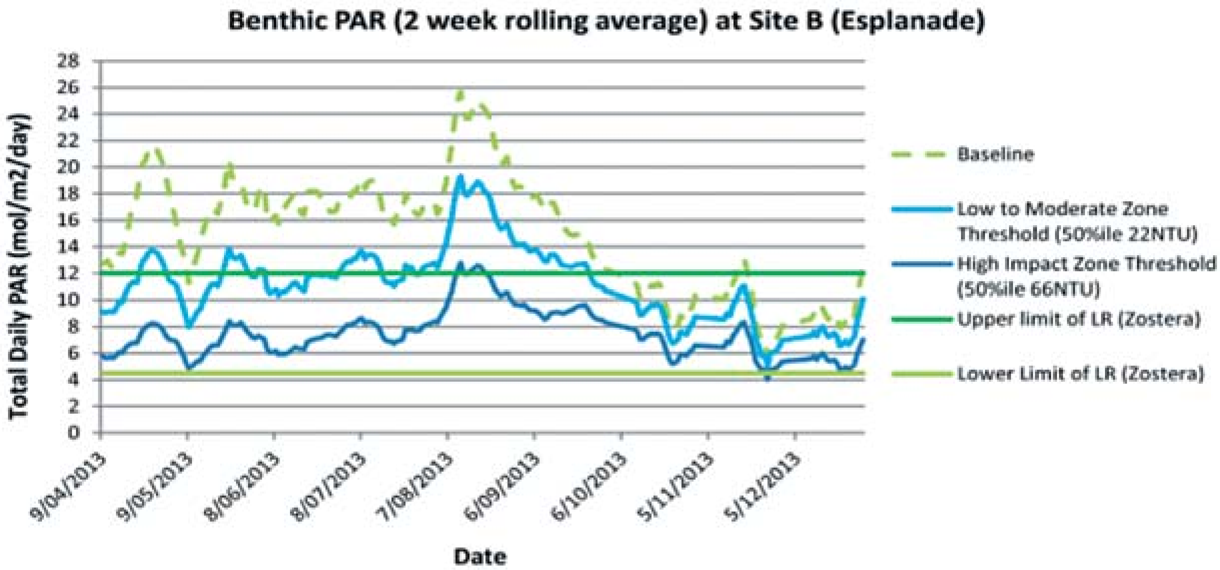
- Using the high impact zone threshold (66 NTU), there would be periods at sites A and C when PAR would be below the Zostera light requirement for longer than six weeks – this would potentially result in total loss of seagrass (as expected of this zone)
- Using the low to moderate zone threshold (22 NTU), there would be short periods (one-six weeks) when PAR would be below the Zostera light requirement, but PAR would remain mostly within the light requirement range
- The zone of influence (no predicted impacts) would be in the range between the baseline and the low to moderate threshold. As indicated in **Figure B5.5.2.2b**, PAR in this range would remain above the lower limit light requirement for most of the simulated period (especially during the growing season of July-December).

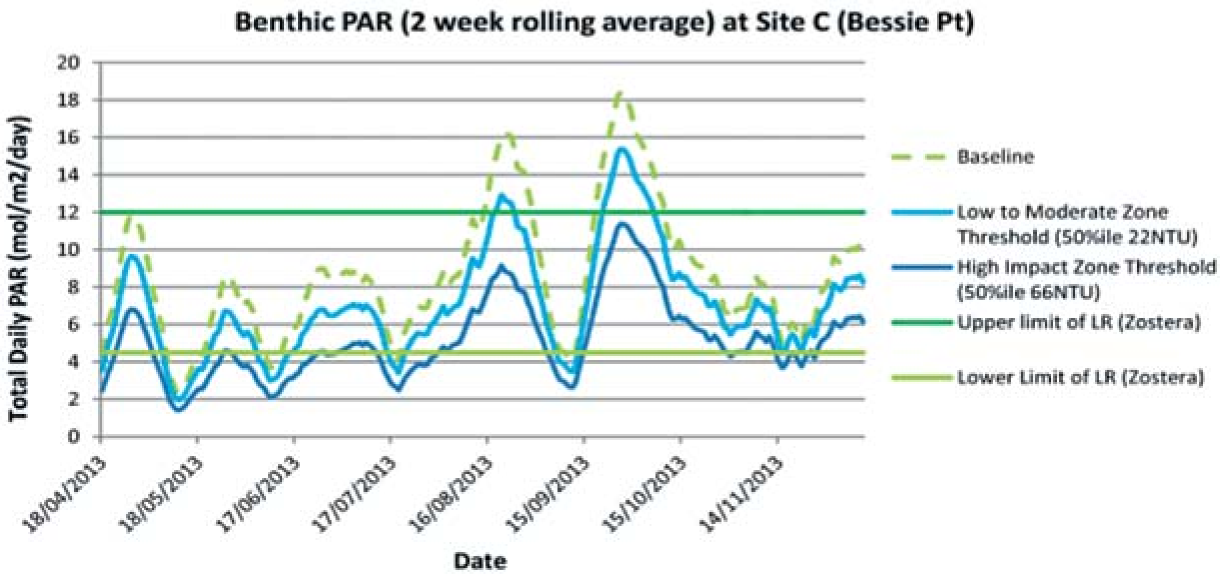
At Site B, PAR would remain within the light requirement range even using the high impact zone thresholds. This indicates the turbidity thresholds are on the conservative side.

Therefore, based on this analysis, the zones of impact derived using the turbidity threshold values in **Table B5.5.2.2b** are considered to be suitable for impact assessment purposes.

Figure B5.5.2.2b Total Daily PAR (mol/m2/day as two week rolling average) at Intertidal Seagrass Monitoring Sites (A, B and C) showing Baseline (actual monitoring data), Addition of Low to Moderate Zone Threshold (22 NTU) and High Impact Threshold (66NTU)







B5.5.3 Modelling Outputs

To assist with the impact assessment, dredge plume modelling results from **Appendix D4, Water Quality Model Development and Calibration Report** were used. These modelling results consist of time series results and percentile contour plots. Percentile contour plots presented in this chapter represent dredge-related turbidity above background. Percentile contour plots showing modelled ambient turbidity (without dredging) are provided in **Appendix D4, Water Quality Model Development and Calibration Report**.

Similar to the analysis of baseline monitoring data, the percentile contour plots were developed using a 30-day moving window. The percentile impacts correspond to the maximum increase due to dredging of the 30-day moving window derived percentile statistics during the entire simulation. Different locations within the model will have experienced their worst period at different times during the simulation and the different percentile statistics may also have occurred during different 30-day windows. Key features of the 30-day moving window percentile analysis include:

- Consideration of a range of impact durations from acute to chronic
- Can be applied to a long-term program and capture periods of high intensity versus low intensity impacts
- A similar analysis applied to the baseline data can quantify the ambient conditions including natural variability across different periods. This can be used to derive meaningful thresholds for the impacts.

When interpreting percentile contour plots presented throughout this chapter, it is important to note that these are not snap-shots in time and therefore do not represent the spatial extent of the dredge plume at any given time. Instead, these plots indicate the areas where turbidity was elevated at some point during the dredge campaign. The type of percentile plot (e.g. 50th percentile or 95th percentile) indicates the amount of time that the turbidity was exceeded at a particular location.

Percentile contour plots included in this chapter represent depth averaged turbidity (i.e. turbidity averaged vertically in the water column from surface to sea bed). Percentile plots also showing near-bed turbidity are presented in **Appendix D4, Water Quality Model Development and Calibration Report**.

Further details on modelling outputs and assumptions are provided in **Appendix D4, Water Quality Model Development and Calibration Report**.

B5.5.4 Construction Phase Impacts – Turbid Plumes from Capital Dredging and Marine Placement

The key capital dredging activities that have the potential to impact on marine water quality include the following:

- Capital dredging of the outer channel (widening and deepening), inner port and swing basins
- Placement of dredge material at the marine DMPA.

Potential water quality impacts on the marine environment associated with stormwater runoff or potential land-based spills are addressed in **Chapter B6, Water Resources**.

A detailed methodology for the project is provided in **Part A** of the EIS. **Chapter B4, Marine Sediment Quality** provides the results of the sediment quality investigations that characterise the material to be dredged.

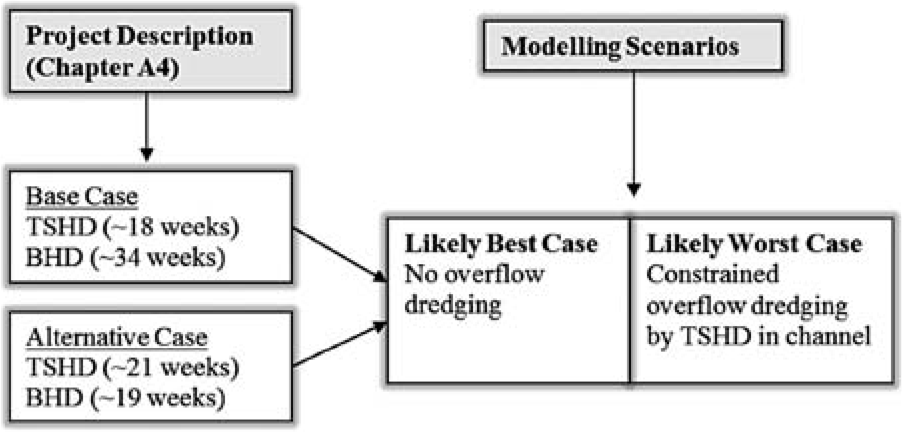
The principal concern regarding water quality for the project is from the release of sediment particles to the water body during the capital dredging program. Turbid plumes may occur to some extent as a result of dredging activities.

The proposed capital dredging using a mechanical backhoe dredge (BHD) and a trailer suction hopper dredge (TSHD) may generate turbid plumes. The turbid plumes have the potential to migrate and impact upon nearby sensitive ecological receptors by reducing light levels required for photosynthesis and smothering of plants and animals. The extent of the plume will depend on a range of factors including season, wind strength and direction, currents, tide status, location and type of dredge, as well as working methods and productivity.

The modelling described in the **Chapter B3, Coastal Processes** and **Appendix D4, Water Quality Model Development and Calibration Report** predicts turbidity above background levels. This modelling includes re-suspension of sediments generated by dredging and dredge material placement. Modelling assumptions are described in detail in **Appendix D4, Water Quality Model Development and Calibration Report**, and these assumptions have been built into the modelling of a ‘likely best-case’ (including a base case and alternative case) and ‘likely worst-case’ scenario (refer to **Figure B5.5.4a**). As dredging is expected to occur during the dry season, modelling was only undertaken for the dry season (March-October).

The difference between the base case and the alternative case within the likely best-case scenario is the use of different dredging equipment in the inner port. These cases represent the likely best case as they assume no overflow during the dredging, while the likely worst case includes constrained overflow during dredging.

Figure B5.5.4a Conceptual Diagram of Modelling Scenarios



The impact assessment of turbid plumes from capital dredging has been undertaken using the following process:

- A high level screening assessment against water quality guidelines and baseline data
- Assessment of percentile exceedance plots and time series plots showing natural turbidity and dredge related turbidity
- Assessment using impact threshold values and impact zones.

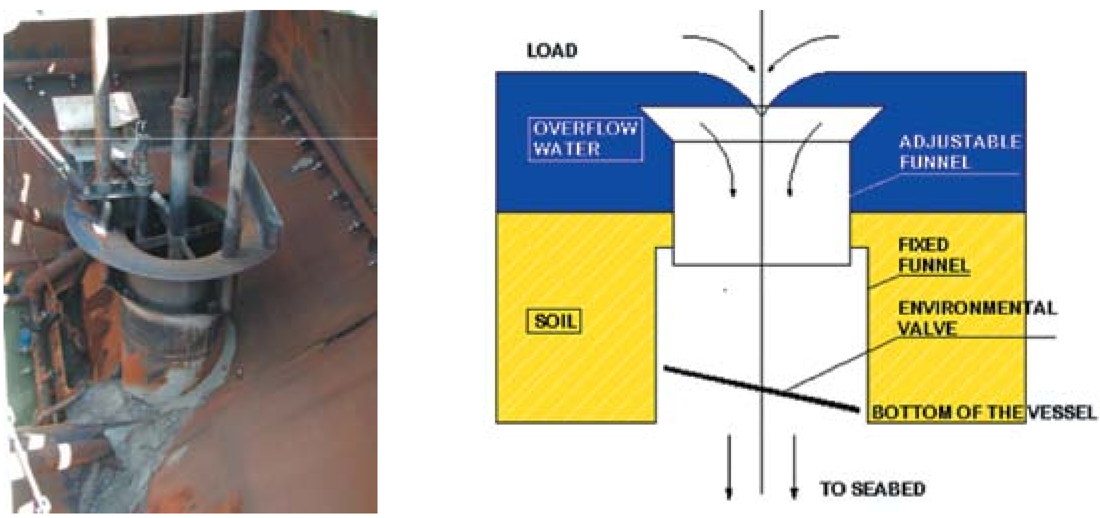
B5.5.4.1 Overflow Dredging

The base case and alternative case dredging scenarios discussed in the following sections assume that dredging will be undertaken without overflow, while the worst-case dredging scenarios assume a limited amount of overflow (i.e. constrained overflow).

Dredging with overflow refers to the release of sediment-laden supernatant water back into the water column once the hopper in a TSHD has reached a certain level. Dredging with overflow allows the TSHD to continue to dredge and fill the hopper with dredged sediments. The discharge of overflow is typically via funnel type structures within the hopper which release the overflow under the keel of the TSHD (**Figure B5.5.4.1a**).

For the project, the type of dredge material (i.e. mostly soft silts and clays) enables the TSHD to operate without overflow with minimal adverse impact on productivity, and positive environmental benefits due to reduction of turbid plumes at the dredge site. This is why the base case and alternative case scenarios assume no overflow. As there may be areas of stiff clays which could require dredging with overflow in order to maintain efficient hopper loads, the worst-case scenario was developed with an assumption that constrained overflow dredging may be required.

Figure B5.5.4.1a Overflow Funnel in a TSHD Hopper – Photo (top) and Schematic (bottom)



B5.5.4.2 Likely Best Case - Base Case Scenario (No Overflow)

The base case capital dredging scenario is based on TSHD dredging of all very soft, soft and firm clay material in the outer channel and BHD dredging of all material in the inner port. The total in-situ volume removed by the TSHD in this scenario is 3,585,000 m^3, with the remaining 764,000 m^3 is accounted for by the BHD. The duration of TSHD dredging would be approximately 18 weeks (not including mobilisation and demobilisation) while the BHD component would actively dredge for around 34 weeks.

The base case capital dredging scenario assumes no overflow dredging from the TSHD. Further details on the base case scenario are included in **Appendix D4, Water Quality Model Development and Calibration Report**.

Along with the base case scenario, an alternative case scenario was modelled and is discussed in **Section B5.5.4.3**. This alternative case scenario differs to the base case in that instead of a BHD dredging all material in the inner port, a TSHD would dredge all the soft material in the inner port while a BHD would dredge the areas of stiff material. However, the ability to undertake inner port dredging by a TSHD (as opposed to a BHD) will depend on a range of factors including greater knowledge of geotechnical conditions and in situ density of the material present, logistics and manoeuvrability of the dredge. Therefore, the most likely dredging scenario is expected to be somewhere between the base case and alternative case scenarios, depending on findings from detailed geotechnical investigations during detailed design. Both cases have been assessed in terms of potential impacts on the environment to provide flexibility and assurances that both methodologies would be acceptable.

Screening Assessment against Water Quality Guidelines and Baseline Data

An initial high level screening assessment of the potential impacts to median water quality concentrations based on the modelling data was undertaken for the sensitive ecological receptor sites where baseline monitoring was undertaken (refer to **Figure B5.4.4a** for locations).

Results for this approach are presented in **Table B5.5.4.2a**, which shows potential increases to median concentrations at the water quality monitoring locations. As dredging is expected to occur during the dry season, ambient median turbidity values during the dry season are used.

Table B5.5.4.2a Predicted Impact to Median Turbidity at Sensitive Receptor Locations (Base Case)

Monitoring Site	Location	Water Quality Region	Water Quality Conditions	Median Turbidity (NTU)
Site 1	Palm Cove Beach	Region 5	Increase above ambient	0.2
			Ambient condition	19
Site 2	Yorkeys Knob	Region 5	Increase above ambient	0.8
			Ambient condition	19
Site 3	Trinity Bay	Region 2b	Increase above ambient	1.8
			Ambient condition	16
Site 4	Trinity Inlet	Region 1b	Increase above ambient	0.2
			Ambient condition	12
Site 5	False Cape	Region 3	Increase above ambient	0.8
			Ambient condition	28
Site 6	Cape Grafton	Region 6	Increase above ambient	0.1
			Ambient condition	31
DMPA	Existing DMPA	Region 4	Increase above ambient	6
			Ambient condition	6
QWQG (annual)				10

Note: Shaded cells indicate exceedance of the QWQG guideline value

The results in **Table B5.5.4.2a** indicate that capital dredging will only minimally increase median turbidity values (up to 11 percent increase) at all near shore locations compared to ambient conditions. In offshore waters near the DMPA, the median value is predicted to increase by approximately 100 percent (six NTU up to 12 NTU). Therefore, while capital dredging as part of the base case is not likely to cause significant impacts to near shore areas in terms of median turbidity, less turbid offshore areas in the vicinity of the DMPA may experience greater impacts. As such, further assessment is undertaken and discussed in the following sections.

Percentile Plots

The following percentile contour plots (**Figure B5.5.4.2b** and **Figure B5.5.4.2c**) show depth averaged dredging-related turbidity above background levels. Note that the scales used on the plots differ between the 50th and 80th percentiles to reflect ambient turbidity during these varying conditions. Plots shown are based on the following percentile values:

- 50th percentile plot (**Figure B5.5.4.2b**) - typical (median) turbidity levels, which occur 50 percent of the time
- 95th percentile plot (**Figure B5.5.4.2c**) - infrequent periods (occurring five percent of the time) of high turbidity.

For context, a percentile contour plot showing modelled ambient turbidity (without dredging) during 95th percentile conditions is provided in **Figure B5.5.4.2a**. Further modelled ambient turbidity plots are included in **Appendix D4, Water Quality Model Development and Calibration Report**.

Figure B5.5.4.2b indicates that as a result of capital dredging as per the base case scenario, median (50th percentile) turbidity is predicted to increase slightly (up to two NTU) along the northern coastline up to Yorkeys Knob. The greatest increase to median turbidity is predicted to be within the outer channel dredging area and at the proposed DMPA, which are predicted to increase by approximately six NTU at both locations. **Figure B5.5.4.2c** indicates that under 95th percentile conditions, turbidity is predicted to increase by approximately 10-20 NTU above background conditions (approximately 100-150 NTU) in close proximity to the outer channel dredging area and the DMPA.

Due to the predominant north-easterly wind and wave direction in the area (**Chapter B3, Coastal Processes**), turbid dredge plumes are not predicted to mobilise in a southerly direction towards False Cape and Cape Grafton.

The impact significance of these results is interpreted using time series plots and zones of impact in the following section.

Figure B5.5.4.2a 95th Percentile of Modelled Ambient Turbidity (without dredging)

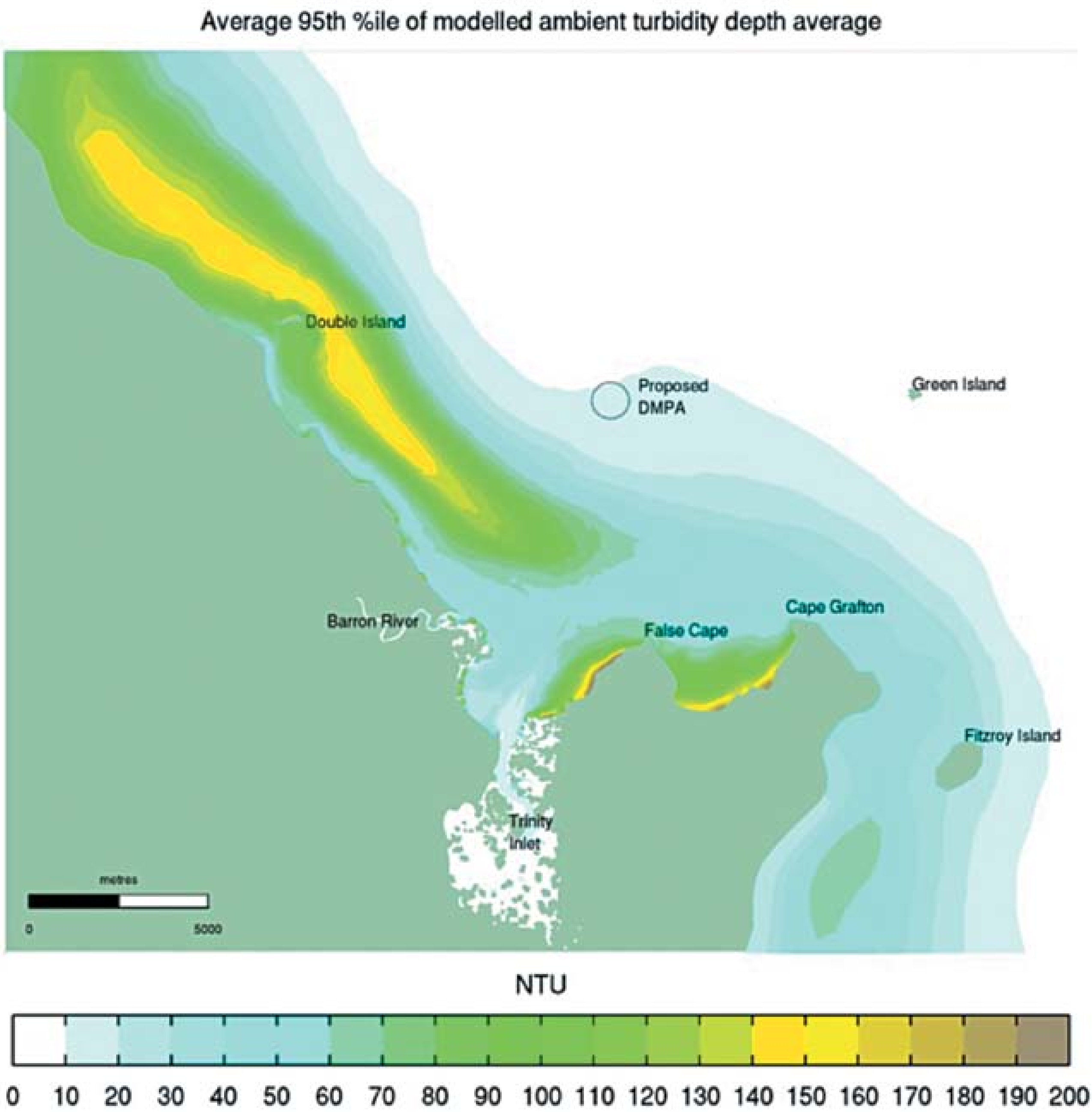


Figure B5.5.4.2b Impact of Dredging on 50th percentile Turbidity *(scale: 2 to 40 NTU)*

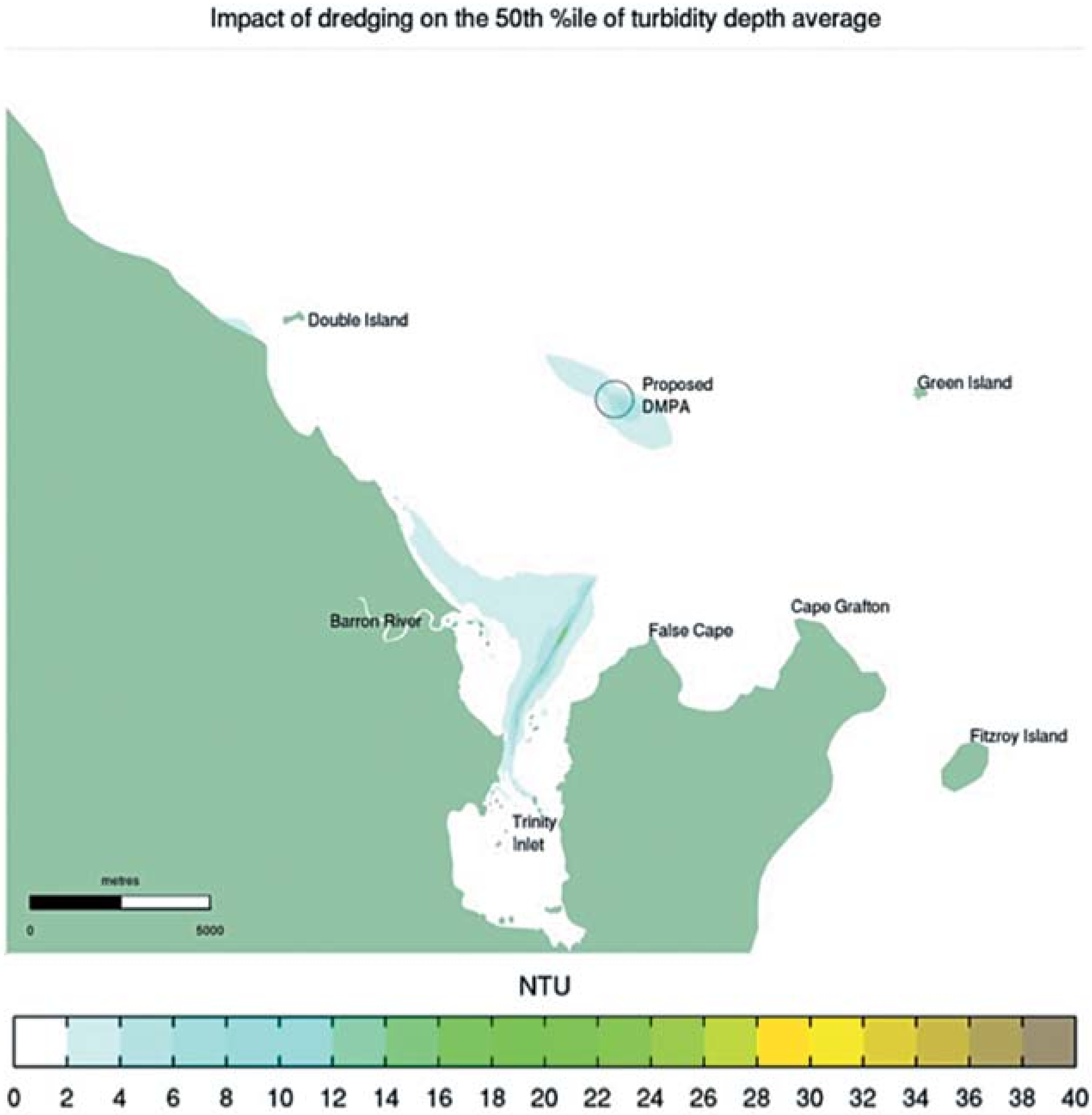
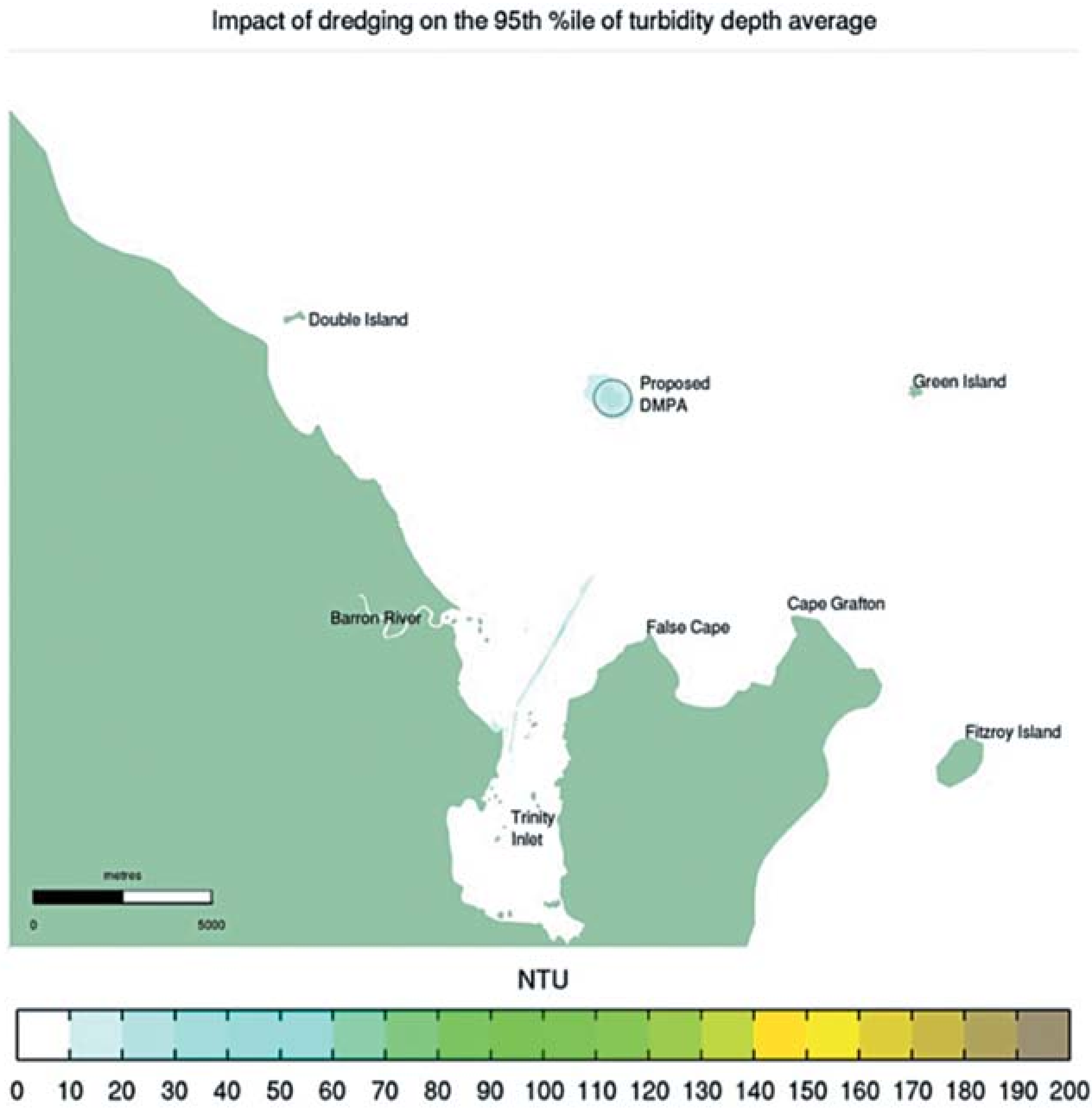


Figure B5.5.4.2c Impact of Dredging on 95th percentile Turbidity *(scale: 10 to 200 NTU)*



Time Series Plots

The above sections presented the turbid plumes predicted by modelling of the base case capital dredging campaign. These predicted turbid plumes would consist of suspended sediment from the dredge plume and subsequent re-suspension of dredge material during wind and wave events over the modelling period. However, in addition to the suspended sediment from dredge material, there would also be a proportion of naturally occurring suspended sediment in the water column from natural re-suspension during windy conditions.

Therefore, to put the magnitude of modelled turbid plumes into some context at locations of sensitive receptors, ambient turbidity from natural re-suspension was modelled for the duration of the dredging campaign. This enables a comparison of ambient turbidity to dredge-related turbidity at sensitive receptors.

The time series data was extracted from the model at the same locations as the six baseline water quality monitoring locations, representing sensitive receptors (refer to **Figure B5.3a** for locations).

Figure B5.5.4.2d and **Figure B5.5.4.2e** present time series plots of ambient turbidity versus dredge-related turbidity, with ambient turbidity shown as green lines and dredge-related turbidity shown as blue lines (note the different turbidity scales on the y axis for each location). These plots indicate that sediment from natural re-suspension is the dominant source of turbidity at all sites. The only plots where dredge-related turbidity is noticeable is at Trinity Bay which is close to the outer channel dredging area, and at Trinity Inlet where ambient turbidity is much lower than other sites and therefore dredge-related turbidity is more noticeable. Nevertheless, spikes in dredge-related turbidity at these two sites also correspond to spikes in ambient turbidity when climatic conditions lead to wave and wind conditions that re-suspend sediment and/or during spring tides in Trinity Inlet.

Figure B5.5.4.2d Natural Re-suspension (Ambient Sediments) vs. Dredge Sediments – Palm Cove Beach (top), Yorkeys Knob (middle) and Trinity Bay (bottom)

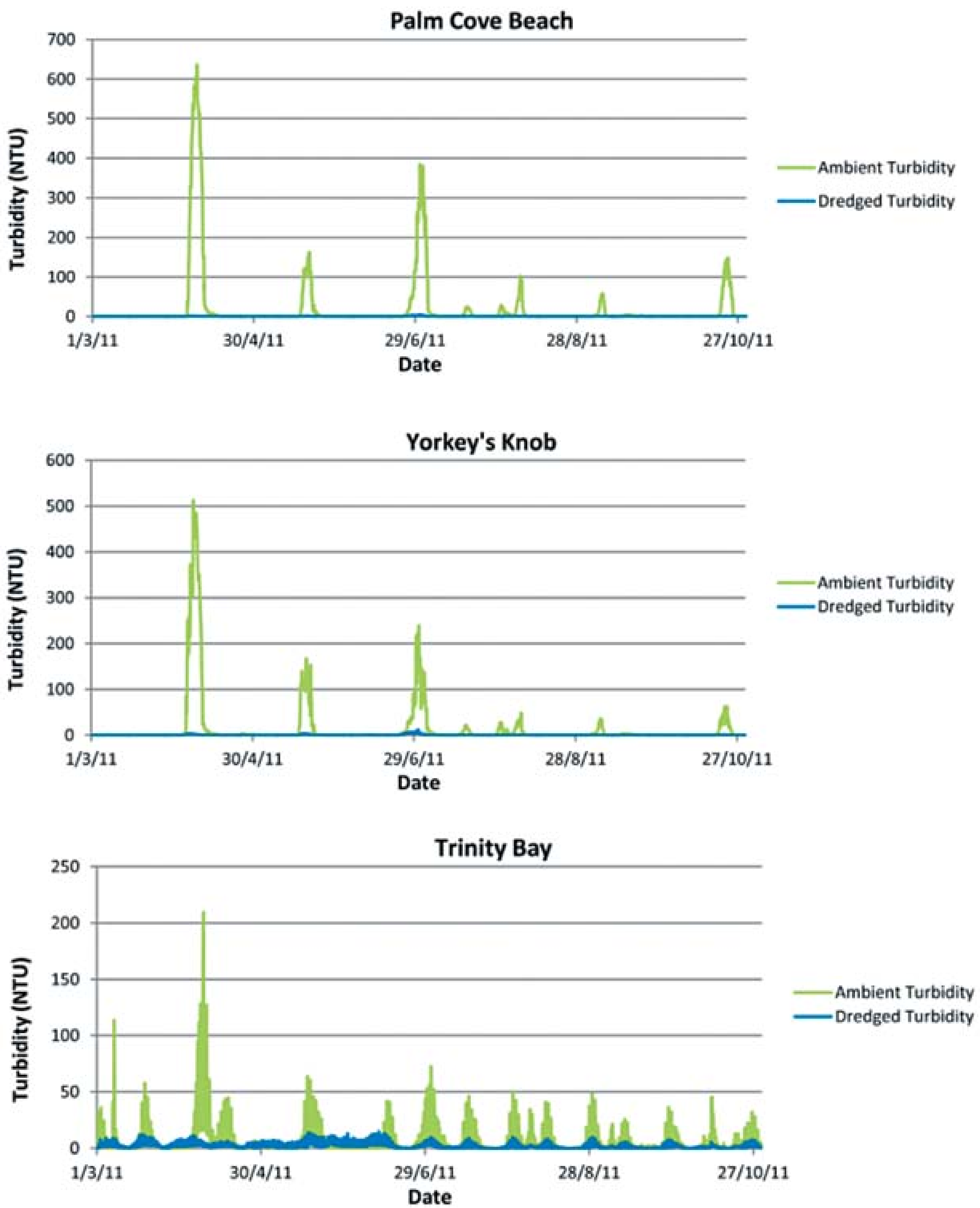
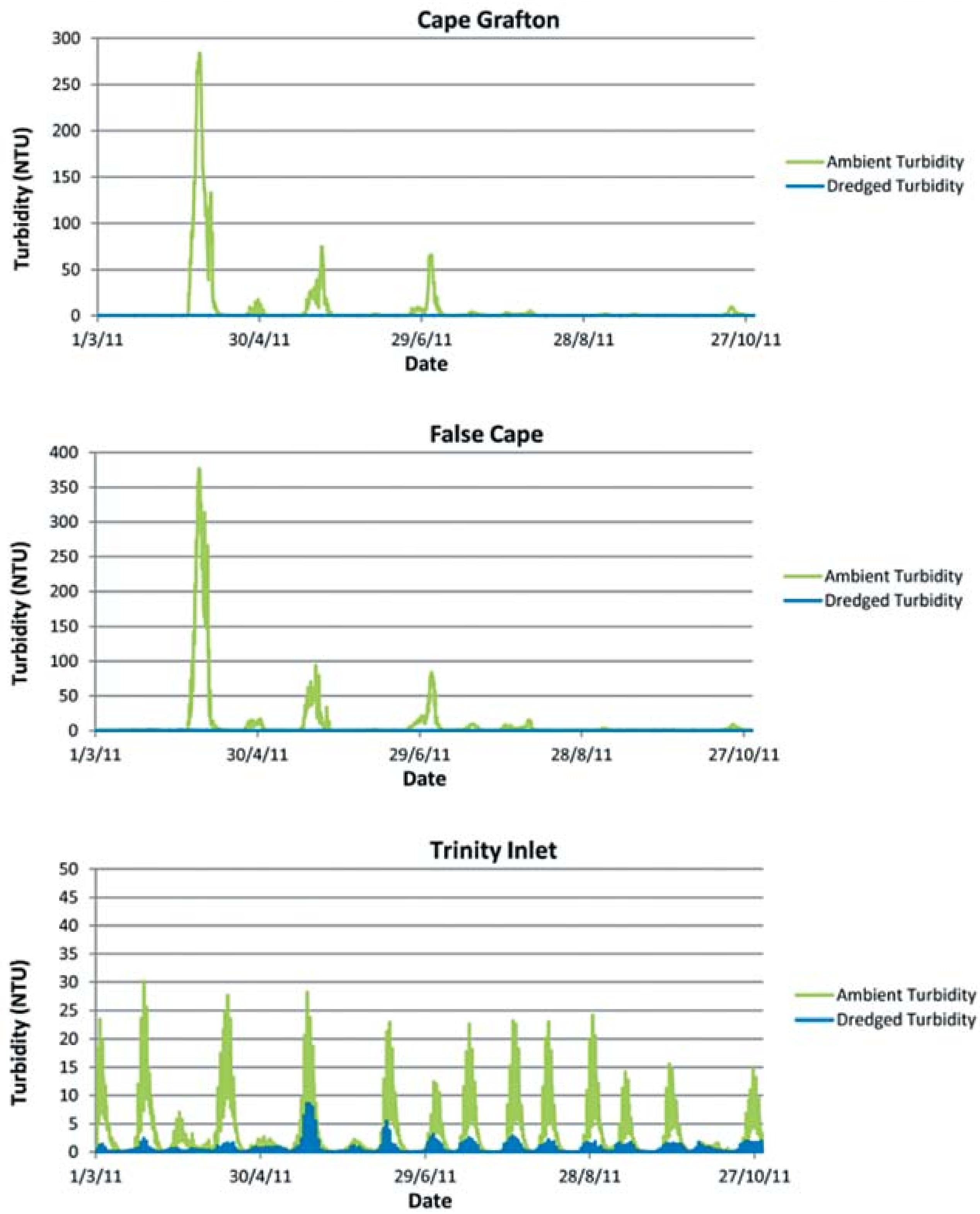


Figure B5.5.4.2e Natural Re-suspension (Ambient Sediments) vs. Dredge Sediments – Trinity Inlet (top), False Cape (middle) and Cape Grafton (bottom)



Zones of Impact

To determine zones of predicted impact as described in **Section B5.5.2** and below, the site-specific impact threshold values from baseline monitoring data (**Section B5.5.2**) were interpolated spatially across the study area to produce three-dimensional (3D) threshold grids. These threshold grids were then analysed against the 3D model output grids using GIS mapping software. This produced impact zone maps which indicate areas where modelled turbidity is higher than the relevant impact threshold value. The impact zone map for the base case is shown in **Figure B5.5.4.2f,** with impact zones briefly described as follows:

- Zone of Influence - extent of detectable plume[3], but no predicted ecological impacts
- Zone of Low to Moderate Impact – water quality may be pushed beyond natural variation potentially resulting in sub-lethal impacts to ecological receptors and/or mortality with recovery between six months (lower end of range) to 24 months (upper end of range)
- Zone of High Impact – water quality would most likely be pushed beyond natural variation (excluding extreme weather events) potentially resulting in mortality of ecological receptors with recovery greater than 24 months.

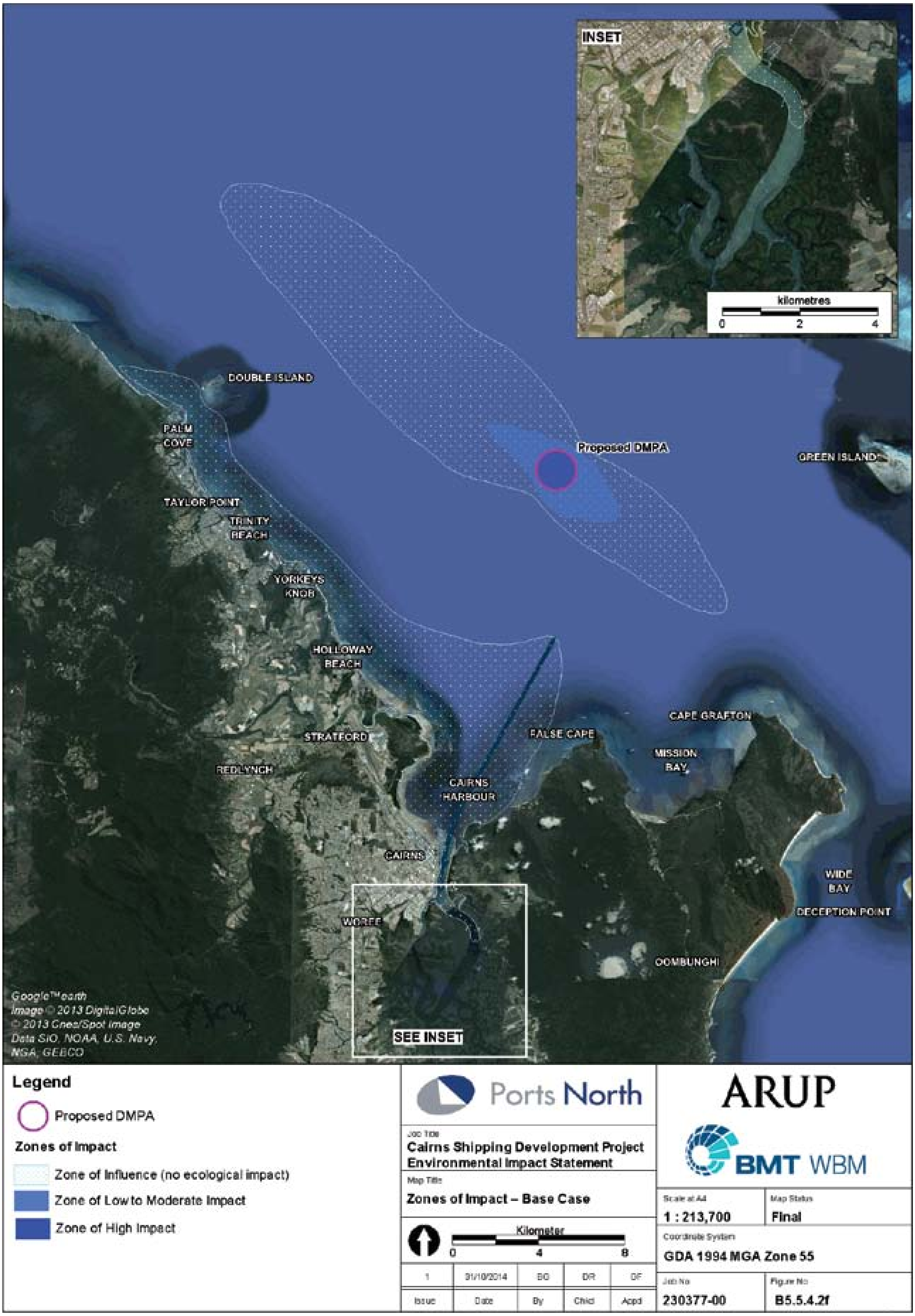
Figure B5.5.4.2f indicates that the zone of influence (i.e. extent of detectable plumes but no predicted ecological impact) extends from the outer channel dredging area northwards along the coastline to Double Island, and south-east towards False Cape. From the inner port dredging area, the zone of influence extends up Trinity Inlet to the eastern extent of Admiralty Island. At the proposed DMPA, the zone of influence extends in a north-west direction approximately 20km, and in a south-east direction approximately 10km. The zone of influence is larger in the offshore area as the ambient conditions are less turbid in this area (i.e. plumes would be easier to detect above background).

The zone of low to moderate impact extends out from the DMPA approximately 2.5km in a north-west and south-east direction, while the zone of high impact is restricted to within the DMPA itself. There are no areas of low to moderate or high impact near the dredging areas.

It should be noted that the zones of impact in **Figure B5.5.4.2f** only relate to potential impacts from increased turbidity in the water column. Other impacting processes which may affect sensitive ecological receptors (such as sediment deposition and benthic habitat disturbance) are discussed further in **Chapter B7, Marine Ecology**.

[3] 'Detectable' plume in terms of detectable by instrumentation deployed in the water column

Figure B5.5.4.2f Zones of Impact - Base Case Scenario



B5.5.4.3 Likely Best Case - Alternative Case Dredging Scenario (No Overflow)

In addition to the base case scenario, which has BHD dredging of all inner port areas, an alternative case scenario was developed whereby some of the inner port dredging would be undertaken by a TSHD instead of the BHD. This would decrease the overall length of the dredge campaign from approximately 34 weeks down to 21 weeks. It should be noted that the majority of the dredging campaign will be in the outer channel, and the duration of outer channel dredging for the base case and alternative case scenarios will be the same (approximately 18 weeks).

The alternative case capital dredging scenario is based on TSHD dredging of all very soft, soft and firm clay material in the outer channel and inner port areas, and BHD dredging of the stiff material only in the inner port. The total ***in-situ*** volume removed by the TSHD in this scenario is 4,030,000 m^3, with the remaining 319,000 m^3 of stiff clay accounted for by the BHD. The duration of TSHD dredging would be approximately 21 weeks (not including mobilisation and demobilisation) while the BHD component would actively dredge for approximately 19 weeks.

The alternative case assumption regarding no overflow dredging is the same as for the base case scenario.

As mentioned in **Section B5.5.4.1**, the ability to undertake inner port dredging by a TSHD as per the alternative case scenario will depend on a range of factors including greater knowledge of geotechnical conditions and ***in situ*** density of the material present, logistics and manoeuvrability of the dredge. Therefore, the most likely dredging scenario is expected to be somewhere between the base case and alternative case scenarios, depending on findings from detailed geotechnical investigations during detailed design. Both cases have been assessed in terms of potential impacts on the environment to provide flexibility and assurances that both methodologies would be acceptable.

Figure B5.5.4.3b and **Figure B5.5.4.3c** show percentile contour plots of the impact of dredging on the 50th percentile turbidity and the impact of dredging on the 95th percentile turbidity (i.e. above background levels).

For context, a percentile contour plot showing modelled ambient turbidity (without dredging) during 95th percentile conditions is provided in **Figure B5.5.4.3a**. Further modelled ambient turbidity plots are included in **Appendix D4, Water Quality Model Development and Calibration Report**.

These alternative case percentile contour plots (**Figure B5.5.4.3b** and **Figure B5.5.4.3c**) show similar magnitude and extent of turbidity plumes as the base case scenario percentile contour plots (**Figure B5.5.4.2b** and **Figure B5.5.4.2c**). That is, median (50th percentile) turbidity is predicted to increase slightly (up to two NTU) along the northern coastline up to Taylor's Point, with the greatest increase to median turbidity near the outer channel dredging area (increase by approximately six NTU). Under 95th percentile conditions, the alternative case is expected to be similar to the base case, whereby turbidity is predicted to increase by approximately 10-20 NTU above background conditions in close proximity to the channel dredging area and the DMPA.

The similar results between the base case and alternative case are likely explained by a couple of factors, as follows:

- Dredging of the outer channel with a TSHD is similar for both scenarios, and as the majority of dredging will occur in the outer channel, the impacting processes are similar.
- The duration of dredging - while the TSHD in the inner port would produce more turbid plumes compared to the BHD, the duration of dredging in the inner port would be considerably less with a TSHD (therefore the duration of exposure to turbid plumes would be less). As such, the level of impacts between the base case and alternative case are considered to be relatively similar.

Figure B5.5.4.3a 95th Percentile of Modelled Ambient Turbidity (without dredging)

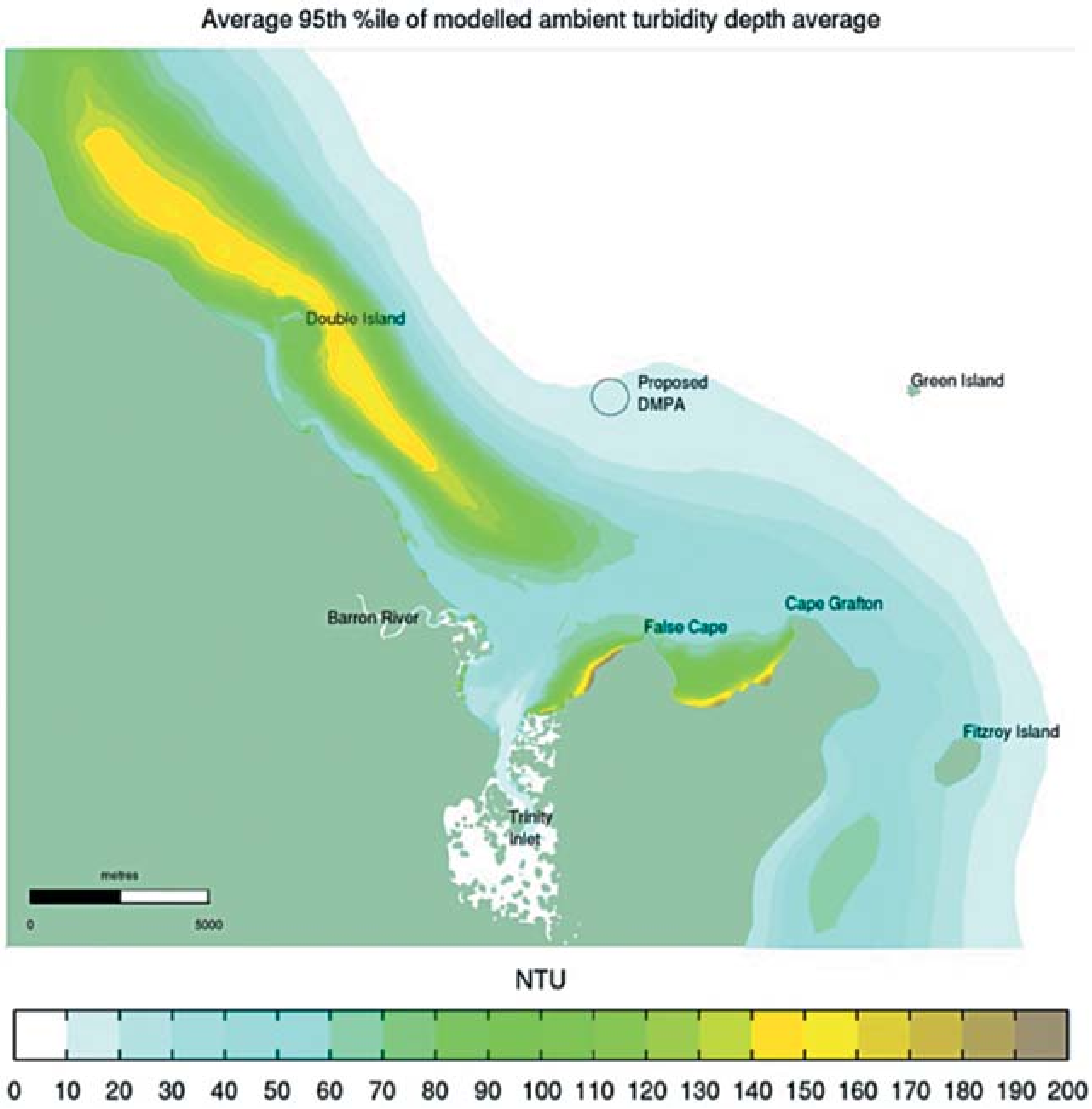


Figure B5.5.4.3b Alternative Case Scenario - Impact of Dredging on 50th Percentile Turbidity *(scale: 2 to 40 NTU)*

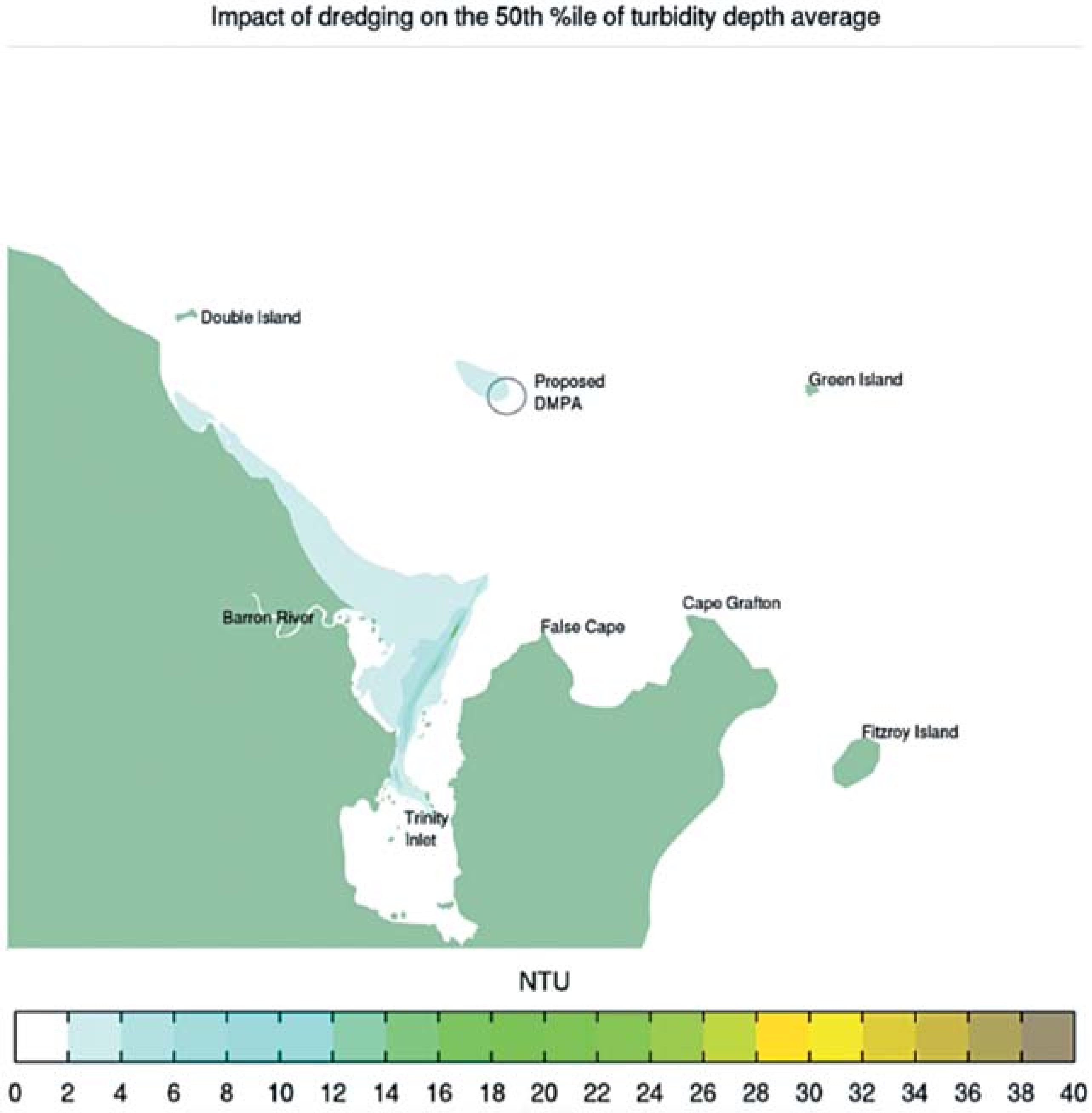
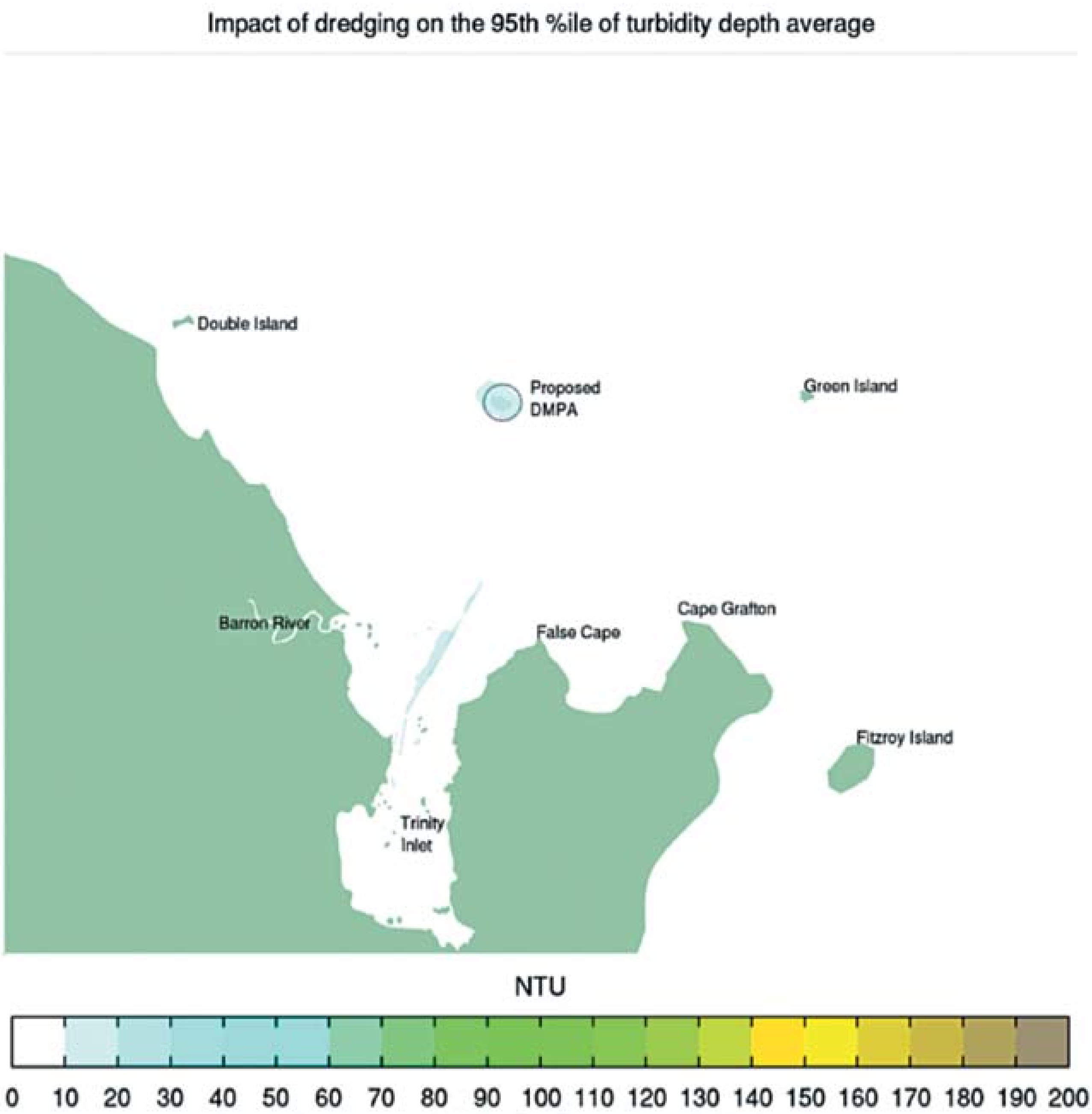


Figure B5.5.4.3c Alternative Case Scenario - Impact of Dredging on 95th Percentile Turbidity *(scale: 10 to 200 NTU)*



B5.5.4.4 Likely Worst Case (Constrained Overflow)

The base case scenario (Section B5.5.4.1) assumed that there was no overflow dredging undertaken in the program. However, occasional limited overflow dredging may be required due to various operational factors. It was therefore considered prudent as an operational worst case scenario to consider dredging with some level of constrained overflow within the TSHD program.

To represent reasonable worst case operational conditions, two scenarios were developed as follows:

- Soft silt and clay material   10 minutes of overflow dredging during 50 percent of TSHD cycles
- Stiff clays – possibility of encountering stiffer than expected clays within the outer shipping channel, resulting in 60 minutes of overflow dredging. This scenario assumes a volume of stiff clay material of 350,000m^3, which would take around three weeks of dredging (including overflow).

The worst case scenarios were not carried out for the entire dredge campaign, but instead were carried out for a single 30-day period that coincided with the most extensive dredge plumes generated during the base case scenario. It is therefore expected that these scenarios are representative of worst case conditions, taking into consideration both climatic (worst case climatically of the 2011 modelling period) and operational factors. It should be noted that extreme climatic events are not included as part of the worst case scenarios as dredging would be unlikely to be occurring during these periods.

Further details on the worst case scenarios and assumptions are included in **Appendix D4, Water Quality Model Development and Calibration Report.**

Percentile Plots

For worst case dredging scenario one (soft material) and worst case dredging scenario two (stiff material), **Figure B5.5.4.4b** and **Figure B5.5.4.4d** show the contour plots of the impact of dredging on the 50th percentile turbidity (i.e. above background levels), while **Figure B5.5.4.4c** and **Figure B5.5.4.4e** show the contour plots of the impact of dredging on the 95th percentile turbidity.

For context, a percentile contour plot showing modelled ambient turbidity (without dredging) during 95th percentile conditions is provided in **Figure B5.5.4.4a**. Further modelled ambient turbidity plots are included in **Appendix D4, Water Quality Model Development and Calibration Report**.

Figure B5.5.4.4b indicates that as a result of capital dredging as per worst case scenario one, dredge plumes are predicted to extend from the outer channel dredging area in a north-westerly direction along the coastline. Median (50th percentile) turbidity is predicted to increase slightly (up to two NTU) along the northern coastline up to Taylor's Point (south of Double Island), with the greatest increase to median turbidity near the outer channel dredging area with an increase of approximately 14 NTU. Median turbidity at the DMPA is predicted to increase by approximately four NTU, which is slightly less than the base case scenario due to less fine sediments being transported to the DMPA. **Figure B5.5.4.4c** indicates that under 95th percentile conditions, turbidity is predicted to increase by approximately 10-30 NTU above background conditions, extending up the coast to Double Island (10 NTU).

Figure B5.5.4.4d indicates that capital dredging as per worst case scenario two is predicted to have slightly worse results compared to worst case scenario one. Median (50th percentile) turbidity is predicted to increase slightly (up to 2 NTU) along the northern coastline up to just south of Taylor's Point. The greatest increase to median turbidity is predicted to be near the outer channel dredging area with an increase of approximately 14 NTU. Median turbidity at the DMPA is predicted to increase by approximately two NTU, which is less than worst case scenario one (and less than the base case). **Figure B5.5.4.4e** indicates that under 95th percentile conditions, turbidity is predicted to increase by approximately 10-40 NTU above background conditions (approximately 100-150 NTU), extending up the coast past Double Island (10 NTU).

Similar to the base case scenario, the worst case scenario indicates that turbid dredge plumes are not predicted to mobilise in a southerly direction towards False Cape and Cape Grafton. This is due to the predominant north-easterly wind and wave direction.

The impact significance of these results are interpreted using zones of impact in the following section.

Figure B5.5.4.4a 95th Percentile of Modelled Ambient Turbidity

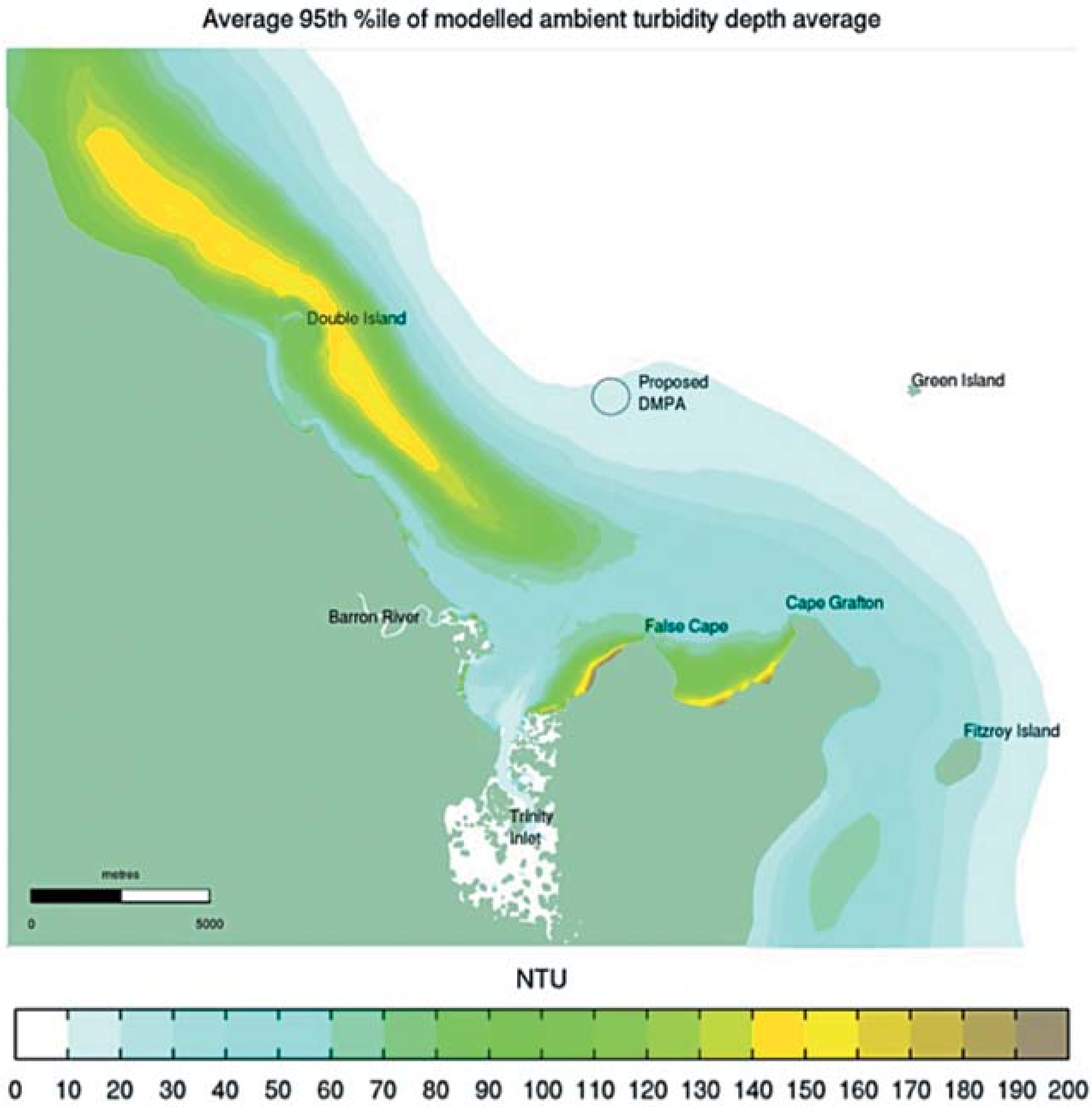


Figure B5.5.4.4b Worst Case Dredging Scenario 1 (Soft Material) - Impact of Dredging on 50th Percentile Turbidity *(scale: 2 to 40 NTU)*

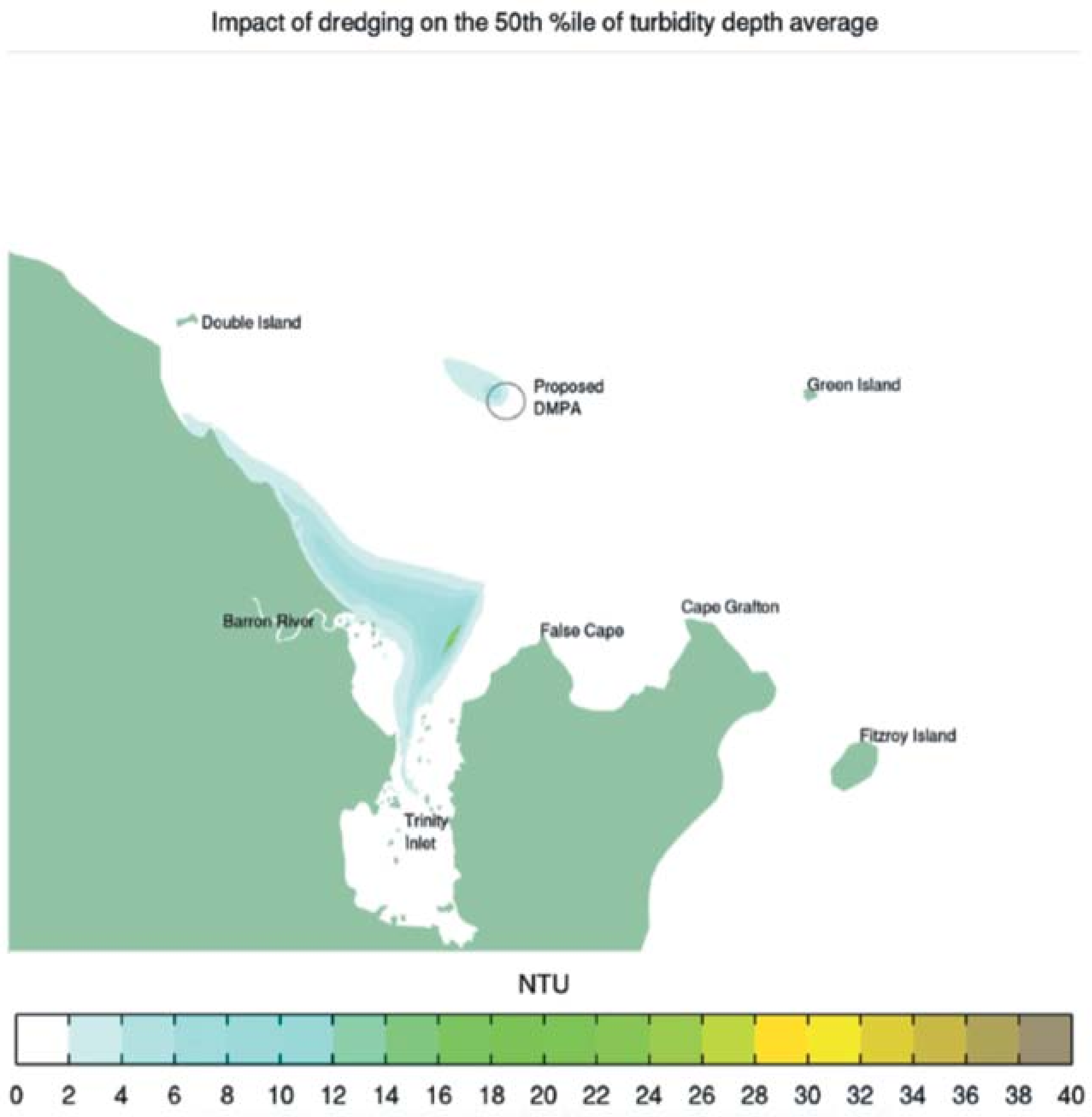


Figure B5.5.4.4c Worst Case Dredging Scenario 1 (Soft Material) - Impact of Dredging on 95th Percentile Turbidity *(scale: 10 to 200 NTU)*

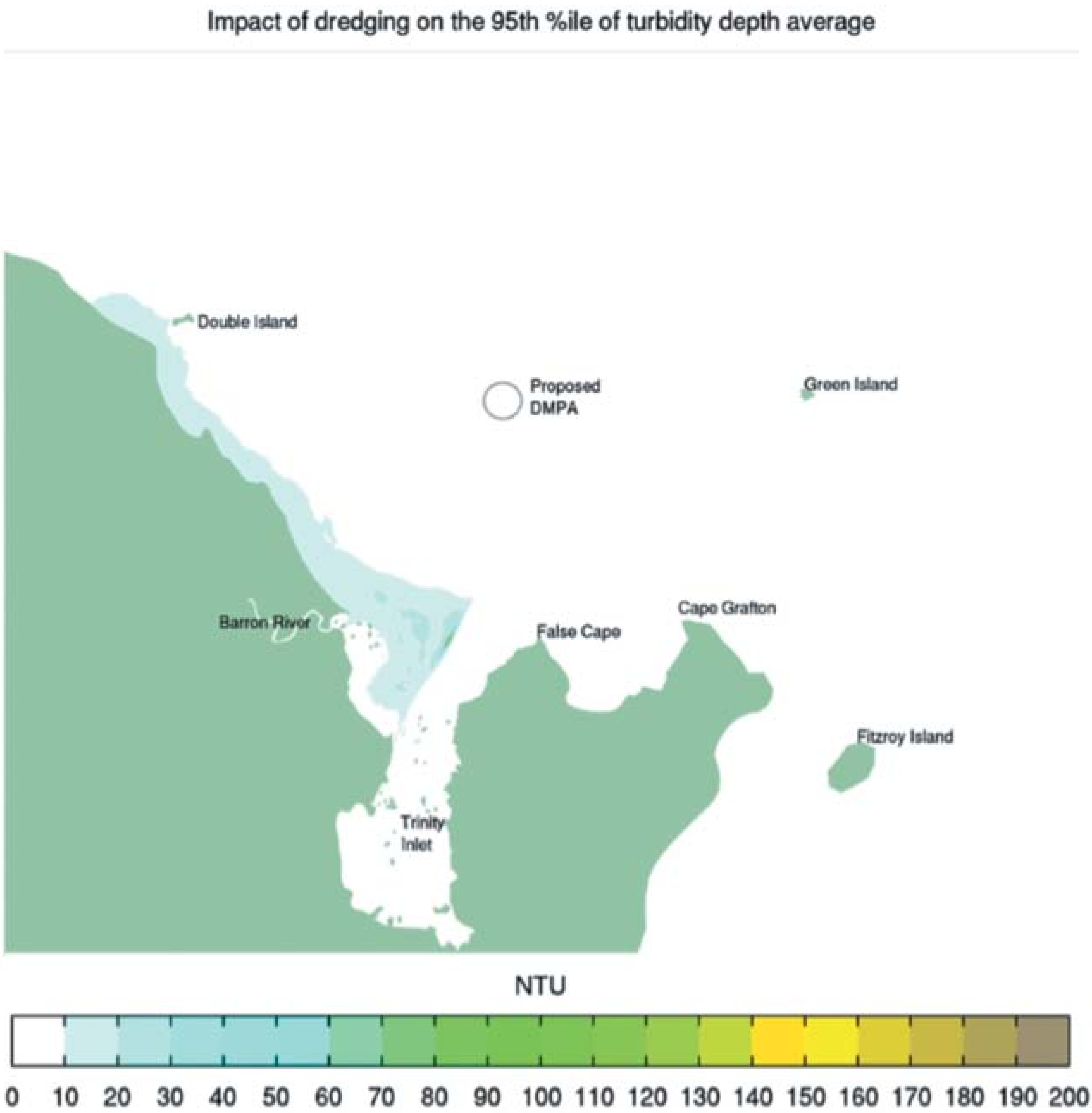


Figure B5.5.4.4d Worst Case Dredging Scenario 2 (Stiff Material) - Impact of Dredging on 50th Percentile Turbidity ***(scale: 2 to 40 NTU)***

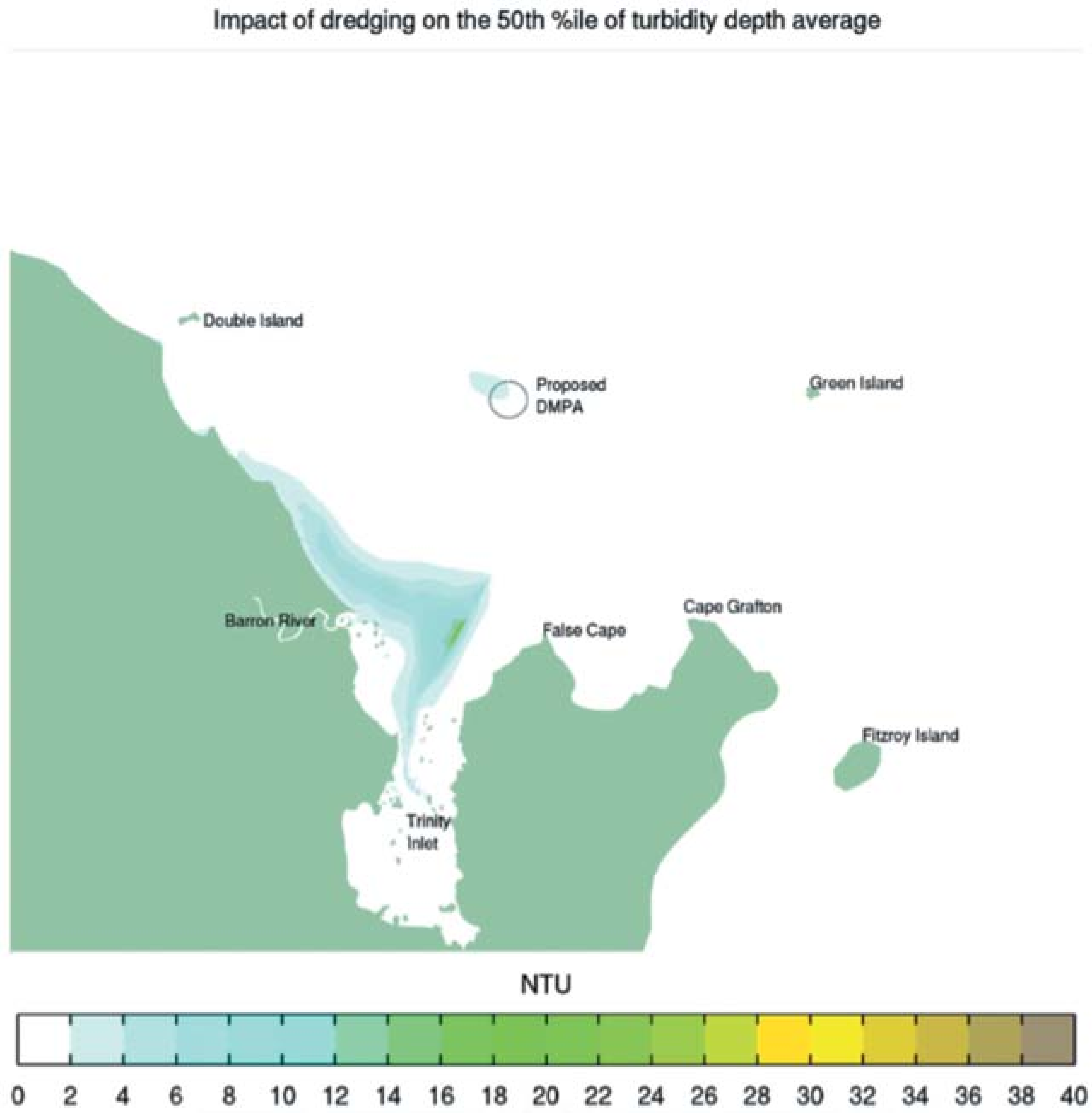
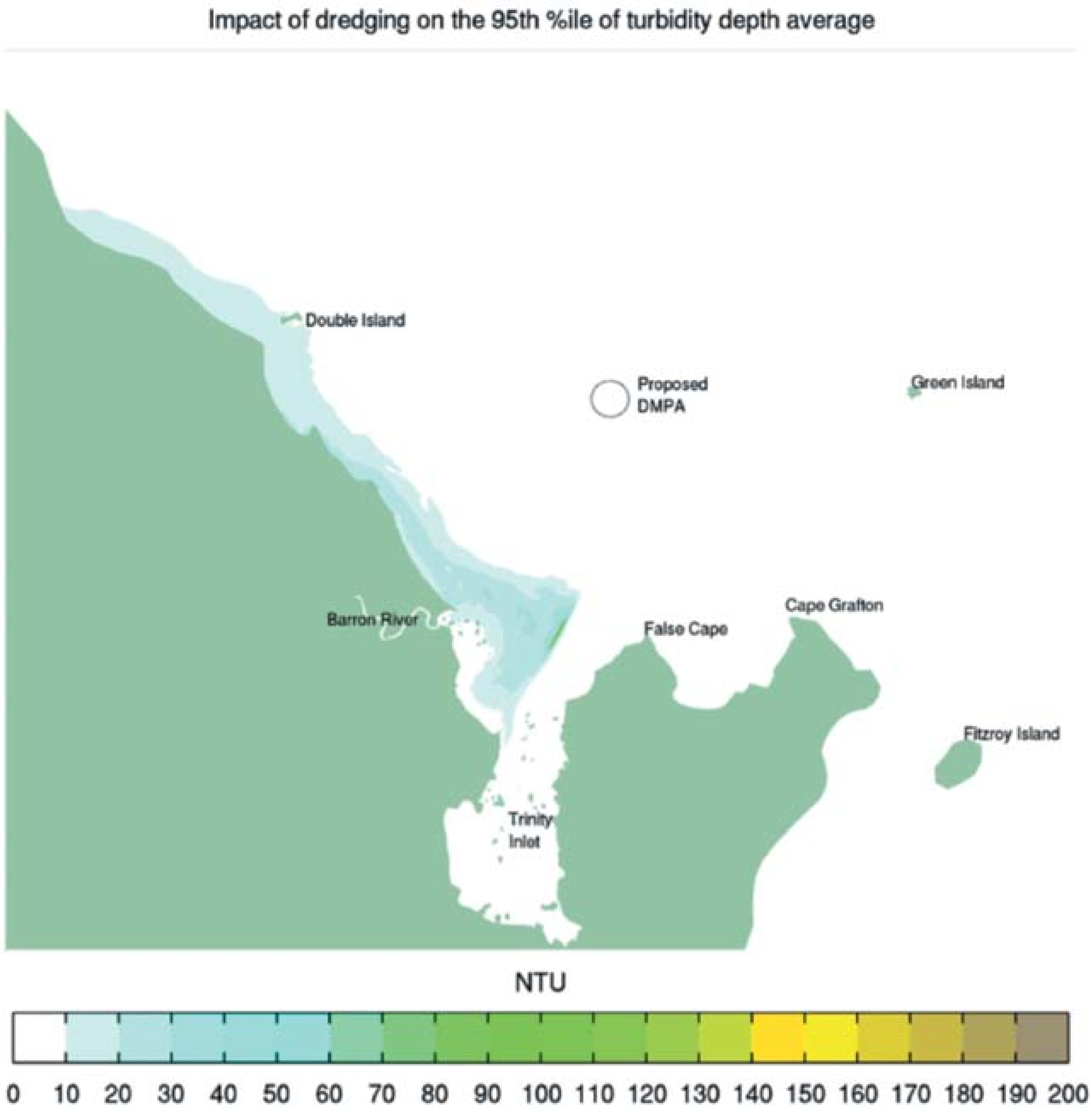


Figure B5.5.4.4e Worst Case Dredging Scenario 2 (Stiff Material) - Impact of Dredging on 95th Percentile Turbidity *(scale: 10 to 200 NTU)*



Zones of Impact

For the worst case dredging scenario, the predicted zones of impact (as described in **Section B5.4.2** and below) were delineated using site-specific impact threshold values from the baseline monitoring data (**Section B5.4.2**) and GIS mapping software. This produced impact zone maps which indicate areas where modelled turbidity is higher than the relevant impact threshold value.

The zones of impact for the worst case dredging scenario are shown in one figure (**Figure B5.5.4.4f**), using the combination of base case, worst case dredging scenario one and worst case dredging scenario two model outputs. This gives an indication of overall worst case zones of impact considering the entire dredge campaign (base case) and the two worst case dredging scenarios.

The zones of impact presented in **Figure B5.5.4.4f** for the worst case scenario are briefly described as follows:

- Zone of Influence - extent of detectable plume[4], but no predicted ecological impacts
- Zone of Low to Moderate Impact – water quality may be pushed beyond natural variation potentially resulting in sub-lethal impacts to ecological receptors and/or mortality with recovery between six months (lower end of range) to 24 months (upper end of range)
- Zone of High Impact – water quality would most likely be pushed beyond natural variation (excluding extreme weather events) potentially resulting in mortality of ecological receptors with recovery greater than 24 months.

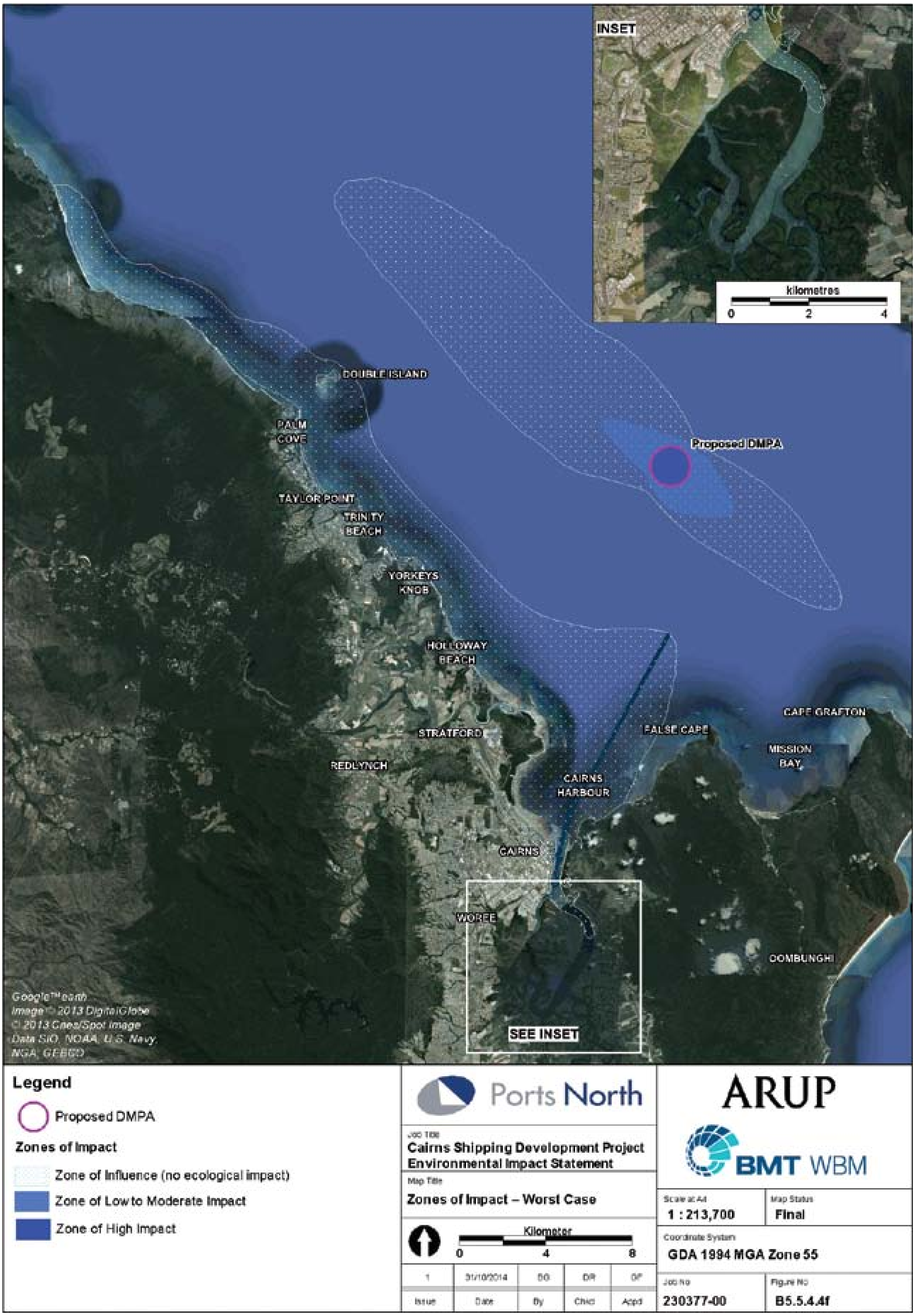
Figure B5.5.4.4f indicates that the main difference in the zones of impact between the base case scenario and worst case dredging scenario is the extent of the zone of influence (i.e. extent of detectable plumes but no predicted ecological impacts) near the coastline. While the base case zone of influence is predicted to extend to Double Island, the worst case zone of influence is predicted to extend approximately 15km past Double Island.

This increase in predicted extent of the zone of influence along the coastline is a result of increased turbidity in the near shore region due to some overflow occurring in the dredging area. However, the predicted increased turbidity is not expected to be sufficient to cause any impacts to water quality or ecological impacts. There is little difference in the predicted areas of the zone of low to moderate impact and the zone of high impact between the base case and worst case scenarios. These zones are still restricted to the vicinity of the proposed DMPA for the worst case dredging scenario.

It should be noted that the zones of impact in **Figure B5.5.4.4f** only relate to potential impacts from increased turbidity in the water column. Other impacting processes which may affect sensitive ecological receptors (such as sediment deposition and benthic habitat disturbance) are discussed further in **Chapter B7, Marine Ecology.**

[4] 'Detectable' plume in terms of detectable by instrumentation deployed in the water column

Figure B5.5.4.4f Zones of Impact - Worst Case Dredging Scenario



B5.5.4.5 Summary of Key Findings

The predicted impacts for each scenario have been determined based on the impact significance criteria defined in **Section B5.5** and can be summarised as follows:

Likely Best Case - Base Case Scenario (No Overflow)

Dredging of Inner Port

As the base case dredging scenario comprises BHD dredging of all material in the inner port, water quality impacts are predicted to be relatively minimal due to the limited turbid plumes created by the BHD. This is supported by the high level assessment against the QWQG, whereby median turbidity levels are not expected to increase significantly at any locations, including Trinity Inlet (increase of 0.2 NTU).

Assessment of ambient turbidity from natural re-suspension versus dredge-related turbidity indicated that Trinity Inlet is predicted to have some noticeable spikes in dredge-related turbidity (note that ambient turbidity is much lower at this site and therefore dredge-related turbidity is more noticeable). However, spikes in dredge-related turbidity at this site are predicted to correspond to spikes in ambient turbidity during spring tides (conditions which typically resuspend sediment within Trinity Inlet).

The percentile contour plots indicated that median turbidity is predicted to increase slightly (up to two NTU) within Trinity Inlet. 95^{th} percentile turbidity is predicted to increase less than 10 NTU above background 95^{th} percentile conditions in Trinity Inlet.

Based on the zone of impact methodology, only the zone of influence (i.e. extent of detectable plumes but no predicted ecological impacts) is predicted to extend into the Inner port and Trinity Inlet.

Therefore, based on these assessments overall, minor impacts are expected from turbid plumes generated from the ‘base case’ capital dredging in the inner port.

Dredging of Outer Channel

As the base case dredging scenario comprises TSHD dredging of the outer channel without overflow, water quality impacts are expected to be relatively minimal from the outer channel dredging area. Based upon the high level assessment against the QWQG, median turbidity levels are not expected to increase significantly at any locations in response to dredging of the outer channel.

Assessment of ambient turbidity from natural re-suspension versus dredge-related turbidity predicted that most areas would receive a much larger proportion of natural sediment re-suspension compared to dredged sediment. This supports the assessment of baseline conditions which indicated that the study area is a naturally turbid environment, and dredging is predicted to increase turbidity by a relatively minor proportion.

The percentile contour plots indicated that median turbidity is predicted to increase slightly (up to 6 NTU) due to dredging of the outer channel. 95^{th} percentile turbidity is predicted to increase by approximately 10-20 NTU above background 95^{th} percentile conditions.

Based on the zone of impact methodology, only the zone of influence is predicted to occur in the vicinity of the outer channel dredging.

Therefore, based on these assessments overall, minor impacts are expected from turbid plumes generated from the ‘base case’ capital dredging in the outer channel.

Placement of Material at DMPA

As the base case dredging scenario comprises dredging without overflow, the majority of fine material which would normally be released into the water column at the dredge site is instead released at the DMPA. Furthermore, ambient water quality in offshore areas where the DMPA is located is generally of lower turbidity compared to near shore areas. As such, water quality impacts at the DMPA are predicted to be slightly higher compared to near shore areas.

Based upon the high level assessment against the QWQG, median turbidity levels at the DMPA are predicted to approximately double from six NTU to 12 NTU. The percentile contour plots also indicated that median turbidity is predicted to increase up to six NTU at the DMPA, and increase by approximately 10-20 NTU under 95^{th} percentile conditions.

Based on the zone of impact methodology, a zone of low to moderate impact is predicted to extend out from the DMPA approximately 2.5km in a north-west and south-east direction, while a zone of high impact is predicted to occur within the DMPA itself.

Notwithstanding the above, the predicted impacts from placement of material at the DMPA have been considered in the context that the impacts are predicted to be relatively localised to the vicinity of the DMPA, there are no sensitive ecological receptors in the predicted impact zones and that affected habitats affected would recover quickly (refer **Chapter B7, Marine Ecology**). Therefore, impacts are predicted to be minor from turbid plumes generated from placement of dredge material at the DMPA as part of the 'base case' capital dredging.

Likely Best Case - Alternative Case Dredging Scenario (No Overflow)

The model outputs indicate little difference between the base case scenario (BHD dredging in inner port) and the alternative case scenario (TSHD dredging of soft material in the inner port without overflow). This is most likely due to both scenarios including similar outer channel dredging where the majority of dredging will occur. As such, the level of impacts between the base case and alternative case are considered to be relatively similar. That is, minor impacts are predicted from dredging of the inner port and outer channel and placement of material at the DMPA as part of the alternative case capital dredging scenario.

Likely Worst Case (Constrained Overflow)

The model outputs suggest that under the worst case scenario, turbid dredge plumes are predicted to be slightly increased in the near shore environment along the coastline to the north of the dredging area (these plumes would be detectable with instrumentation but may not be visible to the naked eye). However, marine water quality is not predicted to change significantly.

In regard to zones of impact, the main difference between the base case scenario and worst case scenario is a slightly increased extent of the zone of influence (i.e. extent of detectable plumes but no ecological impacts) along the coastline under the worst case scenario. However, the larger zone of influence would not result in any change to predicted impacts, with the zone of low to moderate impact and the zone of high impact still restricted to the vicinity of the proposed DMPA under the worst case scenario.

Therefore, based on this assessment, impacts are predicted to be similar to the base case scenario above, i.e. minor impacts are predicted from dredging of the inner port and outer channel and placement of material at the DMPA.

B5.5.5 Construction Phase Impacts – Mobilisation of Contaminants from Capital Dredging and Marine Placement

Mobilisation of contaminants such as nutrients and metals/metalloids is a potential impact which could result from disturbance or dredging of marine sediments. While sediment quality is discussed further in **Chapter B4, Marine Sediment Quality**, the mobilisation of contaminants into the water column from dredging is assessed in this chapter using pore water and elutriate testing results of sediments.

Pore water and elutriate concentrations of nutrients and metals/metalloids were analysed in additional sediment samples collected during the initial sediment sampling campaign for the project (October 2013). These sites were located in the inner port dredge area, and include PWA (near Wharf 10), PWB (near Wharf 1) and PWC (Smith's Creek Swing Basin). These sites correspond to sediment sampling sites M180, H165 and U187 respectively, the locations of which are included in **Appendix D2, Sediment Quality Report**.

B5.5.5.1 Pore water results

As an initial assessment, concentrations of contaminants in pore water were analysed. As stated in the National Assessment Guidelines for Dredging 2009 (NAGD), pore water is assumed to represent the major route of exposure to sediment contaminants by benthic organisms. Where pore water concentrations lie below the ANZECC/ARMCANZ (2000) marine water quality trigger values it is thought unlikely that there would be adverse effects on such organisms.

In the case of nutrients, the key species of interest are ammonia and nitrogen oxides (NOx), which have listed toxicity trigger values. The toxicity trigger value for nitrate, which forms the main form of oxidised nitrogen, is 13 mg/L (assuming 95percent protection of species). For ammonia, the toxicity trigger value currently specified in ANZECC/ARMCANZ (2000) is 0.9 mg/L. However, the trigger value for ammonia in estuarine and marine waters has been revised by Batley and Simpson (2009) with the addition of new data. A new trigger value of 0.46 mg/L was derived for slightly to moderately disturbed systems (95 percent protection).

The pore water results for nutrients are included in **Table B5.5.5.1a**, with highlighted cells indicating exceedance of trigger values. These results indicate that NOx pore water concentrations were below the trigger level and therefore pose a negligible risk.

Table B5.5.5.1a indicates that ammonia pore water concentrations were elevated above the Batley and Simpson (2009) water quality trigger level of 0.46 mg/L at two out of three sample sites. However, for sediment pore water, Batley and Simpson (2009) recommended a trigger value of 3.9 mg/L, which was derived from the 80th percentile of background data from Sydney Harbour. As the pore water ammonia concentrations are well below 3.9 mg/L, ammonia is considered to pose negligible impacts, especially considering elutriate testing results discussed in the following section.

Table B5.5.5.1a Nutrients in Pore Water

Parameter	PWA	PWB	PWC	Water Quality Trigger Levels
	Inner Port (Wharf 10)	Inner Port (Wharf 1)	Inner Port (Smith's Creek swing Basin)	
Ammonia (mg/L)	1.64	1.37	0.46	0.46 *
NOx (mg/L)	<0.01	<0.01	<0.01	13 **
Total Nitrogen (mg/L)	2.2	1.4	0.8	-
Reactive Phosphorus (mg/L)	0.07	0.04	0.05	-
Total Phosphorus (mg/L)	0.13	0.13	0.14	-

Notes:
* Derived from Batley and Simpson (2009)
** Derived from ANZECC/ARMCANZ (2000)

The pore water results for metals/metalloids are included in **Table B5.5.5.1b**. This table includes dissolved concentrations only, which are comparable to the ANZECC/ARMCANZ (2000) trigger levels. As shown in **Table B5.5.5.1b**, there were no dissolved metal/metalloid concentrations elevated above trigger levels in pore water in any of the sediment samples. These results indicate that metal/metalloids in pore water pose negligible impacts.

Table B5.5.5.1b Dissolved Metals/Metalliods in Pore Water

Parameter	PWA	PWB	PWC	Water Quality Trigger Levels
	Inner Port (Wharf 10)	Inner Port (Wharf 1)	Inner Port (Smith's Creek swing Basin)	
Antimony (µg/L)	<0.5	<0.5	<0.5	-
Arsenic (µg/L)	5.5	2.7	3	50
Cadmium (µg/L)	<0.2	<0.2	<0.2	0.7
Chromium (µg/L)	<0.5	<0.5	<0.5	4.4
Copper (µg/L)	<1	<1	<1	1.3
Lead (µg/L)	<0.2	<0.2	<0.2	4.4
Nickel (µg/L)	<0.5	<0.5	<0.5	7.0
Silver (µg/L)	<0.1	<0.1	0.2	1.4
Zinc (µg/L)	<5	<5	<5	15
Mercury (µg/L)	<0.0001	<0.0001	<0.0001	0.1

Notwithstanding the negligible risk from contaminants in pore water as discussed above, this risk is further reduced due to the expectation that these pore water concentrations would become rapidly diluted during the dredging and marine placement process. In support of this, Batley and Simpson (2009) state that ocean disposal of dredged sediments results in rapid decreases in pore water concentrations. This dilution effect is assessed further with elutriate testing results discussed in the following section.

B5.5.5.2 Elutriate results

The elutriate test investigates desorption of contaminants from sediment particulates to waters, and is designed to simulate release of contaminants from a sediment during dredged material disposal. Elutriate tests assess whether contaminant concentrations in the water column are likely to exceed relevant ANZECC/ARMCANZ (2000) water quality trigger values.

NAGD (2009) states that the relevant ANZECC/ARMCANZ (2000) marine water quality trigger values should not be exceeded after allowing for initial dilution, defined as 'that mixing which occurs within four hours of dumping'. Initial dilution will depend on a number of factors, such as depth, layering in the water column, and current velocities and directions.

The laboratory elutriate analysis uses a dilution of 1:4 - one part wet sediment to four parts seawater. NAGD (2009) states that this will greatly overestimate water quality impacts given that, within the initial four-hour dilution period following dumping, dilutions in the order of a hundred times or more (and often much more) would normally be expected. To address this, NAGD (2009) states that the test data should be corrected for the calculated dilution factor after the four-hour mixing period (after taking account of the laboratory dilution of 1:4) to assess whether or not the water quality trigger values will be exceeded following marine placement.

As per NAGD (2009), initial dilution may be approximated as the liquid and suspended particulate phases of the dredge material assumed to be evenly distributed after four hours over a column of water bounded on the surface by the release zone and extending to the ocean floor, or to a depth of 20m, whichever is shallower. Assuming the hopper size of the TSHD is 5,500m^3, and the volume of water in the release zone is a conservative 10,000m^2 (the DMPA footprint is actually 2.7km^2), the minimum initial dilution is calculated as 1:36.

Therefore, as the elutriate test results involved a laboratory dilution of 1:4, these results were further diluted by a factor of 36 to approximate the effects of mixing and dilution of contaminants released from sediment into the water column during dredging and marine placement. The elutriate results for nutrients and metals/metalloids, which represent a final dilution factor of 1:144, are included in **Table B5.5.5.2a** and **Table B5.5.5.2b** respectively.

As shown in **Table B5.5.5.2a** and **Table B5.5.5.2b**, elutriate testing results are well below the relevant water quality trigger levels. Therefore, the mobilisation of contaminants poses negligible impacts to marine water quality.

Table B5.5.5.2a Elutriate Nutrient Concentrations (1:144 dilution)[1]

Parameter	PWA	PWB	PWC	Water Quality Trigger Levels
	Inner Port (Wharf 10)	Inner Port (Wharf 1)	Inner Port (Smith's Creek swing Basin)	
Ammonia (mg/L)	0.11	0.12	0.03	0.46 *
NOx (mg/L)	<0.01	<0.01	<0.01	13 **
Total Nitrogen (mg/L)	0.17	0.12	0.03	-
Reactive Phosphorus (mg/L)	0.0003	0.0003	0.0006	-
Total Phosphorus (mg/L)	0.0011	0.0008	0.0008	-

Note:

[1] Values below the laboratory limit of reporting (e.g. <0.01) did not have the further dilution factor of 36 applied. These values represent a dilution of 1:4.

* Derived from Batley and Simpson (2009)

** Derived from ANZECC/ARMCANZ (2000)

Table B5.5.5.2b Elutriate Metal / Metalloid Concentrations (1:144 dilution)[1]

Parameter	PWA	PWB	PWC	Water Quality Trigger Levels
	Inner Port (Wharf 10)	Inner Port (Wharf 1)	Inner Port (Smith's Creek swing Basin)	
Antimony (µg/L)	0.017	0.050	<0.5	-
Arsenic (µg/L)	0.039	0.092	<0.5	50
Cadmium (µg/L)	<0.2	<0.2	<0.2	0.7
Chromium (µg/L)	<0.5	<0.5	<0.5	4.4
Copper (µg/L)	<1	<1	<1	1.3
Lead (µg/L)	<0.2	<0.2	<0.2	4.4
Nickel (µg/L)	0.014	0.042	<0.5	7.0
Silver (µg/L)	<0.1	<0.1	<0.1	1.4
Zinc (µg/L)	<5	<5	<5	15
Mercury (µg/L)	<0.0001	<0.0001	<0.0001	0.1

Note:

[1] Values below the laboratory limit of reporting (e.g. <0.1) did not have the further dilution factor of 36 applied. These values represent a dilution of 1:4.

* Derived from ANZECC/ARMCANZ (2000)

B5.5.6 Construction Phase Impacts – Potential Acid Sulfate Soil Impacts from Capital Dredging and Marine Placement

Disturbance and exposure of potential acid sulfate soils (PASS) in the dredge material can lead to water quality impacts from changes in pH if the material is allowed to oxidise. As discussed in **Chapter B4, Marine Sediment Quality**, potential ASS is expected to be present in the very soft to soft clay and silt materials below a sediment depth of approximately one metre (the top one metre had shell or other neutralising material).

However, as marine placement of the dredge material is proposed, oxidation of the dredge material is considered highly unlikely as the sediments will stay saturated with seawater. Under normal operating conditions of the dredging vessel (PASS exposure timeframe of substantially less than 24 hours based on an average dredge cycle time of one-three hours), the potential impacts associated with oxidation and changes to pH are considered to be negligible. Measures to ensure that oxidisation of PASS material does not occur are included in **Chapter C2, Dredge Management Plan**.

B5.5.7 Construction Phase Impacts – Turbid Plumes from Re-suspension of Dredge Material from DMPA

Section B5.5.4 included assessment of potential turbid plumes from placement of dredge material at the DMPA during the capital dredging campaign. This section assesses re-suspension of dredge material (i.e. material placed at the DMPA and also settled elsewhere within the model domain) in the 12-month period following capital dredging. This re-suspension has the potential to impact marine water quality due to increased turbidity.

Following the capital dredging campaign, modelling was extended for an additional 12 months to assess re-suspension of dredge material. The initial condition for the 12-month re-suspension scenario was taken from the final state of the base case capital program assessment (i.e. at completion of capital dredging). While the modelling simulations allowed for tracking of both ambient and dredge material in suspension and deposited on the seabed, the results shown relate to the dredge material 'above ambient' amount.

Modelling was undertaken using 'typical' weather conditions and also 'worst case' weather conditions. For the 'worst case' assessment, re-suspension and dispersion associated with the conditions experienced during an extreme weather event Tropical Cyclone Yasi (February 2011) were simulated.

The results for the typical scenario are shown in **Figure B5.5.7a**, while the results for the worst-case scenario was shown in **Figure B5.5.7b**. These results indicate the DMPA is a retentive site, with turbidity levels (both 50th and 95th percentile) generated by the re-suspension of dredge material being generally very low. This is due to the infrequent nature of re-suspension events at water depths greater than 10m in the Cairns area. The only indication of turbidity on the plots are small areas near the channel dredging area and the DMPA (<20NTU above background) at the 95th percentile (i.e. during adverse weather conditions).

As shown in **Table B5.5.7a**, the approximate quantity of material dispersed in the modelled 12 month 'typical' period is very low (<0.1 percent). The quantity of material dispersed during 'worst case' conditions also remains relatively low, corresponding to approximately 1.1 percent of the initial DMPA mass (**Table B5.5.7a**).

Based upon the 12 month re-suspension modelling results, turbid plumes generated from re-suspension from the DMPA are considered to pose negligible impacts to marine water quality.

Table B5.5.7a Predicted Dispersion from DMPA over a 12 month Period (Typical and Worst Case)

Scenario	Initial DMPA mass ($x10^3$ tonnes)	DMPA mass after 12 months ($x10^3$ tonnes)	Percentage Dispersed (%)
Typical Case	4338	4336	< 0.1%
Worst Case (Cyclone)	4338	4290	1.1%

Figure B5.5.7a Typical Case 12 Month Re-suspension - Turbidity Above Background - 50th Percentile (top) and 95th Percentile (bottom)

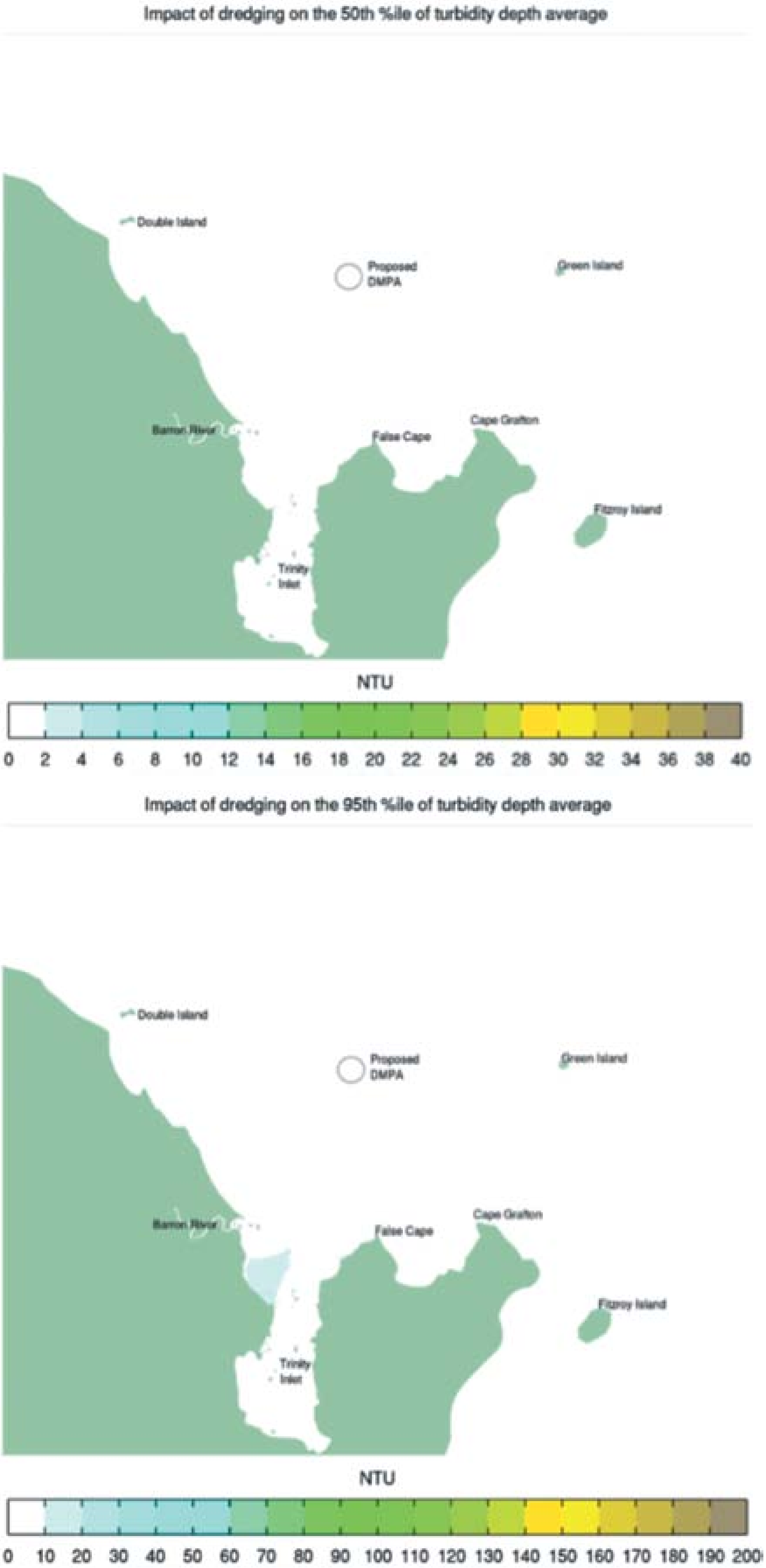
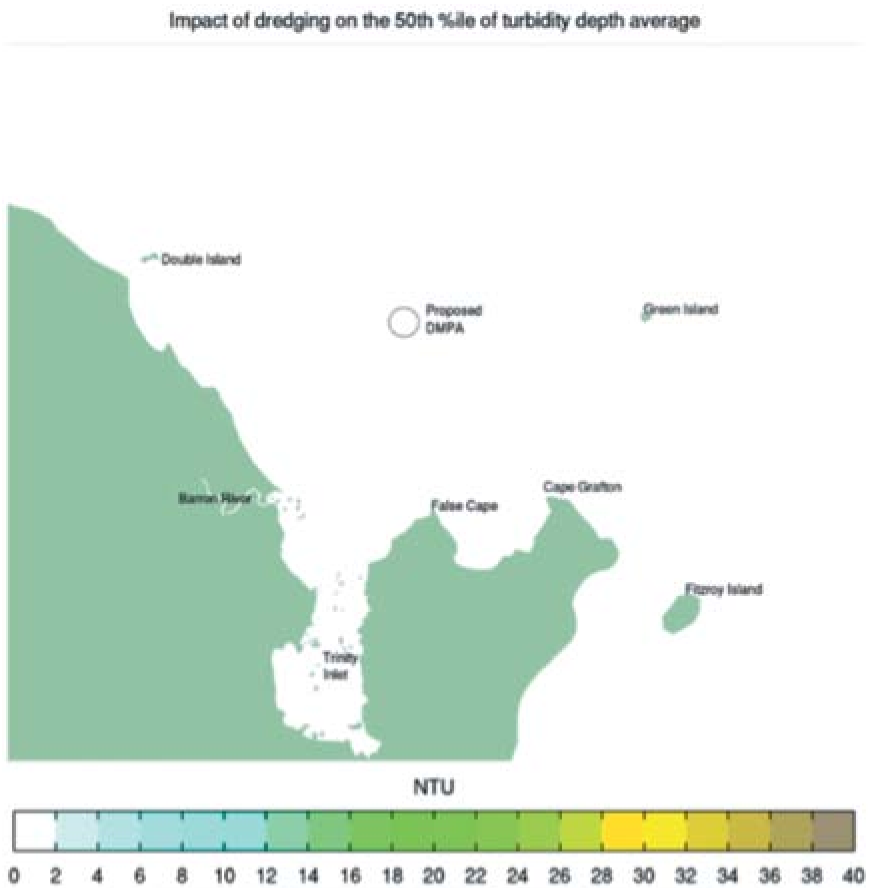
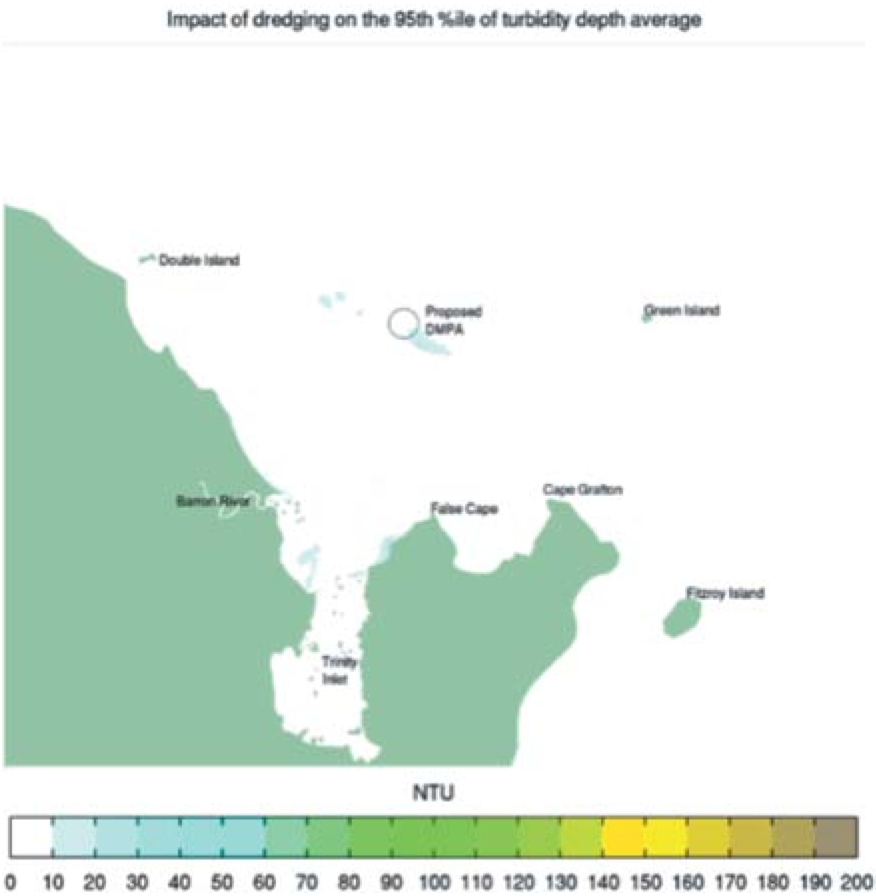


Figure B5.5.7b Worst Case (Cyclone) 12 Month Re-suspension - Turbidity Above Background - 50th Percentile (top) and 95th Percentile (bottom)





B5.5.8 Construction Phase Impacts – Dredging and Construction Plant and Equipment

Upgrade to the wharf infrastructure will involve installation of independent dolphins requiring steel piles. These piles will be driven by a piling rig with crane and hammer from a barge. It is proposed there will be 21 independent dolphins, each requiring four piles. Therefore, 84 piles need to be installed during construction.

Due to the need for construction plant and equipment to upgrade the wharf infrastructure, and the use of dredging plant and equipment for the dredging works, there is potential that fuel/oil spills and other contaminants may pollute marine waters if not appropriately managed.

Dredge operators and construction contractors must, by law, comply with established fuel/oil storage and handling standards and protocols to reduce the risk of incidents. Appropriate operational procedures are included in the Construction Management Plan (**Chapter C1, Construction and Operational Environmental Management Plan**) and the Dredge Management Plan (**Chapter C2, Dredge Management Plan**) which sets out management measures to reduce that the risk of fuel/oil spills and contaminants, and if they occur, how they are managed to minimise impact. The potential for fuel/oil spills presents a negligible impact.

B5.5.9 Operational Phase Impacts – General Considerations

Potential impacts on the marine environment associated with the upgraded wharf will be addressed and mitigated with the implementation of the port's Environmental Management System for port operational activities. Further details are provided in the following sections for shipping operations and maintenance dredging, as these operations are considered to be two key areas with the potential to impact marine waters during the operational phase of the project.

B5.5.10 Operational Phase Impacts – Increased Shipping

Once operational, it is forecast that cruise shipping activity (and associated refueling activity) will increase by approximately 39 percent by 2026 (79 ships to 110 ships).

The increase in shipping and refueling activity may increase the potential for shipping-related contaminants to enter the marine environment. Current and increased shipping operations may introduce contaminants from:

- Hydrocarbons, from refueling or vessel sourced discharges
- Ballast water
- Antifouling systems
- Black water and grey water release
- Other wastewater
- Airborne contaminants from exposed materials (e.g. bulk product) entering the water column
- Solid waste such as packaging materials.

Ballast water, antifouling and wastewater are regulated by the following conventions and legislation which vessels operating in Australia need to comply with:

- International Obligations:
  - *Convention for the Prevention of Pollution from Ships 1973*
  - *Convention on the Prevention of Marine Pollution by Dumping of Wastes and other Matter (London Convention) 1972*
  - *Convention on the Control of Harmful Antifouling Systems on Ships (IMO-AFS Convention) 2001*
  - *Convention for the Control and Management of Ship's Ballast Water and Sediments 2004.*
- Commonwealth Legislation:
  - *Quarantine Act 1908 for management of introduced pests in ballast water, managed by the Department of Agriculture*
  - *Environment Protection (Sea Dumping) Act 1981.*
- State Legislation:
  - *Environmental Protection (Waste Management) Regulation 2000, and Environmental Protection (Water) Policy 2009*
  - *Transport Operations (Marine Pollution) Act 1995 and Transport Operations (Marine Pollution) Regulation 2008*
  - *Maritime Safety Queensland Act 2002.*

On 1 July 2001, Australia introduced mandatory ballast water management requirements to reduce the risk of introducing harmful aquatic organisms into Australia's marine environment through ballast water from international vessels. These requirements are enforceable under the ***Quarantine Act 1908***. The requirements are consistent with the International Maritime Organisation (IMO) Ballast Water Convention 2004 that aims to minimise the translocation of harmful aquatic species in ships' ballast water and ballast tank sediments.

The discharge of high-risk ballast water in Australian ports or waters is prohibited. All internationally plying vessels intending to discharge ballast water anywhere inside the Australian territorial sea must manage their ballast water in accordance with Australia's mandatory ballast water management requirements. This would apply to all international cruise ships visiting the Port of Cairns.

In Queensland's jurisdiction, the international conventions are given force through the ***Transport Operations (Marine Pollution) Act 1995 and Regulation 2008***, which aim to protect Queensland's marine and coastal environment from the adverse effects of ship-sourced pollution. Section 93A(2) of the Act appoints the General Manager, MSQ, as the Marine Pollution Controller to direct the marine pollution response in Queensland coastal waters. Other relevant Queensland legislation is the Maritime Safety Queensland Act 2002 which establishes MSQ and empowers it to 'deal with the discharge of ship sourced pollutants into Queensland Coastal Waters'.

Fuel handling and storage procedures are currently part of the port's existing port operational activities. These procedures will be reviewed and revised as necessary to accommodate the change in shipping and Intermediate Fuel Oil (IFO) refueling activity resulting from the project.

The potential for introduced contaminants from increased shipping presents a negligible impact. Mitigation of these potential impacts will be addressed by compliance with the above legislation administered by the above authorities, and implementation of the port's operational procedures.

B5.5.11 Operational Phase Impacts – Future Maintenance Dredging

Future maintenance dredging will be needed to ensure the project area remains at the required depths for safe navigation of ships. As outlined in **Chapter B3, Coastal Processes**, the widening and deepening of the outer channel will result in an increase in annual maintenance dredging volume in the order of 80,000-100,000 m^3 per year. The existing annual maintenance dredging volume for the inner port is not likely to change significantly as a result of the project as this area does not accumulate sediment as rapidly as the outer channel.

Channel maintenance dredging campaigns typically occur during the months of July and August and generally take about five weeks. The additional volume associated with the expanded channel will likely extend these campaigns to a period of six-seven weeks.

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 for capital dredging as part of this project. 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 limits the amount of material available for re-suspension.

Compared to capital dredging, much smaller volumes of material are involved in maintenance dredging and the timeframes over which dredging will occur will be shorter. Impacts from maintenance dredging are considered to be localised and relatively short term, with limited increases in turbidity adjacent to sensitive environments (refer **Figure B5.5.11a** to **Figure B5.5.11c** below). Furthermore, impacts on sensitive receptors from maintenance dredging have been assessed previously as being acceptable to regulatory agencies (as outlined in the Ports North 10 year maintenance dredging permit and LTMP).

It is proposed future maintenance material be placed at the new marine DMPA (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 of predicted maintenance dredge quantities. 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 in **Chapter B3, Coastal Processes**, marine disposal sites in Trinity Bay have demonstrated a high degree of dredge material retentiveness over time, despite the occurrence of extreme weather events. The new DMPA in water depths between 18 and 22m is considered to have even greater retentive properties.

Further discussion of implications of the project on future maintenance dredging is included in **Chapter B3, Coastal Processes**.

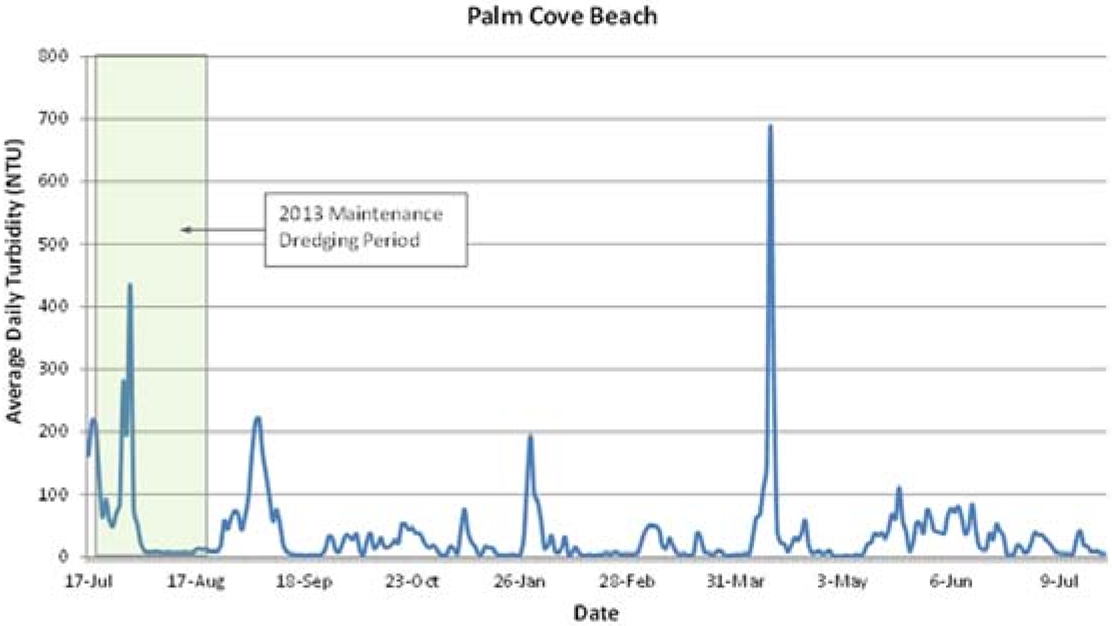
To assess potential impacts from maintenance dredging, water quality monitoring data was reviewed. Water quality monitoring for the EIS was undertaken between July 2013 and July 2014 (Section B5.5.2) at a number of locations. During this monitoring period, annual maintenance dredging was undertaken (between 21 July 2013 and 17 August 2013). The monitoring data was assessed to determine if any discernible impacts due to maintenance dredging could be observed. The time series turbidity data, along with the maintenance dredging period, is presented in **Figure B5.5.11a** to **Figure B5.5.11c**.

Figure B5.5.11a to **Figure B5.5.11c** indicates that all monitoring sites had a similar spike in turbidity which coincided with the commencement of maintenance dredging. However, during this period there were high winds and a spring tide (refer to **Figure B5.4.6.1b**). Once these high winds and spring tides abated, turbidity at all sites was greatly reduced, even while maintenance dredging continued. This confirms the above-mentioned conclusion that turbid plumes from maintenance dredging are localised and short-term, and were not observable in the monitoring data at sensitive receptor locations (refer to **Section B5.5.2.1** for description of monitoring locations).

Based on this assessment, turbid plumes from future maintenance dredging are considered to pose a minor impact to marine water quality.

In terms of potential mobilisation of contaminants from sediment during future maintenance dredging, it is expected that a sediment sampling and analysis plan (SAP) will be developed and implemented to determine the suitability of future maintenance dredge material for marine placement, as is the present process. Any contaminated material detected in future testing will need to be investigated and managed under the NAGD and sea dumping permit process. As such, mobilisation of contaminants from future maintenance dredging is expected to pose a negligible impact to marine water quality.

Figure B5.5.11a Turbidity Data and Maintenance Dredging Period at Palm Cove Beach (top) and Yorkeys Knob (bottom)



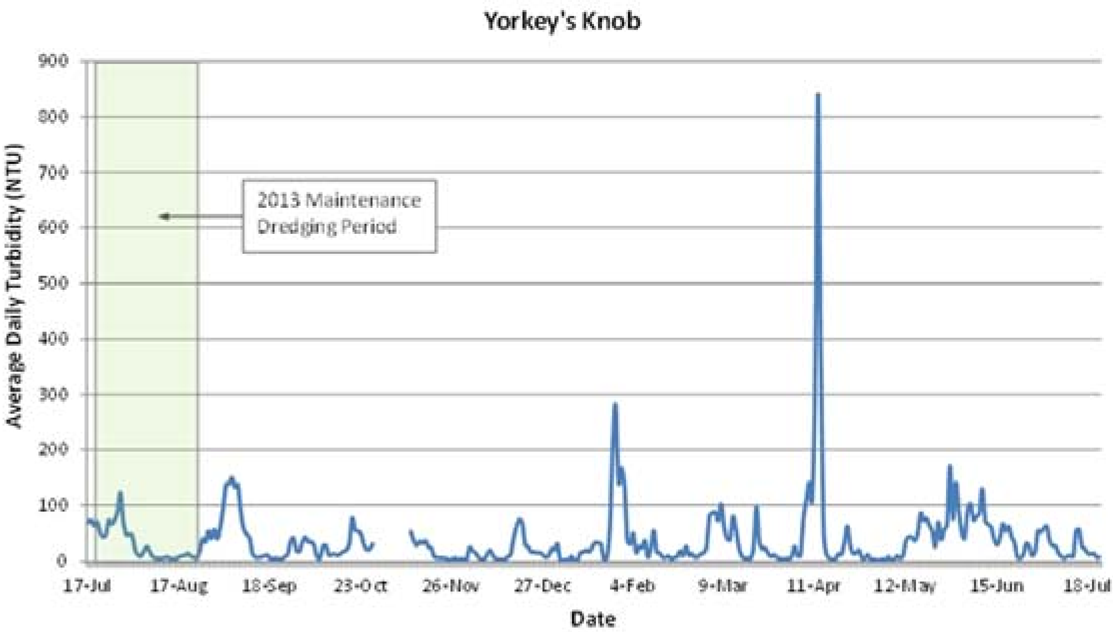
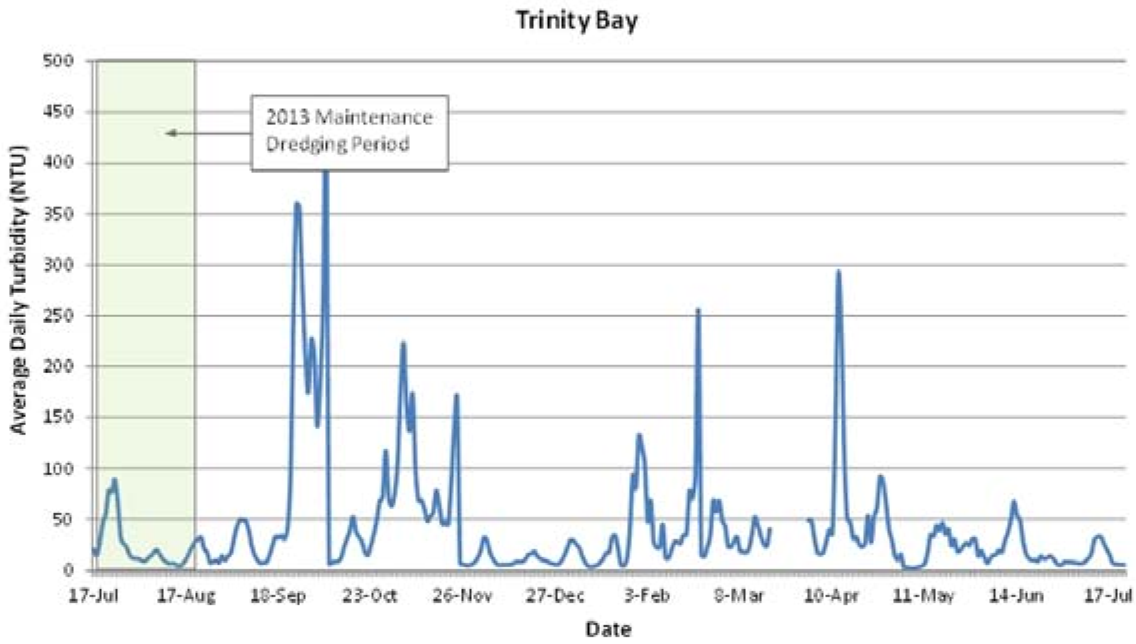


Figure B5.5.11b Turbidity Data and Maintenance Dredging Period at Trinity Bay (top) and Trinity Inlet (bottom)



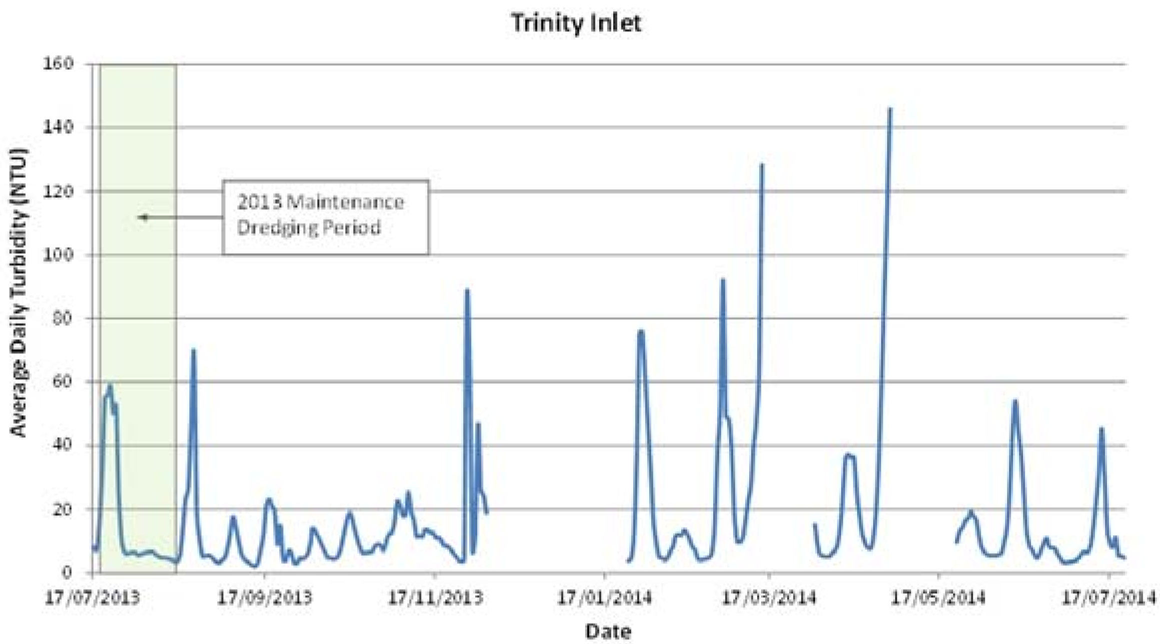
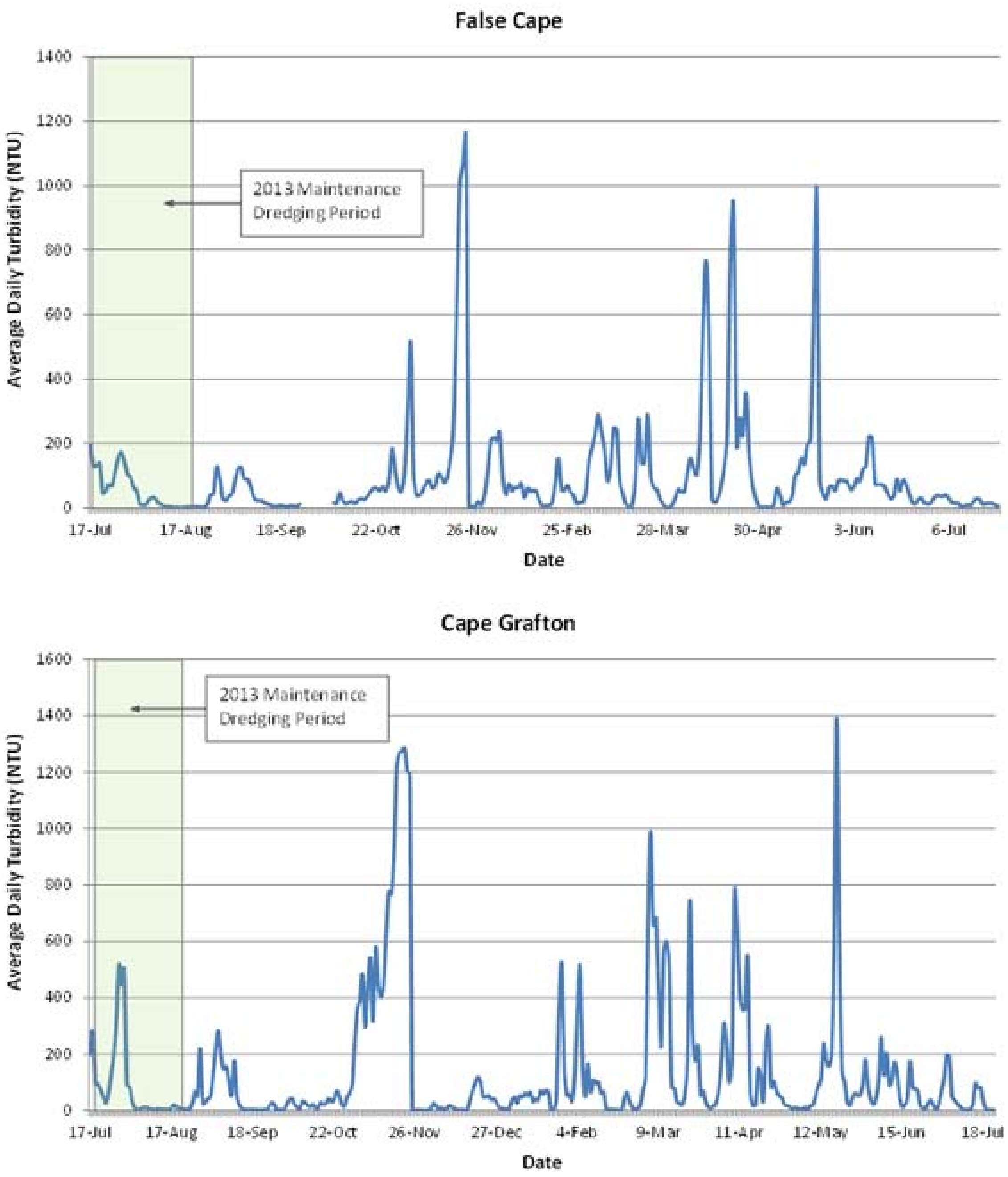


Figure B5.5.11c Turbidity Data and Maintenance Dredging Period at False Cape (top) and Cape Grafton (bottom)



B5.5.12 Mitigation Measures and Residual Impacts

The mitigation measures listed in this section are also included in **Chapter C2, Dredge Management Plan**.

B5.5.12.1 Mitigation Measures – Capital Dredging and Marine Placement

In this impact assessment, it has been assumed that a number of standard mitigation or best practice measures will be employed to minimise potential turbidity impacts generated by capital dredging works. These standard mitigation measures are as follows:

- Ensure the dredge operates within the approved dredge footprint at all times
- Overflow dredging (dredging after a full hopper load has been achieved) by the TSHD is not undertaken unless dictated as required by and in accordance with the worst case (limited dredging) scenario detailed in **Chapter C2, Dredge Management Plan**

- Dredge hopper compartment is to be kept water tight during all dredging activities, except when emptying and washing of the hopper during placement at the DMPA
- Ensure the top of overflow valves are not lowered during the transport component of the dredging cycle (dredging area to DMPA)
- If required, use of high pressure jets on drag heads to loosen materials is restricted to dredging and placement areas only
- The dredge is to be fitted with a 'green valve' in order to minimise the areal extent of turbidity plumes generated by dredge operation. The 'green valve' ensures that overflow from the dredge vessel is released under the keel of the vessel rather than at the water surface.
- Ensure dredge material placement at the DMPA occurs with the TSHD steaming at low speed to avoid creation of larger plumes
- Dredge material is to be uniformly spread over the DMPA to minimise sediment mobilisation and turbidity plume extent beyond the DMPA boundary. This will be achieved through placement patterns that vary with the prevailing current direction. When currents are minimal, deposition will occur relatively uniformly over the DMPA in arc patterns. When currents are present, deposition will occur in arcs in the up-current portion of the DMPA to take into account drift of sediment as it settles. Refer to **Chapter C2, Dredge Management Plan** for further details
- Washing the hopper compartment and pumping out of the hopper must not take place outside the DMPA.

Further to the above standard mitigation measures, the following additional mitigation is proposed to reduce the potential impacts further:

- A reactive water quality monitoring program will be implemented during the dredge campaign to monitor water quality at locations of sensitive receptors (including the same monitoring locations used in the impact assessment section). This strategy will be incorporated to ensure compliance with proposed guidelines (refer to **Chapter C2, Dredge Management Plan**) for dredging and construction works. Monitoring data would be collected and downloaded regularly and the data assessed against threshold triggers, with appropriate management actions implemented if threshold triggers are exceeded.

The reactive water quality monitoring program will be used in real time to guide the dredging campaign and to monitor the effectiveness of the above mitigation measures. If trigger levels are exceeded, the dredge contractor will be responsible for taking actions, in consultation with Ports North, to ensure impacts are avoided at sensitive receptors. These actions are detailed in **Chapter C2, Dredge Management Plan**.

As demonstrated in the Potential Impacts section, potential impacts from nutrients and metals in sediment are negligible and no mitigation measures are required.

B5.5.12.2 Mitigation Measures – Potential Acid Sulfate Soil (PASS) Impacts from Dredging and Placement

It is assumed that the following standard mitigation measure will be employed to minimise potential impacts from oxidisation of PASS dredge material:

- Dredge material should ideally remain waterlogged and not be left within TSHD hopper or dump barges for periods longer than 24 hours to minimise the risk of PASS oxidisation.

B5.5.12.3 Mitigation Measures – Dredging and Construction Plant and Equipment

Standard operational mitigation measures are to be implemented to reduce the risk of fuel/oil spills and other contaminants entering the marine waters, including:

- Development and Implementation of an Operational Dredge Management Plan (in accordance with **Chapter C2, Dredge Management Plan**) which includes management measures to be followed by dredge staff. This document is to be kept as on-board dredge equipment and readily accessible to dredge staff
- A hydrocarbon spill kit is to be located on the dredge and transport barges. This spill kit is to contain such items as absorbent material for spills on deck and also floating booms to contain hydrocarbon slicks if spills manage to enter the water. This spill kit is to be maintained regularly to ensure contents are fully stocked and in good condition
- Consistent with present practice, first strike spill response equipment and appropriately trained staff for the port are accessible and able to respond to events, and have access to more spill response resources if the event escalates

- All fuel and chemical supplies on the dredge and transport barges are to be stored in bunded areas as per the requirements of AS1940:2004 - The storage and handling of flammable and combustible liquids 2004, and applicable WHS Act requirements.

Potential accidental discharges of contaminants during construction and operation of the project will be fully documented in the Construction and Operations Management Plans. Release of contaminants from marine structure and vessels, including anti-foulant coatings will be managed as specified in the Operations Management Plan.

B5.5.12.4 Mitigation Measures – Future Maintenance Dredging

It is assumed that the following standard mitigation measures will be employed to minimise potential impacts from future maintenance dredging:

- Preparation and implementation of a sediment sampling and analysis plan (SAP) to determine suitability of future maintenance dredge material for marine placement (noting maintenance material at Port of Cairns has always been suitable for at sea placement)
- Any contaminated material detected in future testing will be assessed and investigated to determine suitability and management options under the NAGD and sea dumping permit process
- Existing maintenance dredging operations occur in accordance with the approved Long Term Dredge Spoil Disposal Management Plan (LTDSDMP) which contains management measures to reduce impacts on water quality from dredging and placement. This plan will be reviewed and updated in consultation with the established TACC for approval by the Determining Authority.

Further to the above standard mitigation measures, the following additional mitigation measures are proposed to reduce the potential impacts further:

- Update the LTDSDMP to address the additional volumes and duration of maintenance dredging required by the wider channel
- Update the LTDSDMP to address placement at the new DMPA which has marginally improved performance compared to the existing approved DMPA from a water quality perspective (the deeper DMPA site is more retentive and further limits potential re-suspension following placement).

B5.5.12.5 Mitigation Measures – Increased Shipping

It is assumed that compliance with relevant legislation in regard to shipping will be employed as part of standard mitigation measures. To further reduce the potential future risk to marine water quality from refueling activities associated with the provision of IFO at the port, additional mitigation proposed includes revision of fuel handling and spill response procedures in the port’s operational procedures.

B5.5.12.6 Residual Impacts

If all above mitigation measures are implemented, it is expected that there will be low to negligible residual impacts associated with marine water quality.

B5.5.13 Monitoring

Water quality monitoring during the construction phase of the project will be undertaken in accordance with the reactive monitoring program in **Chapter C2, Dredge Management Plan**.

B5.5.14 Assessment Summary

In accordance with the methodology described in **Section B5.5**, **Table 5.5.14a** summarises the marine water quality issues identified by the impact assessment in the previous sections. This assessment table also includes the significance of each of the identified impacting processes, the likelihood of the impact occurring, and the resulting risk rating.

The standard and additional mitigation measures discussed in previous sections are also summarised in **Table B5.5.14a**, with a risk rating indicated for the residual impacts after mitigation. As indicated in this assessment table, all residual impacts are rated as either a low or negligible risk.

Table B5.5.14a Impact Assessment Summary

Marine Water Quality								
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**
Generation of turbid plumes from dredging (outer channel)	• Ensure TSHD dredge operates within the approved dredge footprint at all times. • Overflow dredging by the TSHD is not undertaken unless dictated as required by and in accordance with the worst case (limited dredging) scenario • Dredge hopper compartment is to be kept water tight during all dredging activities, except when emptying and washing of hopper at the DMPA. • Ensure the top of overflow valves are not lowered during the transport component of the dredging cycle • No high pressure jets to be used on drag heads outside of the dredge footprint or the DMPA • Dredge to be fitted with a 'green valve'	Minor	Unlikely	Low	• Implementation of a reactive water quality monitoring program, with management/corrective actions implemented if trigger levels are exceeded (as outlined in **Chapter C2, Dredge Management Plan**).	Minor	Unlikely	Low
Generation of turbid plumes from dredging (inner port)	• Ensure Backhoe and TSHD dredge within inner port areas operate within the approved dredge footprint at all times. • Other standard mitigation for the TSHD are applied as per the 'outer channel' (above).	Minor	Unlikely	Low	• Implementation of a reactive water quality monitoring program, with management/corrective actions implemented if trigger levels are exceeded (as outlined in **Chapter C2, Dredge Management Plan**).	Minor	Unlikely	Low

Generation of turbid plumes from placement (DMPA)	• Ensure dredge places material within the approved DMPA at all times. • Ensure dredge material placement at the DMPA occurs with the TSHD steaming at low speed. • Dredge material is to be uniformly spread over the DMPA with placement patterns that vary with the prevailing current direction. • Washing the hopper compartment and pumping out of the hopper must not take place outside the DMPA.	Minor	Unlikely	Low	• Implementation of a reactive water quality monitoring program, with management/corrective actions implemented if trigger levels are exceeded (as outlined in **Chapter C2, Dredge Management Plan**).	Minor	Unlikely	Low
Mobilisation of contaminants into water column	• Preparation and implementation of a sediment sampling and analysis plan (SAP) to determine suitability of sediment for marine placement. • Dredge material has been assessed as being suitable for at sea placement (as described in **Chapter B4, Marine Sediment Quality**).	Negliglble	Unlikely	Negliglble	Nil	Negliglble	Unlikely	Negliglble
Oxidisation of potential acid sulphate soil material.	• Risks of oxidation are negligible assuming marine (at sea) placement of the dredged material. • Dredge material should ideally remain waterlogged and not be left within TSHD hopper or dump barges for periods longer than 24 hours to minimise the risk of PASS oxidisation in the hopper.	Negliglble	Unlikely	Negliglble	Nil	Negliglble	Unlikely	Negliglble

Turbid plumes from re-suspension of dredge material from DMPA 12 months following capital dredging campaign.	Nil – the impact assessment has concluded that the potential for re-suspension of dredged material following placement at the DMPA is negligible.	Negliglble	Possible	Negliglble	Nil	Negliglble	Possible	Negliglble
Dredging and construction plant and equipment.	• Development and implementation of an Operational Dredge Management Plan by the contractor (in accordance with the DMP contained in Part C). • Hydrocarbon spill kit is to be located on the dredge and transport barges. • First strike spill response equipment and staff are accessible and able to respond to events, and have access to more spill response resources if the event escalates. • All fuel and chemical supplies to be stored appropriately.	Negliglble	Unlikely	Negliglble	Nil	Negliglble	Unlikely	Negliglble
Increased shipping	Compliance with relevant legislation.	Negliglble	Possible	Negliglble	Revise fuel handling and spill response procedures in Ports North operational procedures.	Negliglble	Unlikely	Negliglble

Future maintenance dredging – mobilisation of contaminants into water column	• Preparation and implementation of a sediment SAP to determine suitability of future maintenance dredge material for marine placement (noting maintenance material at the Port of Cairns has always been suitable for at sea placement). • Any contaminated material detected in future testing will be assessed and investigated to determine suitability and management options under the NAGD and sea dumping permit process.	Negliglble	Unlikely	Negliglble	Nil	Negliglble	Unlikely	Negliglble
Future maintenance dredging – water quality from dredge plumes	• Existing maintenance dredging operations occur in accordance with an approved LTDSDMP which contains management measures to reduce impacts on water quality from dredging and placement.	Minor	Unlikely	Low	• Update the LTDSDMP to address the additional volumes and duration of maintenance dredging required by the wider channel. • Update the LTDSDMP to address placement at the new DMPA which has marginally improved performance compared to the existing approved DMPA from a water quality perspective (the deeper DMPA site is more retentive and further limits potential re-suspension following placement).	Minor	Unlikely	Low

B5.6 References

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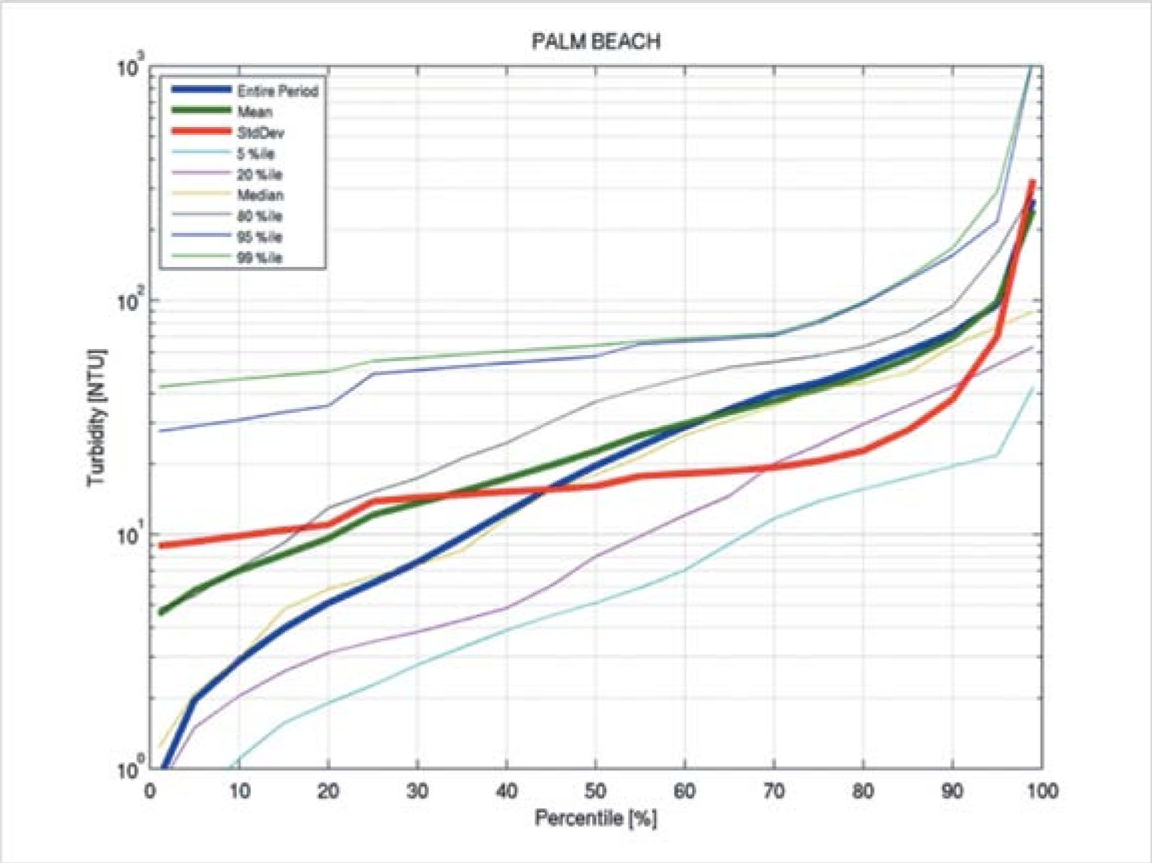
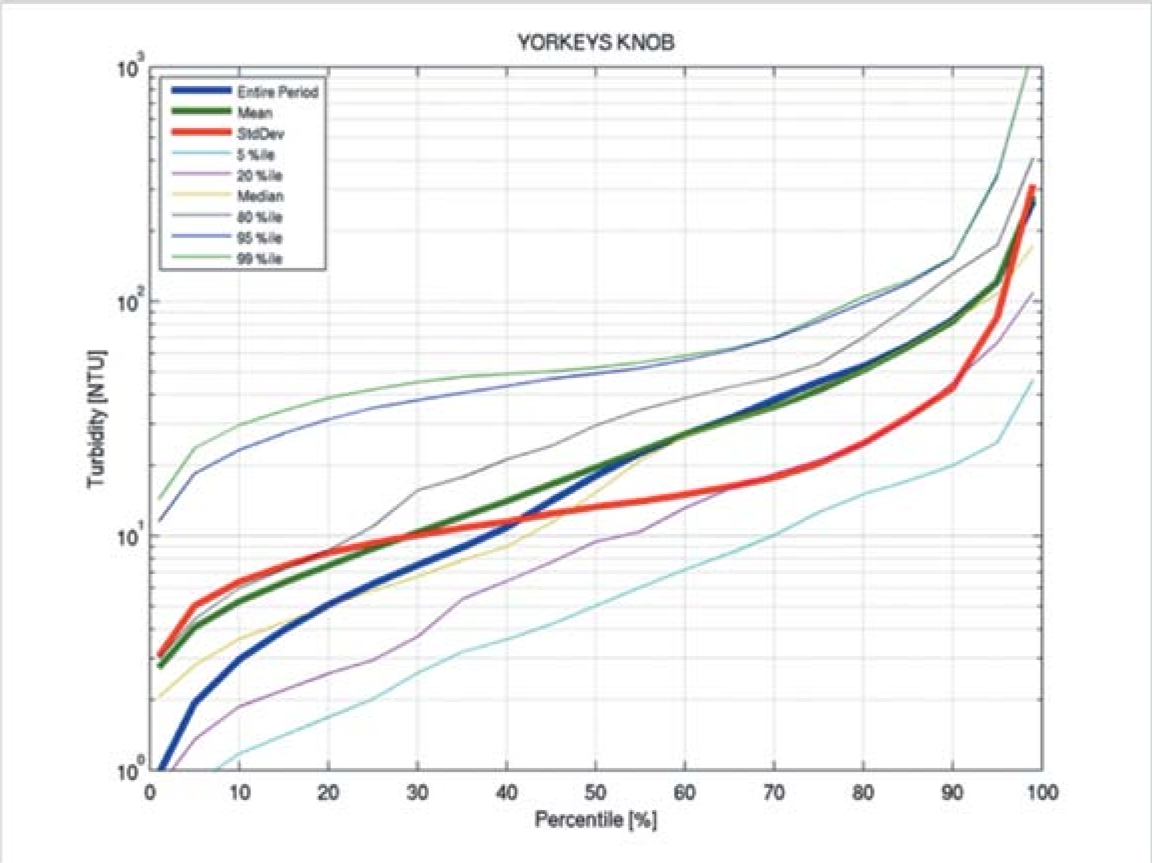
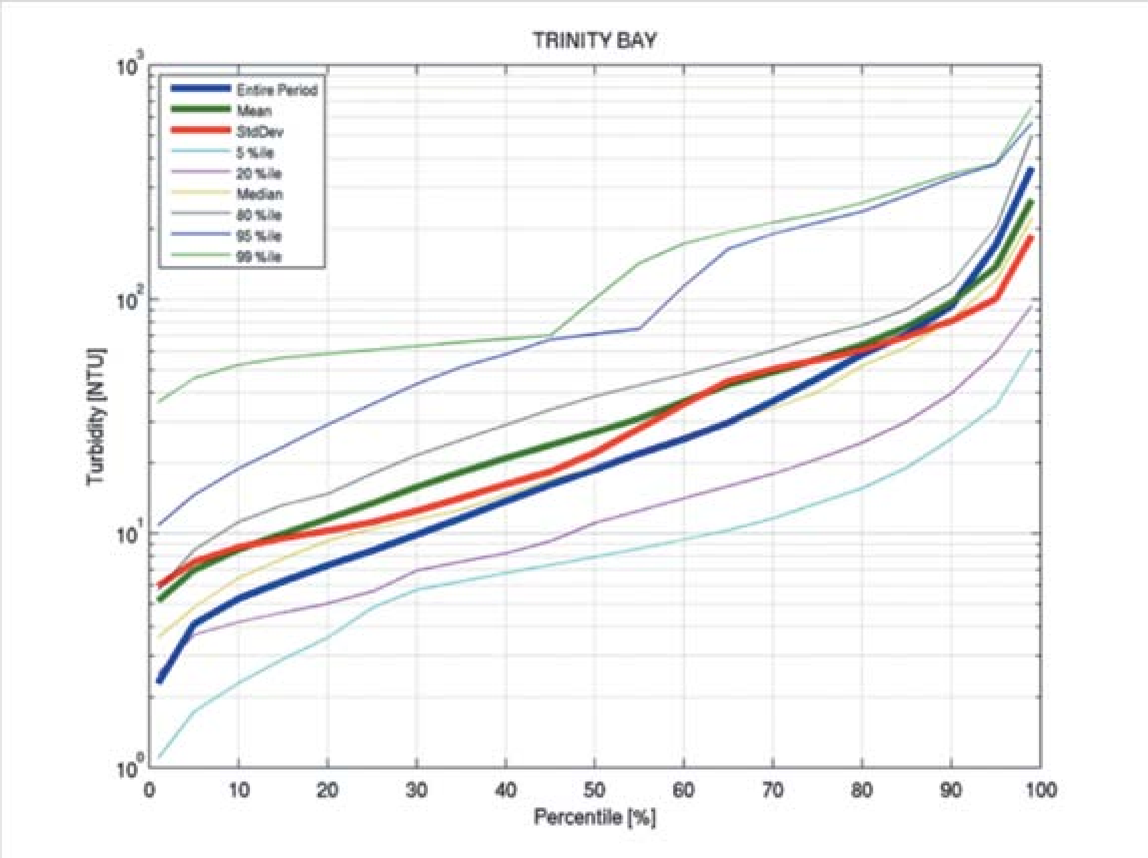
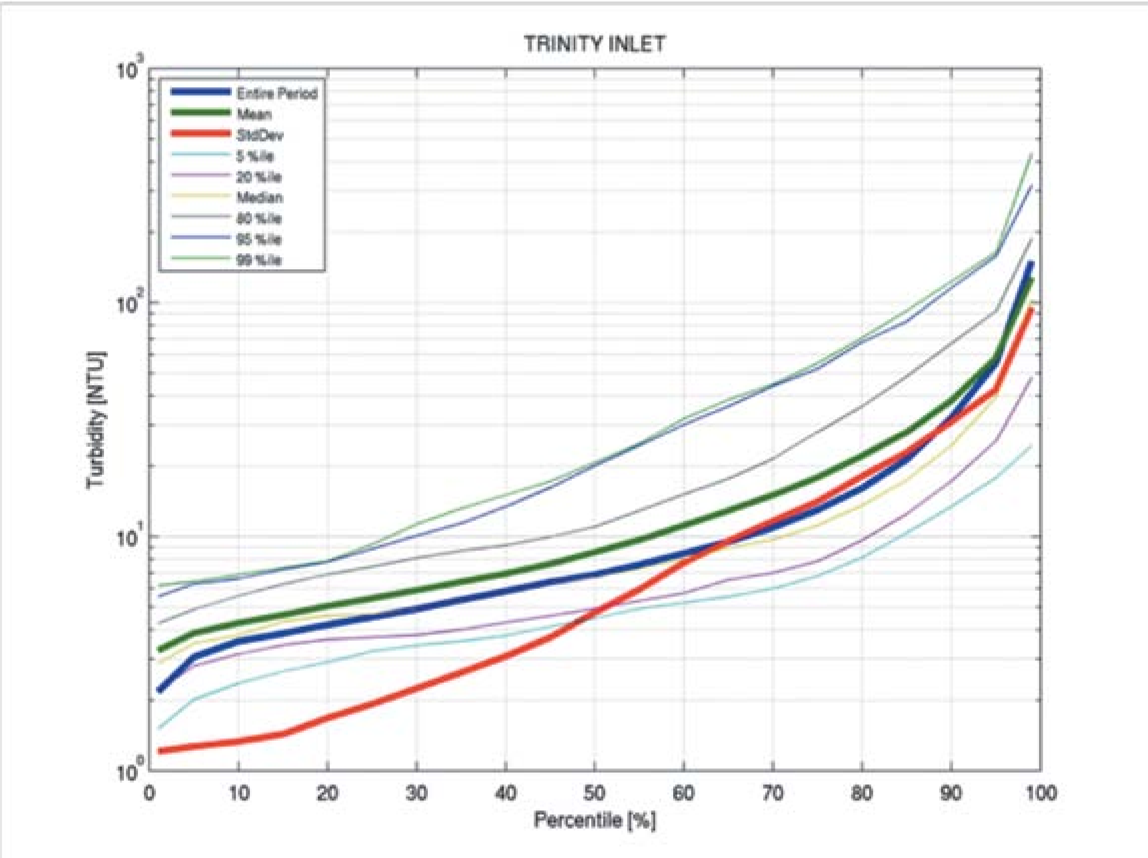
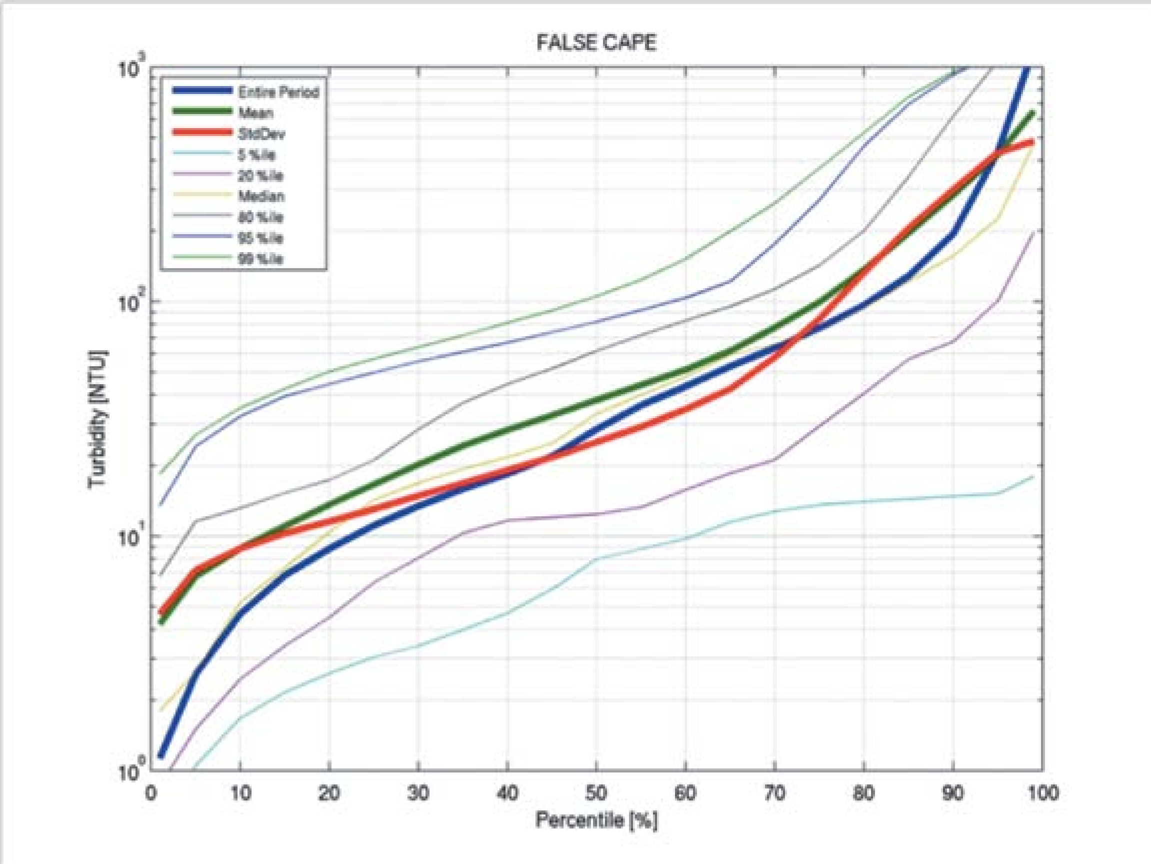
Appendix B5a Baseline Data Percentile Curves

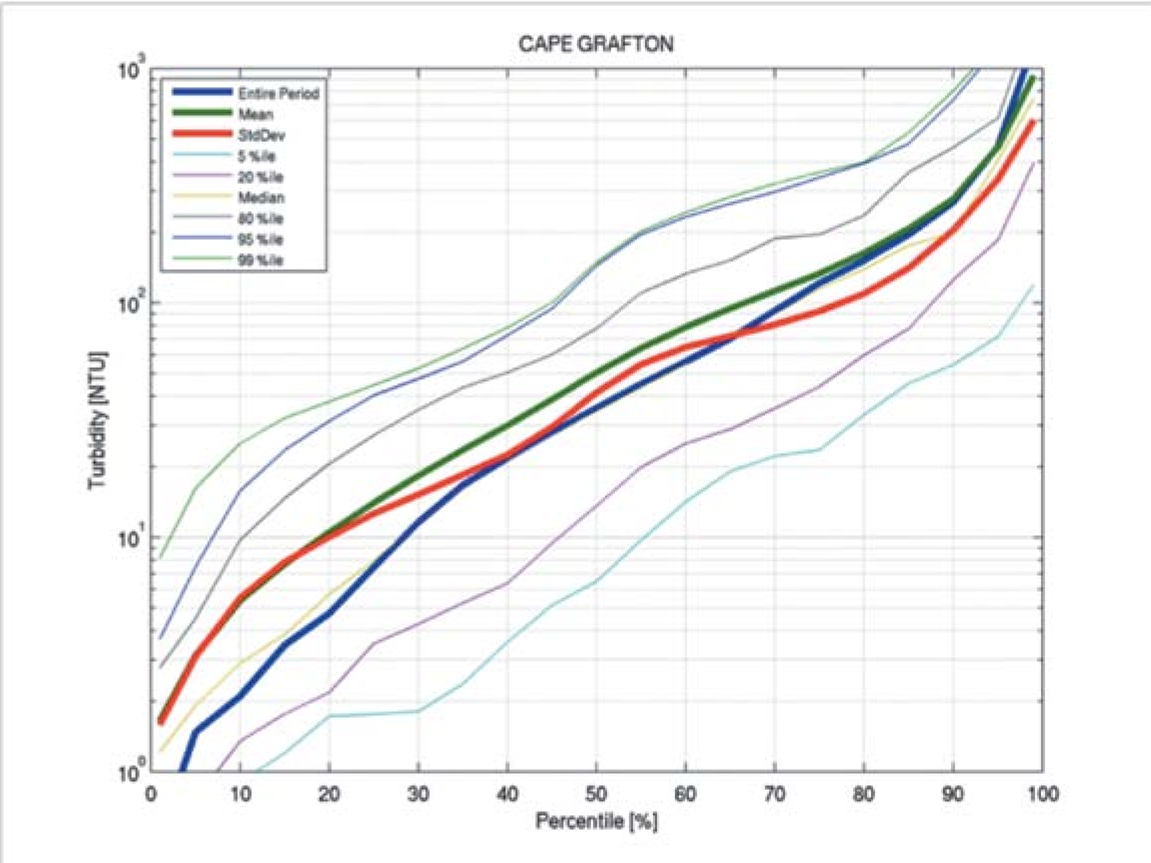





TRINITY BAY
Entire Period
Mean
StdDev
5 %ile
20 %ile
Median
80 %ile
95 %ile
99 %ile
Turbidity [NTU]
10^3
10^2
10^1
10^0
0
10
20
30
40
50
60
70
80
90
100
Percentile [%]


TRINITY INLET
Entire Period
Mean
StdDev
5 %ile
20 %ile
Median
80 %ile
95 %ile
99 %ile
Turbidity [NTU]
10^3
10^2
10^1
10^0
0
10
20
30
40
50
60
70
80
90
100
Percentile [%]


FALSE CAPE
Entire Period
Mean
StdDev
5 %ile
20 %ile
Median
80 %ile
95 %ile
99 %ile
Turbidity [NTU]
Percentile [%]


CAPE GRAFTON
Entire Period
Mean
StdDev
5 %ile
20 %ile
Median
80 %ile
95 %ile
99 %ile
Turbidity [NTU]
Percentile [%]

Appendix B5b Summary Statistics of 12 Month Baseline Turbidity Data

Monitoring Site	Location	Percentile	Turbidity (NTU)								
			Entire Monitoring Period	Mean of 30 Day Windows	Standard Deviation	5%ile of 30 Day Windows	20%ile of 30 Day Windows	50%ile of 30 Day Windows	80%ile of 30 Day Windows	95%ile of 30 Day Windows	99%ile of 30 Day Windows
1	Palm Cove Beach	20%ile	5.1	9.6	11.0	1.9	3.1	5.8	13.0	35.5	49.8
		50%ile	19.6	22.7	16.0	5.1	8.1	18.0	37.0	57.7	64.2
		80%ile	51.4	47.9	22.7	15.6	29.7	44.4	63.5	96.7	98.5
2	Yorkeys Knob	20%ile	5.1	7.5	8.5	1.7	2.6	5.0	8.7	31.4	38.8
		50%ile	18.0	19.5	13.3	5.0	9.4	15.3	29.5	49.2	52.2
		80%ile	52.8	50.9	24.8	15.1	24.6	50.8	70.3	98.9	104.5
3	Trinity Bay	20%ile	7.3	11.5	10.3	3.6	5.0	9.3	14.7	29.2	58.6
		50%ile	18.7	27.0	22.0	7.9	11.1	19.1	38.6	71.2	100.5
		80%ile	58.3	64.1	60.8	15.6	24.4	52.1	77.6	237.2	258.0
4	Trinity Inlet	20%ile	4.2	5.1	1.7	2.9	3.6	4.6	6.9	7.8	7.8
		50%ile	6.9	8.6	4.7	4.5	4.9	6.7	11.0	20.1	20.7
		80%ile	16.1	22.1	18.1	8.1	9.6	13.6	36.1	67.9	70.8
5	False Cape	20%ile	8.8	13.6	11.5	2.6	4.5	10.4	17.4	44.4	50.3
		50%ile	28.5	38.0	25.2	8.0	12.4	33.2	61.6	82.0	105.4
		80%ile	96.6	136.7	133.2	14.0	40.6	94.0	200.6	460.5	525.3
6	Cape Grafton	20%ile	4.7	10.5	10.1	1.7	2.2	5.7	20.6	31.3	38.0
		50%ile	35.6	50.4	41.4	6.5	13.6	34.5	77.7	144.3	149.1
		80%ile	151.9	163.1	109.4	33.3	59.9	139.8	236.1	394.0	397.5