

# Appendix E Draft Dredge Management Plan

# Dredge Management Plan

East Arm Wharf Expansion Project



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Prepared for  
Department of Lands and Planning

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## Executive Summary

The Northern Territory Department of Lands and Planning (DLP) have proposed an expansion of the East Arm Wharf (EAW) to accommodate the requirements of prospective wharf users, including commercial users and the Department of Defence. The expansion will require dredging within Darwin Harbour to provide for effective and efficient vessel access and manoeuvring. The proposed expansion also involves the development of additional land at East Arm Wharf by reclamation.

DLP are required to prepare a Dredge Management Plan (DMP) to support environmental approvals for the proposed East Arm Wharf expansion. The DMP details the proposed dredging work and the measures recommended in managing its potential environmental impacts. The DMP specifically addresses:

- the probable dredging methods (capital and maintenance work)
- the quantity and characteristics of material to be dredged, and the disposal of unsuitable materials
- the reuse and/or disposal of dredged material
- the environmental management framework for the proposed dredging work, comprising the environmental management objectives, performance criteria, mitigation measures and reporting and monitoring requirements.

The purpose of this DMP is to provide a general framework for planning and implementation of dredging and spoil management activities in Darwin Harbour in relation to the EAW project. It is prepared at a high level and refers to broad principles and objectives, nominating potential actions and equipment/plant for adoption.

Dredging as part of the East Arm Wharf expansion project will be undertaken at three locations:

- the ramp and hardstand
- Marine Supply Base
- Small vessels and Tug berths area.

A summary of the dredging work plan for each of these areas is presented below. Dredging will largely be undertaken using Cutter Suction Dredge for subsurface materials. The decision regarding whether to use two dredges (small and large) will be made based on availability and economic consideration, however the level of environmental management and protection identified will be maintained.

A Trailer Suction Dredge (TSD) is unlikely to be used at East Arm Wharf as TSDs typically require a greater depth of water than other methods of dredging, and a TSD small enough to operate in the shallow waters in the vicinity of east arm wharf is unlikely to be economical.

Area of Operation	Ramp and Hardstand	Marine Supply Base approach channel	Approach channel/Tug berths area
Vessel Type	Small CSD	Large CSD	Large CSD
Dredge depth	-2.0mCD	-7.7mCD	-7.7mCD
Estimated dredge volume	62,000 m <sup>3</sup>	640,000 m <sup>3</sup>	115,300 m <sup>3</sup>
Duration of dredging operation (days)	42.8	63.1 (max)	5.6

### Geotechnical information

Darwin 1:100,000 geological series sheets indicate that the East Arm Wharf Dredge Areas are underlain by quaternary and tertiary aged sediments comprising unconsolidated silty clay, loose silty sand, ferruginous and clayey sandy gravel pisolitic and mottled laterite. Beneath these sediments are Proterozoic bedrocks from the Burrell Creek Formation (BCF) comprising metamorphosed sandstones; siltstones and phyllites. Quartz veins are widespread.

The BCF has been investigated extensively for various structures in the Darwin area. and the sedimentary beds comprise mainly siltstone with some sandstone and claystone. The rock strength varies from very low strength phyllites to very high strength quartz and quartz sandstones. Drill holes indicate that sub vertical beds of these rock layers with boreholes drilled 1 m apart indicating very different rock strengths. The formation has weathered



over time and vertical and horizontal clay seams of 400 mm or greater existing with the straight of a stiff to very stiff clay soil. Most boreholes indicate that the BCF consists of lower strength meta siltstones and clay seams. Only deep excavations strike high strength rock.

### **Environmental effects**

Dredging activities risk a number of impacts on the marine environment. In some cases, impacts may be more relevant to particular dredging methods. Environmental issues that are typically relevant for dredging and reclamation projects include the following:

- changes to water quality;
- changes to coastal processes (waves and currents);
- effects on marine ecology (flora and fauna);
- mobilisation of sediment and contamination resident in interstitial pore waters;
- introduction of marine pests;
- impacts on cultural heritage values; and
- nuisance environmental effects (noise and air emissions).

Environmental effects are described in Section 5.0.

### **Environmental management**

Section 5 contains the sub-plans that describe the specific management actions and preventative measures that will be implemented during construction works at the East Arm Wharf, in order to minimise the risk of harm on environmental and heritage values and minimise impacts from dredge related activities.

The sub-plans outline specific objectives and performance indicators that can measure the relative success of an implemented plan. These sub-plans also specify specific monitoring and reporting requirements associated with the potential environmental impacts and associated risks. The results of the monitoring will be used to assess the effectiveness of management actions and site compliance with performance indicators. The DLP Project Manager will be required to report regularly on environmental performance, including incidents/complaints and corrective actions.

The management procedures outlined in this section may be subject to change following environmental assessment by governing bodies. Responsibilities allocated are indicative only and may change depending on the company structure of the construction contractor and/ or final proponent.

## Acronyms

Acronym	Definition
AAPA	Aboriginal Areas Protection Authority
ABWMAC	Australian Ballast Water management Advisory Council
AECOM	AECOM Australia Pty Ltd
AHU	Aquatic Health Unit
AHD	Australian Height Datum
ANZECC	Australia and New Zealand Environment Conservation Council
AQIS	Australian Quarantine and Inspection Service
ASS	Acid Sulfate Soils
BCF	Burrell Creek Formation
BGBS	Beagle Gulf Benthic Survey
BHD	Backhoe Dredge
BPP	Benthic Primary Producers
BPPH	Benthic Primary Producer Habitat
CD	Chart Datum
CEMP	Contractors Environmental Management Plan
CMS	Contractors Method Statement
CSD	Cutter Suction Dredge
DC	Dredging Contractor
DEIS	Draft Environmental Impact Statement
DHAC	Darwin Harbour Advisory Committee
DHF	Department of Health and Families
DIPE	Department of Infrastructure, Planning and Environment
DMP	Dredge Management Plan
DPC	Darwin Port Corporation
DPI	Department of Planning and Infrastructure
EIS	Environmental Impact Statement
EMS	Environmental Management System
EO	Explosive Ordnance
EPA	Environment Protection Authority
EPBC Act	<i>Environment Protection and Biodiversity Conservation Act 1999</i>
ESCP	Erosion and Sediment Control Plans
ESD	Ecologically Sustainable Development
Ha	Hectare
HAZIDs	Hazard Identification Studies
kg	Kilogram
km	Kilometre
km <sup>2</sup>	Square Kilometres
km/hr	Kilometres per hour
km/s	Kilometres per second
kg/m <sup>3</sup>	Kilograms per cubic metre
LAT	Lowest Astronomical Tide
LTDSMS	Long-term Dredging and Spoil Management Strategy

Acronym	Definition
m	Metre
MBES	Multi-beam Echo Sounder
m <sup>2</sup>	Square Metres
m <sup>3</sup>	Cubic Metres
M <sup>3</sup> /week	Cubic metres per week
Mm <sup>3</sup>	Million cubic metres
MARPOL	International Convention for the Prevention of Pollution from Ships
mm	Millimetre
MSBA	Marine Supply Base Area
MSB	Marine Safety Branch
NEPC	National Environment Protection Council
NEPM	National Environment Protection Measures
NES	National Environmental Significance
NOI	Notice of Intent
NPI	National Pollution Inventory
NRETAS	Department of Natural Resources, Environment, the Arts and Sport
NT	Northern Territory
NTU	Nephelometric Turbidity Units
OCS	Offshore Constitutional Settlement
OSCP	Oil Spill Contingency Plan
%	Percent
PAR	Photosynthetically Active Radiation
PSD	Particle Size Distribution
PWCNT	Parks and Wildlife Commission of the NT
SEWPaC	Department of Sustainability, Environment, Water, Population and Conservation
SOPEPs	Ship Board Oil Pollution Emergency Plans
SPT	Standard Penetration Tests
TSHD	Trailer Suction Hopper Dredge
TAG	Technical Advisory Group (for Dredging)
TSS	Total Suspended Solids
UXO	Unexploded Ordnance
WQPP	Water Quality Protection Plan
WRL	Water Research Laboratory

## 1.0 Background and scope of the Dredge Management Plan

### 1.1 Introduction

The Northern Territory Department of Lands and Planning (DLP) are proposing an expansion of the East Arm Wharf to accommodate the requirements of prospective wharf users, including commercial users and the Department of Defence. The proposed expansion will require dredging within Darwin Harbour to provide for effective and efficient vessel access and manoeuvring.

DLP engaged AECOM Australia Pty Ltd (AECOM) to prepare a Dredge Management Plan (DMP) to support the environmental approvals process for the proposed East Arm Wharf expansion project. The DMP details the proposed dredging work and the measures recommended to manage any potential environmental impacts from the action and will specifically address:

- the probable dredging methods (capital and maintenance work),
- the estimated quantity and the characteristics of the material to be dredged,
- the reuse and/or disposal of dredged material, as well as disposal of unsuitable material offshore,
- the environmental management framework for the proposed dredging work, comprising environmental management objectives, performance criteria, mitigation measures, reporting and monitoring requirements.

Parallel to the development of this project-specific DMP for the East Arm Wharf expansion, it is recognised that the establishment of an overarching long-term strategic approach to dredging and reclamation projects within Darwin Harbour will be beneficial as will the preparation of a Long-term Dredging and Spoil Management Strategy (LTDSMS) to provide a framework for integration of future dredging and reclamation projects proposed by DLP and by other proponents. NRETAS will be the responsible authority for the LTDSMS.

It will guide the future planning and implementation of dredging and reclamation projects within Darwin Harbour and recognise and protect the Harbour's environmental values. It will also assist to review and evaluate known future dredging and reclamation projects, describe baseline environmental conditions and environmental values, establish objectives for management of dredging and dredge spoil and describe a framework for management of dredging and dredge spoil within Darwin Harbour.

This specific DMP will describe the dredging component of the proposed East Arm Wharf expansion project and will form a component of the environmental approvals documentation (Draft / Supplementary Environmental Impact Statement (DEIS)). This DMP is consistent with the East Arm Wharf DEIS/SEIS.

### 1.2 Purpose of the DMP

The purpose of this specific DMP is to provide an environmental framework for the planning and implementation of the dredging and spoil management activities for the East Arm Wharf expansion project. The document addresses the broad range of proposed operations, presenting principles and objectives to provide the regulatory authorities an understanding of the operational options that exist in the implementation of the proposed activity.

The DMP presents a common approach to Dredging and Spoil Management for the East Arm Wharf expansion project and represents a basis for the future LTDSMS.

## 1.3 Structure of the DMP

The structure of the DMP is as follows:

### **Section 1 Background and scope of the DMP**

This section introduces the project, providing an overview and outlining the need for the DMP. Included is the location of the site location within the broader Northern Territory context with the existing environment at East Arm Wharf and the wider Darwin Harbour described in the context of studies previously carried out in the area.

### **Section 2 Description of dredging and associated development**

This section breaks the dredging operation down into key activities and describes the various dredging methods proposed at East Arm Wharf and for completeness includes an assessment of alternate methods. The dredge footprint is presented and results from bathymetric and geotechnical studies relevant to dredging in the area are summarised. Dredge material placement options and a reclamation strategy are presented.

### **Section 3 Legislation and statutory obligations**

The section presents a summary of Territory and Commonwealth legislation relevant to the proposed dredging at East Arm Wharf. Non statutory policies and documents including guidelines and codes of practice for dredging are also presented in this section as are relevant permits and licence approvals.

### **Section 4 Environmental processes and responsibilities**

This section summarises the roles and responsibilities of each of the major stakeholders in the proposed dredging project, including regulatory bodies, the proponent, the primary contractor and the DLP Technical Advisory Group (TAG).

### **Section 5 Environmental and coastal management issues**

Environmental and coastal management issues are presented for each of the project activities including material extraction; dredge plant and vessel operation and dredge material placement. Environmental Management strategies are also presented for each of the key environmental factors and major work aspects.

## 1.4 Project overview

Dredging as part of the East Arm Wharf Expansion project will be undertaken at three locations. These are as follows:

- the ramp and hardstand
- Marine Supply Base
- small vessel berth areas.

These proposed dredge footprints are outlined in Figure 1, with each area described in detail in Section 1.5.

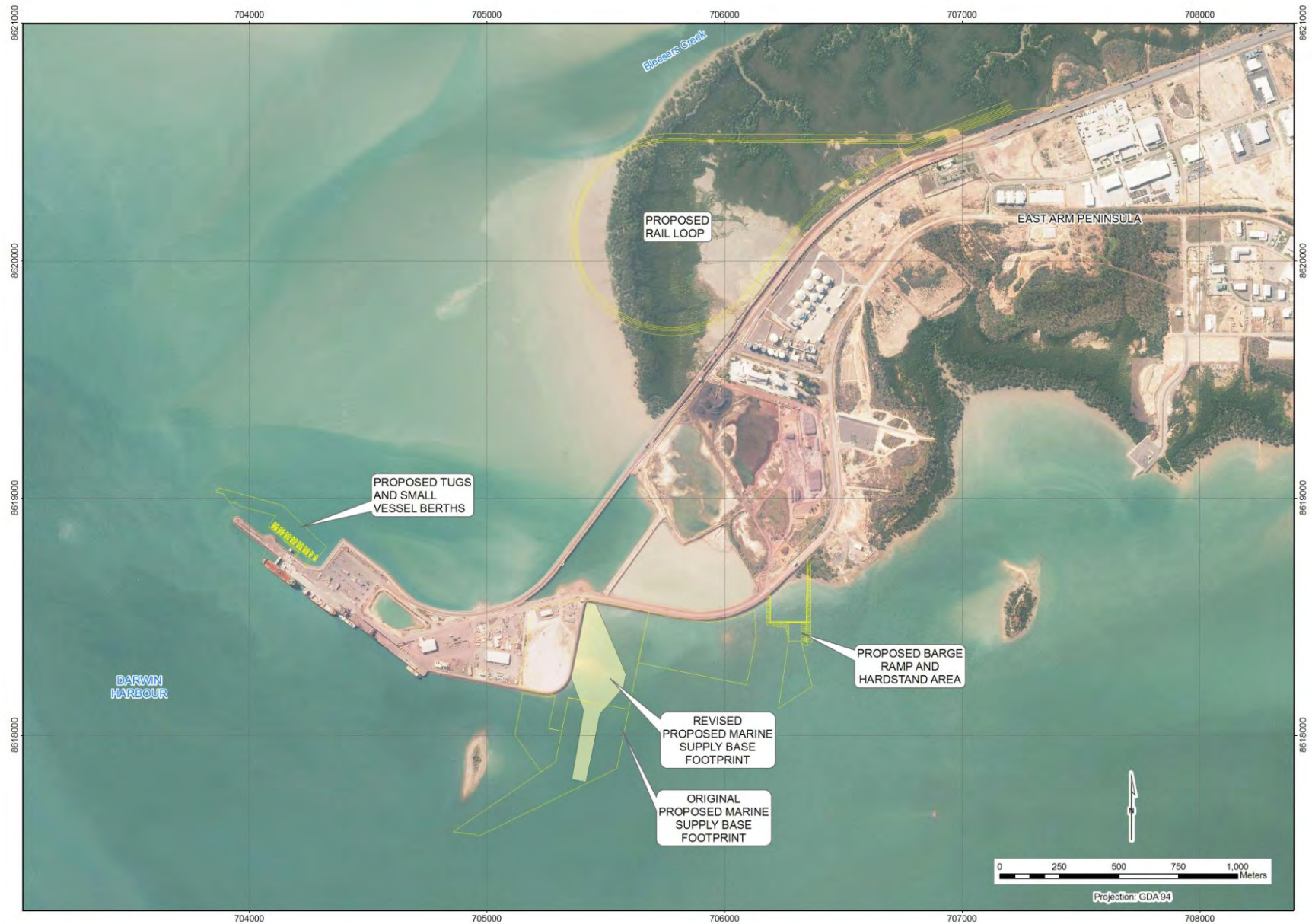


Figure 1 East Arm Wharf – Proposed Dredge Footprint (Source URS 2011)

## 1.5 Dredging methods

The predominant plant will be cutter suction dredgers (CSDs). It must be noted that the EIS assessment included the use of two dredgers (small and large) to determine optimal equipment selection. However, the number and type of dredgers selected will be based on availability and economic considerations and availability, but the level of environmental protection and management will be maintained independent of equipment option. Back hoe dredgers may also be used in shallow waters and/or on stiff or hard sediments.

### 1.5.1 The ramp and hardstand

The intent of the project is to establish a small barge ramp and hardstand on the southern side of the Peninsula. This area will be constructed by linking the existing land based hardstand and proposed offshore hardstand with a harbour facing sea wall established on a combination of disturbed land, backfilled, bunded ponds and the Harbour foreshore.

The design considers that the CSD will be deployed to dredge an approach channel to the new ramp and hardstand area (Figure 1). Table 1 (sourced by DLP from URS/Scott Wilson, 2011) sets out the dredger work plan based on the vessel capacity, speed and efficiency to define the dredge duration). It is estimated that the dredger will operate continuously over a 43 day period.

Table 1 Dredging work plan - dredging at the ramp and hardstand area

Vessel Type	CSD
Area of Operation	Ramp and hardstand
Dredge depth	-2.0m Chart Datum (CD)
Estimated dredge volume	62,000 m <sup>3</sup>
Duration of dredging operation (days)	42.8 (maximum)
Total duration of simulation (days)	43*

\*From modelling reported by URS 2011

### 1.5.2 Marine Supply Base (MSB)

A portion of the Marine Supply Base will be developed into hardstand to provide a rock load out facility. This will involve preparation of the surface to allow the area to be used for the storage and the load out of rock materials.

There is a current requirement for this facility to be developed as soon as possible. The design considers that the large CSD will be deployed to dredge an approach channel to the new Marine Supply Base facility (Figure 2).

Table 2 (source but modified for changes in anticipated volumes by DLP: URS/Scott Wilson 2011) sets out the dredge work plan based on the vessel capacity, speed and efficiency to define the dredge duration. It is estimated that the dredge will operate continuously over a 64 day period.

Table 2 Dredging work plan – dredging at the Marine Supply Base

Vessel Type	CSD
Area of Operation	Marine Supply Base approach channel
Dredge depth	-7.7mCD
Estimated dredge volume	640,000 m <sup>3</sup>
Duration of dredging operation (days)	Maximum of 63.1
Total duration of simulation (days)	64 days *

\*From modelling reported by URS 2011

### 1.5.3 Small vessel berths

It has been determined (URS/Scott Wilson 2011) that the dredge design requires the deployment of a large CSD to dredge an approach channel to the new tug berth facility (Figure 3). Table 3 sets out the dredger work plan based on the vessel capacity, speed and efficiency to define the dredge duration. It is estimated that the dredger (of large capacity) will operate continuously over a 6 day period.

**Table 3 Dredging work plan – dredging at the small vessels/tug berth**

Vessel Type	CSD
Area of Operation	Small vessel berths
Dredge depth	-7mCD
Estimated dredge volume	115,300 m <sup>3</sup>
Duration of dredging operation (days)	6
Total duration of simulation (days)	6*

\*From modelling reported by URS 2011

## 1.6 Dredging and disposal of spoil

### 1.6.1 Dredging emission rates

The dredge method statement (URS/Scott Wilson 2011) proposed the use of one CSD, which will include a vessel and dredge at 125,000 m<sup>3</sup>/week, with the final arrangements dependent on the appointed contractor, vessel availability and the dredge location.

A 1 percent (%) rate of sediment loss from the dredgers was agreed prior to commencing the modelling simulations. A summary of release rates is provided in URS/Scott Wilson (2011) and Bray *et al.* (1997). Compared to other dredging plant, the proposed CSDs to be utilised at the site generate a relatively low loss of fines.

**Table 4 Comparison of typical fine material discharge loss rate for different types of dredging plant**

Dredge method	Cutter suction	Trailing suction (no overflowing)	Bottom dump placement	Trailing suction hopper (overflowing)
Loss rate	1%	2%	5%	34%

### 1.6.2 Disposal emission rates

Table 5 sets out the spoil disposal work plan based on the vessel capacity, speed and volume of material for disposal. The discharge site will be onshore within existing EAW ponds via either a flexible floating or a submerged pipeline.

**Table 5 Disposal work plan**

Vessel Type	Pumped
Area of Operation	Existing ponds within EAW
Water depth (m)	-20mCD
Estimated dredge volume	817,300 m <sup>3</sup>
Duration of dredging operation (weeks)	6.3 (max)



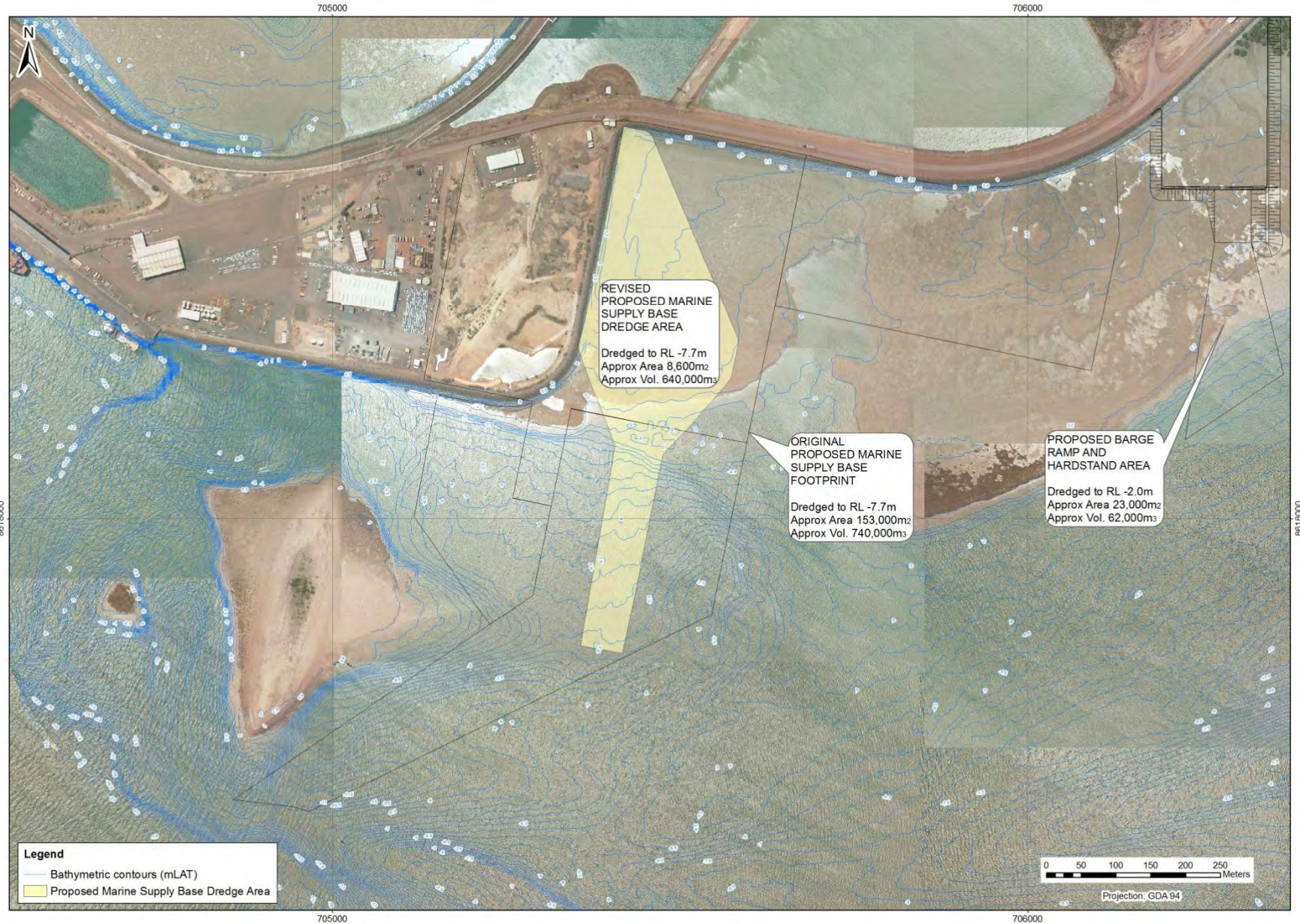


Figure 2 East Arm Port ramp and hardstand area and the Marine Supply Base (URS 2011)

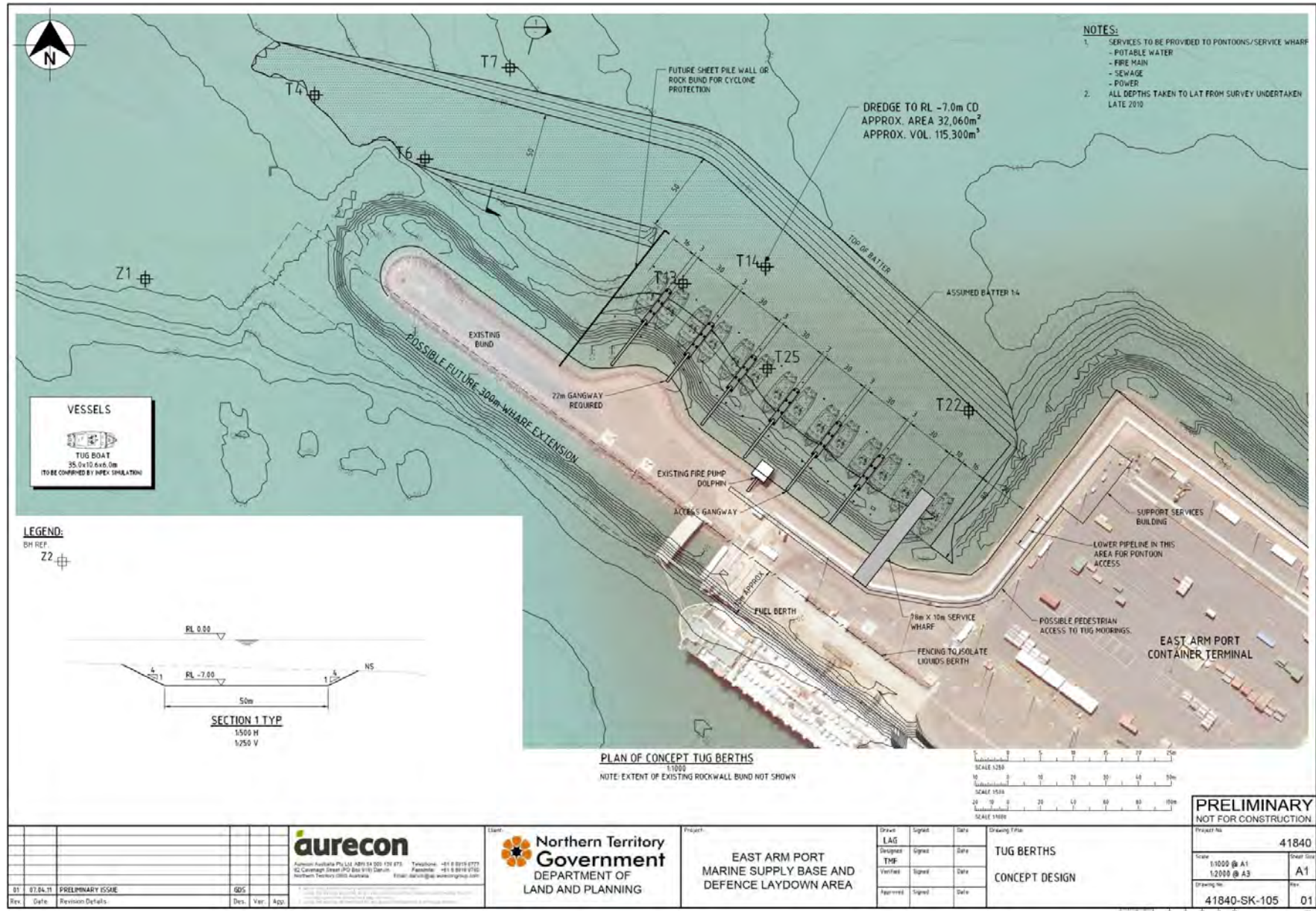


Figure 3 East Arm Port tug berth areas (Aurecon 2011)

## 1.7 Site location and context

The proposed construction activities are to be carried out on the East Arm Peninsula, within Darwin Harbour (Figure 1). The East Arm Wharf extends into the Darwin Harbour and is bounded by Bleesers Creek to the north and Hudson Creek to the east. Two small islands lie directly south and east of the proposed project area; South Shell Island and Catalina Island.

The peninsula has been developed to form the East Arm Wharf and to support associated wharf related industries, in accordance with the DEIS for the East Arm Wharf Expansion (URS 2011). The East Arm Wharf and surrounding infrastructure is designated the 'East Arm Port Development Zone' (DV Zone in the East Arm Control Plan 1998, Northern Territory Planning Act 2008). The DV Zone allows for development of major strategic industries including gas based, road, rail or port and provides land for major industrial development.

## 1.8 Previous studies

The Darwin Harbour region encompasses 2,417 square kilometres (km<sup>2</sup>) of total land area that includes the catchment boundaries of the rivers and streams that flow into the harbour, including the Howard River, Elizabeth River, and Blackmore River, as well as the large estuarine/marine water body that is Darwin Harbour.

The Darwin Harbour Regional Plan of Management (DHAC 2003) provides an understanding of the important role that the Darwin Harbour region plays in the economy, lifestyle and character of the Top End of the Northern Territory, and has developed, through consultation with the community, a comprehensive list of the natural, social, cultural and economic values of the harbour.

The Darwin Harbour region has many uses, including fishing, bait gathering, foraging, boating, camping, diving, sailing, tourism, aquaculture (pearling), industrial, urban and cropping (fruit). Natural resources of the harbour include mangrove worms, cockles, crabs, plant fibres, dyes, fish, ducks, magpie geese, wallabies, possums, goannas, turtle eggs, long bums, stingrays, bush fruit and vegetables.

The Larrakia people, the traditional people of Darwin, continue their use and consumption of natural resources in the region, with usage tending to be greatest at the beginning of the wet season. Other Aboriginal users of the Darwin Harbour region include residents of Kulaluk, Knuckey's Lagoon, 15 Mile, 1 Mile Dam, Bagot Reserve, as well as local townspeople and visitors from other regions.

Darwin Harbour is considered a relatively undisturbed environment.

### 1.8.1 Physical environment

#### 1.8.1.1 Geology

Reference to the Darwin 1:100,000 Geological Map Series sheet indicates that the region is underlain by Quaternary intertidal marine alluvium consisting of clay and mud, and colluvial sediments deposited by unconcentrated surface runoff consisting of sand, silt and clay.

Unconsolidated and concretionary lateritic soils of Cainozoic age have been mapped in the area. Early Proterozoic metamorphic Burrell Creek Formation form isolated outcrops on the Peninsula.

The Peninsula landform comprises a combination of:

- lower intertidal areas of marine alluvium consisting of wet soft silt and clay with variable amounts of sand
- upper intertidal areas of mixed marine colluvium and alluvium consisting of soft/loose silty sand and gravelly sand (Pietsch 1983).

East Arm specifically is underlain by Quaternary age intertidal marine alluvium comprising mud, silt, sand and coral remnants, then by bedrock belonging to Proterozoic metasediments of the Burrell Creek Formation consisting of meta-siltstone, meta-sandstone and phyllite, which strike almost north-south and are steeply dipping to the east or west. Quartz veins are widespread within the Burrell Creek Formation.

Many geotechnical investigations have historically been undertaken for various sites within Darwin Harbour, and therefore localised information is known. A geotechnical investigation has been completed which included a seismic refraction survey that can be used to interpret a continuous geological profile of the harbour, and to interpret the material dredgeability.

### 1.8.1.2 Bathymetry and coastal landforms

Coastal processes, including the hydrodynamics of Darwin Harbour have been considered as part of the Numerical Hydrodynamic Modelling, undertaken by the University of New South Wales Water Research Laboratory (WRL) and will be used to update and validate the currently used models.

The bathymetry of Darwin Harbour is described by Acer Vaughan Consulting Engineers (1994) as consisting of a main channel of greater than 20 metre (m) water depth (below Lowest Astronomical Tide [LAT]) extending in a south-easterly direction into the Harbour to the confluence of Middle and East Arms. The channel favours the eastern side of the harbour, with broader, shallower areas occurring on the western side. The intertidal flats and shoals are generally more extensive on the western side of the harbour than on the eastern side.

The channel continues into East Arm, although the bathymetry in this area has been modified by previous dredging for the East Arm Port Development. A slightly deeper channel extends into Middle Arm, up to the western side of Channel Island. A shallower channel (generally <10 mLAT depth) separates Wickham point from Channel Island and terminates in Jones Creek.

For the selected channel alignment, full seabed coverage high resolution multi-beam bathymetry surveys have been undertaken that would be applicable for critical port areas. This will deliver detailed digital terrain models, illuminated seabed terrain imagery and contour plots. Magnetometer survey for Unexploded Ordnance (UXO) and Explosive Ordnance (EO) have been completed under separate survey from the bathymetry and side-scan sonar.

The tidal range in Darwin Harbour is -0.1 up to 8 mCD metres. The mean spring tide range is 5.5 m and the mean neap tide range is 1.9 m. Two high and low tides are experienced daily and the tidal range fluctuates over a lunar cycle.

The daily harbour inflow and outflow is 216 million m<sup>3</sup> (Mm<sup>3</sup>) on a spring tide and 71 Mm<sup>3</sup> on a neap tide. These flows represent 69% and 29% of water flows in Darwin Harbour respectively (Williams, Wolanski and Spagnol 2006).

Although the wave climate at Darwin is mild most of the time, severe cyclones can generate large waves that may enter the Port. As previously mentioned, tidal ranges are large at Darwin and have the capacity to generate strong currents in the channels.

The coastline of Darwin Harbour has changed significantly over time, with the first wharf constructed in the harbour in 1874, and a decade later was expanded to accommodate a railway. This original railway wharf was destroyed by termites and replaced with a new wharf called the Town Wharf (the same site as the current Stokes Hill Wharf). This wharf was then severely damaged during the Japanese bombing raids in 1942, and this was later replaced with a new wharf called Fort Hill Wharf.

Stokes Hill Wharf was constructed in 1956, and Iron Ore Wharf was constructed in 1967 and has subsequently been demolished. The Old Fort Hill Wharf was replaced with the New Fort Hill Wharf in 1981, which was the main general cargo wharf for the Port of Darwin. Subsequently, the East Arm Wharf was developed in 1994. The Darwin Naval Base, located at Larrakeyah, has been developed, and was originally designed to supply and service fast patrol boats.

Also changing the coastal landforms has been the construction of numerous marinas, such as Bayview, Cullen Bay, Tipperary Waters, Francis Bay and the Darwin City Waterfront. Most of these marinas have lock gates, and are therefore not affected by tidal movements. Wickham Point (Conoco Phillips Gas Plant) has also been developed, and includes an access jetty. Future anticipated changes in landforms will include the East Arm Wharf Expansion and the proposed INPEX Browse Limited Ichthys Gas Field Development Project, which will see the development of Blaydin Point. INPEX has an extensive dredging program which has been approved by NRETAS and the Commonwealth Government.

Dredging activities in the harbour occur periodically to allow for continued access by vessels. The Darwin Port Corporation undertakes dredging annually to ensure the central harbour channel remains open (pers. comm. Grant Henderson, DLP).

### 1.8.1.3 Hydrodynamics and sediment transport

Darwin Harbour has semidiurnal macro-tides (two highs and two lows per day) with a strong diurnal inequality. The highest astronomical tide is 8 mCD. The mean spring tidal range is 5.5 m and the mean neap tidal range is 1.9 m, with a maximum range of 7.8 m. It is a well mixed system with large volumes of water moving into and out

of the harbour with tidal fluctuations. Tidal movement plays an important role in re-suspending material from the harbour floor into the water column.

Williams, Wolanski and Spagnol (2006) investigated the link between hydrodynamics, sediment and nutrient dynamics in the harbour to assist in the management of infrastructure developments. Near headlands and embayments, a complex circulation occurs that includes jets, eddies, separation points and stagnation zones. These currents are different at flood and ebb tides and the asymmetric dispersion of particles results in trapping at headlands and embayments. Sediment is delivered to the upper arms by runoff. Despite being macrotidal the harbour was found to be poorly flushed, with much of the riverine fine sediment remaining trapped in mud flats and mangroves with little escaping to the sea. The residence time of pollutants in the upper reaches of the harbour was found to be in the order of 20 days.

Smith and Haese (2009) analysed the role of sediments in nutrient cycling in the tidal creeks of Darwin Harbour. One of the study sites in the report was Myrmidon Creek in the Elizabeth River of East Arm. Treated sewage effluent is discharged from sewage treatment plants into mangroves fringing Myrmidon Creek. The study found there to be negligible release of nutrients into the overlying water column in Myrmidon Creek. Overall impacts of discharged sewage effluent were found to be temporary and localised.

Hydrodynamic modelling of Darwin Harbour has been undertaken, which comprises the synthesis of validated wave transformation and tidal hydraulic modelling and sediment characteristics to assess sediment transport potentials under the combined actions of waves and tidal currents. The modelling includes Wave Transformation Modelling, Cyclone Offshore Wave Modelling, Nearshore Wave Modelling, Tidal Current Modelling, and Morphological and Water Quality modelling.

#### **1.8.1.4 Sediment quality**

Sediment quality information has been derived from historical environmental and geotechnical reports and investigations, and includes results from sampling events from 1984 through to 2009 in Darwin Harbour. Data from historical geotechnical investigations tended to focus on the assessment of the depth, types and geotechnical characteristics of sediment and rock, soil profiles, Standard Penetration Tests (SPT's), and the classification and strength parameters of the soils encountered. Environmental investigations tended to focus on the physical and chemical characteristics of sediments, as well as grain size analysis.

Approximately 80% of the Darwin Harbour region's seafloor is estimated to be covered with soft surfaces consisting of mud and fine sand. Soft surfaces containing varying amounts of gravel and sand are found in the main channels around reefs, on beaches and on spits and shoals near the mouth of the harbour (Fortune 2006).

Studies by Warren (2001) provide the most recent data on the sediment physical and chemical properties of Darwin Harbour. As part of the study samples were collected from ten sites around Darwin Harbour for chemical analysis, and twelve sites were sampled for physical analysis. Sampling occurred in 1999. The sample locations included Fishermans Wharf, Hornibrooks Wharf, Stokes Hill Wharf, Hudson Creek, Fort Hill Wharf, Iron Ore Wharf, Cullen Bay Marina, Francis Bay Mooring Basin, East Point, Mandorah, Blesers Creek, and two locations at East Arm, one off the face of the wharf, and one in the embayment.

That study concluded the consistent levels of iron, manganese, cobalt and nickel throughout the harbour were indicative of a non-point, anthropogenic source for these metals. For cadmium, copper, lead and zinc, however anthropogenic point sources are the most likely pathway for the significant sediment enrichment by these metals, especially at the Port Darwin wharves.

The study also found that most of the trace metals are bound in the inert phases of the sediments, however lead was found in high concentrations in sediments in a potentially more bio-available phase, which indicates a greater chance of mobilisation and becoming bio-available if sediments are disturbed and oxidised. Only one site was identified in the study as having polycyclic aromatic hydrocarbons in notable concentrations, being Fishermans Wharf. Sediments at the majority of sites sampled for TPH C15-C28 were found to be above laboratory detection limits, with the highest concentrations at the Francis Bay Mooring Basin and Fishermans Wharf.

Warren (2001) allowed the classification of various locations as Moderately to highly contaminated, with a moderate risk of toxicity (Fishermans Wharf, Iron Ore Wharf, and Francis Bay Mooring Basin); Moderately contaminated, with a low to moderate risk of toxicity (Cullen Bay Marina and Hornibrooks Wharf); and Slightly to moderately contaminated, with no or low risk of toxicity (Fort Hill Wharf, Stokes Hill Wharf, and Hudson Creek).

The secondary part of the Warren (2001) study was to analyse sediments at sampling sites for physical characteristics. This consisted of testing the following characteristics of sediment samples:

- particle size (texture)
- fall velocity
- bulk density
- relative density (specific gravity).

Sampling sites at Stokes Hill Wharf, East Arm Wharf and Bleaser's Creek had at least 95% silt/mud, with progressively decreased silt/mud proportions at Cullen Bay Marina and Francis Bay Mooring Basin (89%), Hudson Creek (mid-channel) (88%), Fort Hill Wharf (81%), East Arm Port embayment (77%) and Hudson Creek (west bank) (76%).

The most comprehensive data available on the sediment grain size in sediments in Darwin Harbour is provided in a report by Fortune (2006), based on data collected from 114 samples taken throughout the harbour, including the East and Middle Arms, in 1993. The report also includes the analysis of heavy metals content. Though comprehensive, this report has limited value as a baseline for existing conditions as samples were obtained prior to the establishment of the East Arm Wharf facilities. Both the East and Middle Arms were found to have largely coarse and fine sands with moderate granules and minimal silt and clay. Some samples taken at East Arm were found to have elevated concentrations of heavy metals, including lead, zinc and nickel. Elevated levels of arsenic within East Arm and other parts of the harbour are believed to be a result of local geology rather than anthropogenic sources.

#### **1.8.1.5 Acid sulfate soils**

A study was undertaken by the Land and Water Division of the Northern Territory Department of Natural Resources, Environment, the Arts and Sport (NRETAS), with the technical report Acid Sulfate Soils of the Darwin Region released in November 2008 (Hill and Edmeades, 2008) as well as the production of the Greater Darwin Region: Acid Sulfate Soils 1:50,000 Map Sheet 5073-2 (NRETAS 2009a). The report provides the most comprehensive inventory of acid sulfate soils of the estuarine and floodplain environments of Darwin Harbour, Bynoe Harbour, Adelaide River, Fog Bay and the Finniss River. It provides detailed mapping supported by quantitative data on the presence and absence of these particular soils at particular locations as well as depth and potential acidity. In doing so it provides an assessment of the risk associated with disturbance.

#### **1.8.1.6 Water quality**

Several studies have been conducted relating to the water quality of Darwin Harbour. Water quality varies with tide, season and location and some studies have focused on how these variables affect water quality.

Studies by Padovan (1997) analysed the effects of season, water depth, harbour location and tidal movements on various water quality parameters from seven sampled sites. Many parameters, such as pH, total organic ammonium and nitrogen, were found to be relatively stable throughout the year. Water temperature and nitrate and nitrite concentrations changed with season while turbidity and total suspended solids were affected by location in the harbour and tidal activity. Concentrations of chlorophyll *a* and nutrients were found to be very low.

Duggan (2006) conducted research on the water quality of Darwin Harbour from 2002 to 2004. The study involved the sampling of nine sites in the harbour on a quarterly basis. Results of the study indicate that rainfall has the greatest impact on water quality. Increased rainfall significantly impacted concentrations of nutrients, suspended solids and chlorophyll *a*. Water quality was found to vary depending on location in the harbour. Tidal variations were not found to significantly impact water quality. Seasonal aspects, rather than spatial or tidal aspects, were found to be the most important determinant of water quality. Overall water quality was found to be similar to previous studies by Padovan (1997). This is despite considerable development taking place in the harbour and surrounding catchment in the twelve years between the respective studies.

Padovan (2003) summarised current knowledge on the sediment and water quality of Darwin Harbour and Shoal Bay and identified knowledge gaps. He found that large areas of the harbour estuary have yet to be investigated including the tidal creeks of Middle and East Arm. The full range of seasonal and tidal effects on water quality has yet to be fully described. Many studies do not address the fate of discharged contaminants and their ecological consequences. Padovan suggested that models can be developed to predict the effect of discharges on sediment and water quality. Such an approach would be beneficial for assessing management options for developments within the harbour.

The Aquatic Health Unit (AHU) of NRETAS has been responsible for monitoring the biological health of Darwin Harbour. Together with the DLP, the Darwin Harbour Advisory Committee (DHAC) and the Commonwealth

Department of Sustainability, Environment, Water, Population and Communities (SEWPaC) they have helped develop a management plan called the Water Quality Protection Plan (WQPP) for Darwin Harbour. This plan establishes water quality objectives for a range of different water quality parameters, including dissolved oxygen, pH, total nitrogen and Total Suspended Solids (TSS), to be monitored throughout Darwin Harbour and its catchment. The water quality objectives act as “trigger values” and are sourced from ANZECC/ARMCANZ (2000) guidelines to act as a reference to guide future planning and management.

The first series of *Darwin Harbour Region Report Cards* (2009) developed by the Darwin Harbour Advisory Committee (DHAC) summarises water quality data collected from 2001-2007. In addition to routine monitoring the AHU has undertaken event based monitoring at eight catchment gauge stations to calculate wet season flows. These data enable the calculation of event loads of TSS, nutrients and metals. The report includes a section on the Elizabeth River and estuary. Whilst finding that overall water quality is good, total nitrogen, chlorophyll a and dissolved oxygen levels did not meet marine water quality objectives. A significant source of pollution into the estuary comes from sewage treatment plant wastewater discharged into Myrmidon Creek.

Hanley and Caswell have produced a number of reports on water quality of the East Arm Wharf and data gathered included water quality monitoring during the construction of the Bund and Access Road (Hanley and Caswell 1995 and 1997a), and during dredging and post dredging operations (1997b). These reports aimed to identify and monitor the impacts on marine biota caused by changes in the patterns of erosion of the seabed, sedimentation onto the seabed and increased turbidity caused by mobilisation of sediments during dredging activities.

Bioindicators (corals and oysters) located at South Shell Island were an element of the monitoring, as well as the direct analysis of the turbidity, suspended sediment concentration, sedimentation rates, heavy metals, percentage sediment cover on coral surfaces, and light attenuation. The dredge return water was also assessed for pH, heavy metals and sediment concentration, to determine if acid leachate is produced as a result of the dredging activities (Hanley and Caswell 1997b).

The findings of Hanley and Caswell (1997b) (based on the baseline data collection before dredging, and monitoring during and post dredging activities) is summarised below:

- Baseline pre-dredge (dry season) water quality results for Photosynthetically Active Radiation (PAR), salinity, dissolved oxygen, turbidity and suspended solids concentrations were typical of the waters of Darwin Harbour for that time of year. Heavy metals concentrations were consistent with results from an earlier monitoring event (Hanley and Caswell 1995).
- The water quality during the dredging activities declined, as determined by turbidity increasing to up to 82 NTU, increased total suspended solids and volatile suspended solids, and lowered PAR.
- Dredge return plumes created by the dredging activities (dredge return water was discharging through the mangroves from the retention pond receiving the dredge spoil) at times covered over 1km<sup>2</sup> in the harbour.
- Heavy metal concentrations varied throughout the monitoring program, with notable significant increases in the levels of particulate arsenic and heavy metals at various sites, including South Shell Island, caused by the dredge plumes.
- Post dredge monitoring (over a period of 2 weeks) indicated that in the absence of any dredge return water discharge, and the cessation of dredging, the physio-chemical parameters and metals concentrations at all sites returned to the same range as the baseline data collection.
- Acid leachate assessments found that the dredge return water discharging back into the harbour had significantly lower dissolved oxygen concentrations (down to 32.7%) and pH (down to 7.80), and significantly higher turbidity (up to 416 NTU- caused by the dredging of fine muds and the failure of the sediments to settle in the ponds prior to discharge) than the receiving waters.

AECOM have received numerous datasets from NRETAS which includes water quality data from various gauging stations as well as locations throughout Darwin Harbour, obtained from the Aquatic Health Unit. AECOM has also been informed that further water quality data will be received from the Department of Defence, ConocoPhillips and Darwin City Waterfront.

A water quality monitoring program will be established to be undertaken before, during and after dredging, so as to allow determination and documentation and if management of the effects on water quality. The program will include both physical and chemical analysis.

### **1.8.2 Ecological values and marine habitat**

Refer to Appendix A for background descriptions of ecological factors and values of Darwin Harbour and near coastal region.



## 2.0 Description of dredging and associated development

### 2.1 Key activities under the DMP

The dredging and reclamation strategy outlined in this section aims to identify the most likely methods of dredging and reclamation for the proposed East Arm Wharf expansion project, based on the current understanding of dredging quantities and material characteristics, the proposed end-use of the dredged material (reuse or disposal) and the development program for the proposed works.

The specific type and capacity of dredging equipment will be subject to working methods developed by prospective dredging contractors and would be subject to a range of considerations that cannot be fully considered in the preparation of this dredging and reclamation strategy, such as market conditions and competitive factors. Notwithstanding, the strategy provides an assessment of the most likely dredging and reclamation methods and equipment, suitable for assessment of potential environmental impacts and preparation of a DMP for the East Arm Wharf expansion project.

### 2.2 Dredge material extraction

#### 2.2.1 Preferred dredging methods

The *Dredging and Spoil Management Assessment Framework for Darwin Harbour* (AECOM 2009b) provided a summary of common dredging methods. The major considerations for selection of the preferred method for the East Arm Wharf expansion project include the following:

- the type and quantity of material to be dredged
- the end-use of the material and the location of placement or disposal
- the available water depth for dredge equipment access and the finished surface profile required
- the potential for conflict with cargo vessels or other port operations including notification to mariners
- the potential environmental impacts from dredge overflow and discharge of reclamation tailwater
- environmental factors, such as exposure to wind, waves and currents.

The preferred dredging method for the East Arm Wharf expansion project involves:

#### 1) Mechanical dredging of surface sediments

Mechanical dredging of the surface sediments may be required from a barge-mounted excavator or clam-shell dredge suited to accessing the shallow water areas of the proposed East Arm Wharf expansion project. Soft and loose material can be readily dredged using mechanical methods and these methods are expected to be economical for the quantity of material to be dredged.

#### 2) Cutter-suction dredging of subsurface materials

Cutter-suction dredging of the firm subsurface materials is preferred because this method is well suited to direct hydraulic placement of dredged material to reclamation, it is effective for dredging of firm and stiff materials, it is effective in shallow water areas and the CSD is effective in trimming and shaping the final profile of the dredged basin.

As noted in Section 3.0, quartz lenses are known to occur within the Burrell Creek formation and may be encountered during dredging for the expansion project. The degree of weathering of these quartz lenses will determine whether CSD is effective in removing the quartz material. Previous cutter-suction dredging undertaken as part of the Frances Bay Small Ships Facility encountered problems with quartz lenses that were not previously identified (Acer Vaughan 1994).

### 2.2.2 Assessment of alternative dredging methods

Alternative dredging methods have been considered in the selection of the preferred dredging strategy outlined above. A brief assessment of alternative methods for dredging of the surface sediments and subsurface materials is presented below to highlight the limitations anticipated using alternative methods.

- Dredging of surface sediments using a CSD: A cutter-suction dredge would not be well suited to transport of the surface sediments to an offshore disposal location. This type of dredge is best suited to hydraulic delivery (via pipeline), which would impede vessel movements with Darwin Harbour.
- Dredging of surface sediments using a trailer-suction hopper dredge: A trailer-suction hopper dredge would typically require greater water depth than available within the dredging area. A very small trailer-suction hopper dredge may access the dredging area during high tide conditions, but it is unlikely that such an operation would prove economical.
- Dredging of subsurface material using mechanical methods: Mechanical dredging methods would not be well-suited to direct placement of material to reclamation. Double-handling of material, using land-based equipment would likely be required to allow the material to be placed to reclamation. It is unlikely that this would prove to be an economical operation. Further, it is expected that the firm nature of the subsurface material would reduce the effectiveness of mechanical dredging equipment.
- Dredging of subsurface material using trailer-suction hopper dredge: A trailer-suction hopper dredge with sufficient power to remove the firm subsurface materials is unlikely to have sufficient access within the shallow water dredge areas and this dredge type is not well suited to direct hydraulic placement of materials with the cohesive characteristics that are expected within the subsurface material.

In addition, the preferred dredging methods identified in the previous section are likely to vary if the material reuse and disposal strategy was to vary significantly. For example, if it is envisaged that suitable land-based or marine-based fill is available and may be used as reclamation fill, the cutter-suction method proposed for dredging of firm subsurface material is unlikely to be practical. Under this scenario, an alternative approach, such as mechanical dredging and offshore disposal is likely to be more suitable. At this stage, the opportunity to employ a range of dredging methods should be considered.

### 2.2.3 Description of work: dredge footprint

The first stage of the proposed East Arm Wharf expansion project comprises the following dredging work.

- Dredging, as part of the Marine Supply Base and barge ramp facility to create a harbour basin for vessel access and manoeuvring. Dredge works at East Arm Wharf will also be undertaken at a proposed tug berth area.
- Concept engineering design has been undertaken to prepare layouts for the proposed Marine Supply Base and ramp and hardstand as well as the tug berth area. Concept designs for these areas are presented in Figure 2 and Figure 3.

#### 2.2.4 Results of bathymetric investigations

iXSurvey Pty Ltd was commissioned by the DLP to undertake hydrographic surveys during October and November 2010 in the vicinity of East Arm and its environs; Elizabeth River; Blackwood River and Middle Arm. Results were presented in the report *Hydrographic Survey Report for Darwin Port Corporation for Provision of Hydrographic Services* (iXSurvey, 2010). The iXSurvey utilised the Kongsberg EM3002D Multi-Beam Echo Sounder (MBES) as the primary Bathymetric Sonar. Data were collected between 17 October and 7 November 2010.

Hydrographic products provided by iXSurvey included:

- A1 Sounding sheets
- BASE sheets (sun illuminated survey sheets provide intuitive visual description of the survey area)
- Bathymetric Attributed grid files containing depth and position information
- GeoTIFF georeferenced image files which can be opened in graphics applications as well as Geographic information systems
- ASCII point text files containing soundings
- GeoTIFF mosaics which combine all processed data.

Bathymetric surface and selected soundings in the immediate vicinity of East Arm Wharf are presented in Figure 4.

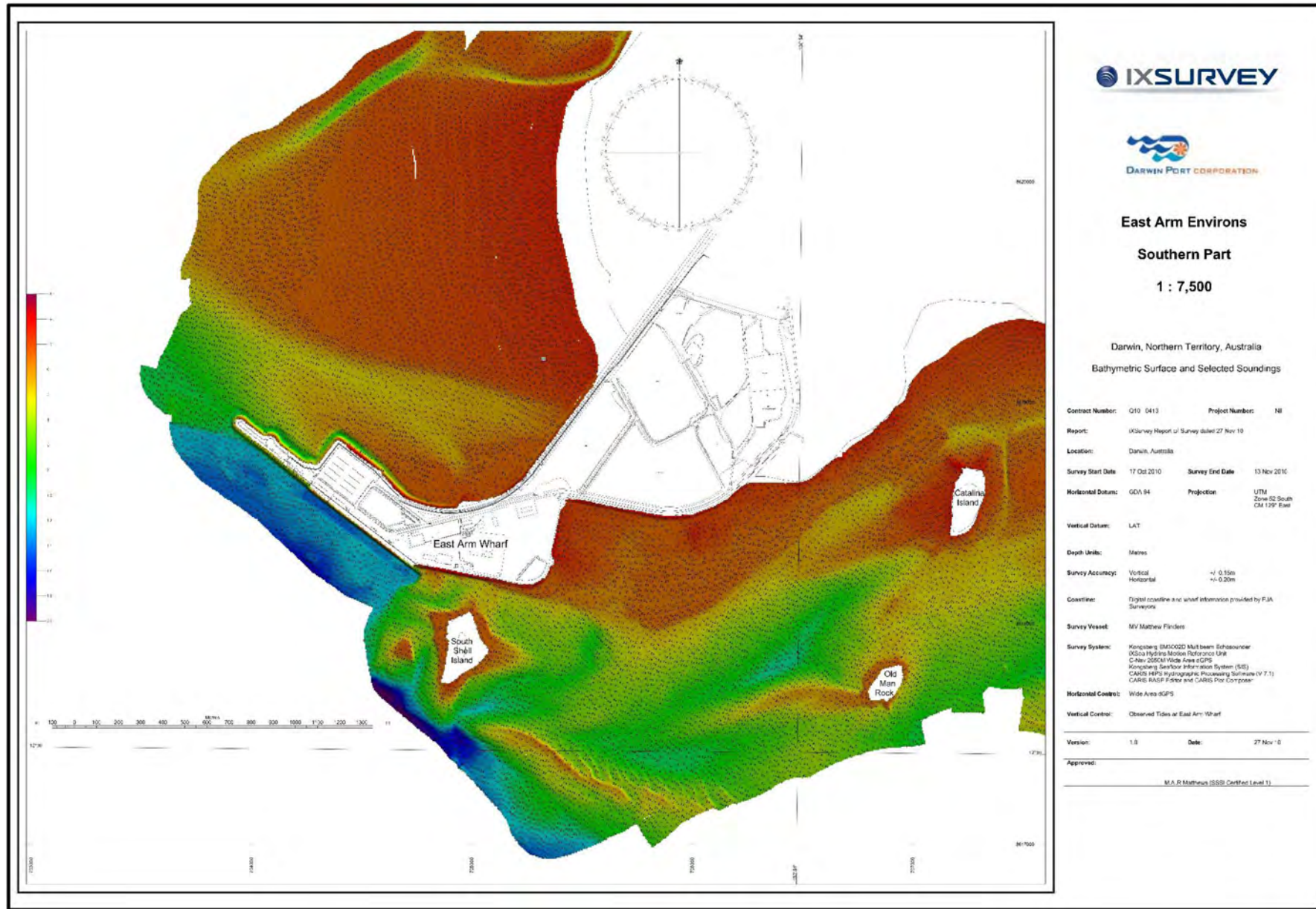


Figure 4 East Arm environs southern section

### 2.2.5 Results of geotechnical investigations

Douglas Partners (2010) collated and assessed information from previous geotechnical investigations undertaken at East Arm Port and other sites in the Darwin Port area. Attention was focused on subsurface soil and rock conditions and consisted of:

- Review of geological maps and description of dominant geological formations.
- The location of reports from previous drilling investigations carried out in and around dredge areas and the collation of data where available.
- Review logs and highlighting of critical information for the assessment of dredgeability of the soil and rock to the prescribed depths and levels.
- The provision of a scope of work for further drilling to provide further necessary information in dredge areas.
- The provision of preliminary advice on fill areas including subsurface conditions, method of placement and further investigation to determine depth of compressible material. Subsurface characteristics of fill areas will not be discussed further here.

Results of the Douglas Partners investigation indicated the following:

- Darwin 1:100,000 geological series sheets indicate that the East Arm Wharf Dredge Areas are underlain by quaternary and tertiary aged sediments comprising unconsolidated silty clay, loose silty sand, ferruginous and clayey sandy gravel pisolitic and mottled laterite. Beneath these sediments are Proterozoic bedrocks from the Burrell Creek Formation (BCF) comprising metamorphosed sandstones; siltstones and phyllites. Quartz veins are widespread.
- The BCF has been investigated extensively for various structures in the Darwin area. and the sedimentary beds comprise mainly siltstone with some sandstone and claystone. The rock strength varies from very low strength phyllites to very high strength quartz and quartz sandstones. Drill holes indicate that sub vertical beds of these rock layers with boreholes drilled 1 m apart indicating very different rock strengths. The formation has weathered over time and vertical and horizontal clay seams of 400 mm or greater existing with the straight of a stiff to very stiff clay soil. Most boreholes indicate that the BCF consists of lower strength meta siltstones and clay seams clay seams. Only large excavations strike high strength rock.
- Boreholes drilled historically in the dredge areas indicate the following:
  - Marine Supply Base:
    - below the RL -3 mCD contour indicate dredging will be in up to 4 m of soft sediments and overburden soils with only a less than 0.5 m depth of low strength phyllite.
    - above the RL -3 mCD contour there could be 5.2 m of overburden soils, then up to 1.8 metres of low – medium strength meta-siltstone. There could be about 3.5 m of overburden soils, then 3 m of very low to low strength meta-siltstone to the limit of drilling at RL-1.3 mCD. There is no information on the rock between this level and the proposed dredge level of RL-7.7 mCD in this northeastern corner of the dredge basin.
  - Ramp and hardstand area
    - A borehole close approximately 170 west southwest of the ramp and hardstand area indicates that there is about 3.2 m of overburden soil overlying the BCF. The depth and strength of overburden soils over the proposed dredge area is unknown.
  - Small vessel berth area
    - The study did not find any information on the depth and strength of overburden in the tug berths area.
- Douglas Partners (2010) recommended further investigations and testing in dredge areas. Boreholes from 5 to 13 m should be drilled from a jack-up barge using rotary water or mud flush drilling. Soft sediments and overburden soils should be sampled at 1 to 1.5 m intervals using Standard Penetration Tests in cohesionless soils and U60 push tubes in cohesive soils. Where rock is encountered a rotary diamond core drill should be used using HQ3 wireline drilling equipment, with mud flush and a surface set drill bit to enhance recovery. Recommended borehole numbers and depths within each dredging area are presented below:

- Marine supply base: drill, log, sample and test cores from six additional boreholes to depths of 10 m, 9 m and 6 m.
- Ramp and hardstand area: drill, log, sample and test cores from three boreholes to depths of between 4 m and 3 m.
- Tug berth area: drill, log, sample and test cores from five boreholes distributed through the dredge areas to depths of about 8 and 10 m, depending on borehole location.

### 2.2.6 Summary of quantity and rate of removal of material

The dredge method statement proposes the potential use of CSDs. A larger vessel would have a production rate of c.125,000 m<sup>3</sup>/week depending on the dredge location. The dredging volumes and periods for dredging are presented in Table 6. Average dredging rates were assumed by URS (2011) throughout the area.

**Table 6 Quantities of dredge materials and period of dredging (source URS 2011)**

Area of operation	Marine Supply Base	Ramp and hardstand area	Small vessel berth area
Estimated Dredge Volume	640,000 m <sup>3</sup>	62,000 m <sup>3</sup>	115,300 m <sup>3</sup>
Duration of dredging operation (days)	63.1 (max)*	42.8 (max*)	6
Average Modelled Dredge Rate	17,750 m <sup>3</sup> /day	1,450 m <sup>3</sup> /day	17,900 m <sup>3</sup> /day

\*sourced from modelling by URS (2011)

## 2.3 Dredge plant and vessel operations

### 2.3.1 Dredge plant and equipment

This section of the document will provide the details of the likely methods required for dredging sediments including the characteristics of the materials to be dredged such as particle size distribution (PSD) and density. This information will be used to determine the final selection of dredge plant, equipment and dredging option.

As discussed, there are three proposed dredge areas: the Marine Supply Base area (MSB), Ramp and hardstand area and the Small Vessel berth area. The current sea bed surface levels fall from approximately 2 m above Chart Datum (CD) along the northern edge of the site to approximately 10 m below CD at the southern extremity of the proposed dredge area at MSB.

While dredging could be undertaken using a combination of dredgers, depending on the type of material to be dredged and the location of the dredging works, cutter suction (CSDs) will be the predominant plant and method for dredging.

### 2.3.2 Cutter-suction dredging

Cutter-suction dredging uses a rotary cutting head to excavate seabed materials and suction to remove excavated materials from the seabed, as illustrated in Figure 5. Dredged material is normally pumped to its discharge site via either a flexible floating pipeline or a submerged steel pipeline. (Material may be also be pumped to hopper barges should handling for offshore disposal be required and approved). CSDs may be self-propelled vessels or may be barge-mounted. CSDs are essentially stationary equipment which hold their position using anchors and spud poles. The main spud (or working spud) is used to hold the stern of the dredge in place. The cutter-suction head is moved in an arc around the bow of the vessel by winching on the anchor cables. Repositioning of the spud poles allows the dredge to move forwards in small increments. When repositioning the main spud, the stepping spud holds the stern of the vessel in place.

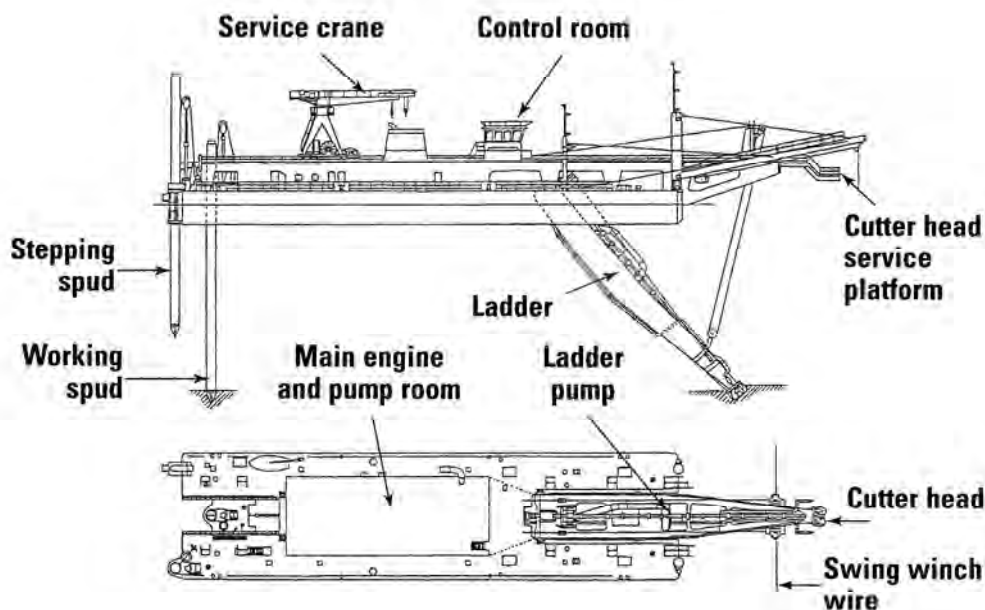


Figure 5 Schematic of cutter-suction dredge

Cutter-suction dredges are generally suitable for the following applications:

- dredging of firm to stiff consolidated material, up to a compressive strength of around 25 MPa (soft rock)
- dredging in shallow water environments, where the cutter-head can excavate a path in front of the dredge
- where the site for placement of dredged material, whether to land or offshore, is relatively close.

The cutter-suction dredging technique causes significant disturbance to the dredged material, as the material must be sufficiently fluidised to be pumped to its placement site. Material is usually pumped at approximately 20% solids (by volume), although this ratio is dependent on a range of factors, including the type of material and the pumping distance. When using cutter-suction dredges to place material to reclamation, substantial ponds are required to allow for settling of fine suspended sediments prior to discharge of the supernatant water. The cutter-suction dredging method is not well suited to operation within areas that are subject to commercial shipping operations, because it is time consuming to move the dredge off-line to allow passage of commercial vessels.

### 2.3.3 Mechanical dredging

Mechanical dredging normally involves the use of either a mechanical grab (clam shell bucket) or back-hoe excavator, mounted on a barge, as illustrated in Figure 6. Dredged material is normally loaded to hopper barges for transport to the disposal site. Material is typically discharged from the underside of the hopper barge, but may also be pumped from the hopper using additional dredging equipment.

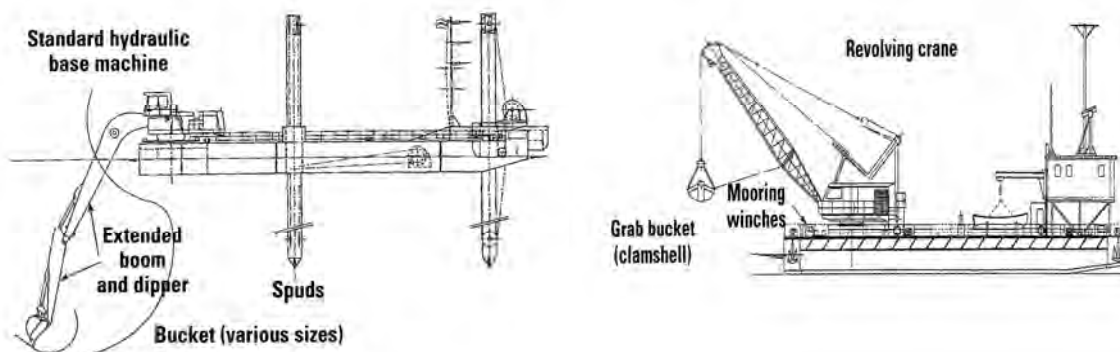


Figure 6 Schematic of backhoe excavator and mechanical grab dredges

Mechanical dredgers are generally suitable for the following applications:

- excavation of firm and stiff materials
- dredging of relatively small quantities of material, as it is not economical for large quantities
- dredging in shallow water environments or close to existing structures, where access and manoeuvrability of other dredge types would limit their use
- accurate trimming and shaping of the seabed and where the quantity of material to be dredged is relatively low.

Excavation of consolidated seabed materials using a mechanical dredge tends to retain the consolidated state of the material. In this regard, turbidity generated during excavation with a mechanical dredge is normally lower than other dredge types.

The higher degree of consolidation of material dredged with a mechanical dredge effects the material behaviour at the placement location. If placed to reclamation, the material is likely to retain large voids between "clumps" of dredged material. While providing a more competent fill initially, voids within the reclamation will result in differential settlement.

Consolidated material dredged with a mechanical dredge which is disposed offshore is less likely to be rapidly dispersed by tide or wave and wind driven currents, due to the retention of its consolidated state. Mechanical dredges are not well-suited to placing material direct to reclamation. Rehandling of dredged material may be required to enable reuse of dredged material as reclamation fill.

#### **2.3.4 Vessel operation**

Dredging of the three EAW reclamation project components involves the removal of less than a total of 1Mm<sup>3</sup> of weak materials.

A backhoe dredger with a 15 m<sup>3</sup> bucket capacity may be used to dredge weak materials to RL-6 m CD within East Arm. The backhoe dredger will load to a containerised system directly to onshore disposal. However, there will be losses from the bucket whilst excavating materials and from the barge during placement at the disposal ground (INPEX 2010).

All other weak materials from -6m CD to the final dredge level of RL-7 m CD could be removed using a CSD and placed onshore. However, in this activity there will be losses from the cutter head and, at times, from propeller wash. The stronger phyllite and conglomerate (UCS 10 to 30MPa) below -6 mCD may be pre-cut using a cutter-suction dredger and possibly placed back to the seabed for a second pass collection. Very strong rock will be drilled and broken up and backhoe dredgers may be used to load this material.

## **2.4 Dredge material placement**

Onshore disposal to Pond K, immediately adjacent to the proposed Marine Base is an option as it has been used historically for the disposal of maintenance dredge spoil. Other reclaim ponds will be filled with the dredged materials. Offshore disposal is not part of the current development proposal.

#### **Small vessel / tug berth area- dredge**

This area comprises three distinct sediment types situated to the southwest and southeast by wharf area filling and to the northwest and southwest by water. The seabed surface comprises intertidal marine sediment of mud and fine sand (URS 2011) with the current seabed levels ranging from -2 mCD to -5 mCD in the proposed dredge area (Douglas Partners 2010). The design considered requires a CSD and the operation is estimated to be undertaken over a period of approximately one week.

#### **Marine Supply Base**

The current seabed surface levels fall from approximately -2 mCD to -7.7 mCD and the area comprises intertidal marine sediment including mud, sand and coral fragments to at least CD with the sand and coral fragments possibly extending below the CD (Douglas Partners 2010, URS 2011). The design considered in this area requires the use of the CSD to dredge the site. The dredger is estimated to be operational continuously over approximately a two month period.



## **Ramp and hardstand area**

In this area the current sea bed level varies from approximately -2 mCD to -5 mCD with the seabed surface comprising intertidal marine sediments of mud, sand and coral fragments to at least the depth of CD (Douglas Partners 2010). The design of this area allows the CSD to dredge an existing channel to the ramp and hardstand area. The dredger is assumed to operate continuously over a period of 42.8 days using a moving point source within the dredge area to simulate the vessel movement (URS 2011).

### **2.4.1 Reclamation**

The proposed East Arm Wharf expansion project requires dredging and reclamation. The loose and soft materials known to exist within the proposed dredging area are unlikely to be suitable as foundation materials for infrastructure or as reclamation fill material. The geotechnical investigation conducted by Douglas Partners as part of the East Arm Wharf expansion project (Douglas Partners 2009, 2010) indicates that the soft and loose materials should be removed from the footprint of bund walls, prior to construction.

The material is proposed to be placed in bunded areas designated for the disposal of dredge materials. The disposal of this program needs to be considered as part of a viable strategy for the overall long-term development of East Arm Wharf.

## **2.5 Reclamation strategy**

### **2.5.1 Preferred reclamation strategy**

The firm subsurface material (likely to be predominantly fine grained sedimentary and metasedimentary rocks) once dredged is not expected to form ideal reclamation fill based on the anticipated engineering properties of the disturbed material after dredging and pumping onshore, unless there is a program of ground improvement works undertaken to provide sufficient strength and stiffness for future development. The time and cost required for ground improvement works varies depending of the approach, methodology and engineering characteristics of the dredge fill. Regardless of the method adopted, it is expected that the duration of several years would be required to achieve a competent reclamation. The period required to achieve a competent reclamation is a major factor in the development of the reclamation strategy.

Section 1.0 provides an outline of the infrastructure proposed as part of the East Arm Wharf expansion project. That outline identifies the following activities that require land reclamation:

- Development of the Marine Supply Base
- Development of the Ramp and Hardstand Area
- Development of the Small Vessel tug berths.

Based on the development timeframe indicated in Section 1.0, it is expected that land-based or suitable marine-based fill material may also be required to facilitate other reclamation.

### **2.5.2 Reclamation staging**

The East Arm Wharf Facilities Masterplan (GHD 2009) highlights the reclamation proposed for near-term (2012-2013), medium-term (2017-2018) and long-term (2030) development of East Arm Wharf. Figure 7 summarises timeframes for reclamation proposed under the Masterplan.



**Figure 7** Indicative reclamation staging (East Arm Wharf Project)

Reclamation to the north-west of the existing rail access (refer Figure 8) is considered the most practical, in terms of consistency with the masterplan, the functionality of reclaimed land for future port operations and the proximity to the dredging areas (Marine Supply Base and Ramp and Hardstand area).



**Figure 8** Indicative extent of future long-term reclamation for dredged material

Based on the indicative extent shown in Figure 8, it is estimated that around 3,000,000 m<sup>3</sup> (order-of-magnitude) of fill material may be accommodated within future reclamation area.

## 2.6 General vessel operations and environment management

General vessel operations have the capacity to effect the marine environment irrespective of the nature of the vessels on this project as dredging vessels. Vessel operations, independent of dredge operations, which may also potentially affect the environment include:

- animal strike or potential entrainment including marine mammals and turtles
- propwash suspension of bed materials creating turbid plumes
- translocation of marine pests in ballast waters both into the Darwin Harbour and from Darwin Harbour onto future dredge locations
- waste discharge or release to marine waters
- hydrocarbon discharge to marine waters
- generation of greenhouse gases and air emissions through burning of fuels
- noise generation.

## 3.0 Legislation and statutory obligations

Legislative requirements (both Territory and Commonwealth) as well as relevant documents, guidelines and codes of practice relevant to construction works at the East Arm Wharf include, but may not be limited to, those outlined in the following sections.

### 3.1 Territory legislation

Northern Territory Acts relevant to the construction of East Arm Wharf are presented in Table 7.

**Table 7** Applicable Northern Territory legislation and relevance to the project

Applicable Legislation	Relevance
<i>Energy Pipelines Act 2009</i>	The Act provides protection for licensed pipelines in the Northern Territory and permits may be required should activities encroach within the buffer zone of designated pipelines.
<i>Environmental Assessment Act 1994</i>	This Act provides for the assessment of the potential environmental effects of development proposals prior to the determination of project consent through the preparation and review of an environmental report. Recommendations arising from environmental assessment are referred to the Minister responsible for project approvals for incorporation into any relevant approval conditions.
<i>Fire and Emergency Act 2010</i>	This Act outlines the regulatory framework and responsibilities of the proponent in managing, reporting and investigating fires and emergencies in relation to the proposed action.
<i>Fisheries Act 2009</i>	This Act considers the management of the Northern Territory's aquatic resources in accordance with the principles of Ecologically Sustainable Development (ESD). The Act aims to promote a flexible approach to management of aquatic resources and habitats.
<i>Heritage Conservation Act 2008</i>	The principle object of this Act is to provide a system for identification, assessment, recording, conservation and protection of places and objects of, amongst other things, historic, social or aesthetic value. This includes geological structure, ruins, buildings, gardens, landscapes and coastlines of the Northern Territory.
<i>Marine Pollution Act 2004</i>	This Act aims to protect the Territory's marine and coastal environment by preventing intentional and negligent discharge of ship-sourced pollutants into coastal waters. The Act follows the International Convention for the Prevention of Pollution from Ships (MARPOL) requirements.
<i>Northern Territory Aboriginal Sacred Sites Act 2006</i>	This Act establishes procedures for the protection and registration of aboriginal sacred sites in the development and use of land.
<i>Planning Act 2008</i>	Provides a framework of controls, for the orderly use of land.
<i>Soil Conservation and Land Utilisation Act 2003</i>	The Act focuses on the regulation and protection of sensitive areas with the intention of ensuring the proponent reduces potential impact of sediment on downstream areas. Dependant on the activity, there may be a requirement for Erosion and Sediment Control Plans as part of the approvals process.
<i>Territory Parks and Wildlife Conservation Act 2009</i>	This Act makes provisions for and in relation to establishment of Territory Parks and other Parks and Reserves. The Act is also relevant to the study, protection, conservation and sustainable utilisation of wildlife.

Applicable Legislation	Relevance
<i>Waste Management and Pollution Control Act 2009</i>	This Act aims to protect and, where practicable, restore and enhance the quality of the Northern Territory environment; encourage ecologically sustainable development and facilitate the implementation of National Environment Protection Measures (NEPM) established by the National Environment Protection Council (NEPC).
<i>Water Act 2008</i>	This Act covers the investigation, use, control, protection, management and administration of water resources in the Northern Territory. The Act prohibits the release of certain restricted substances into watercourses.
<i>Weeds Management Act 2001</i>	This Act aims to prevent the spread of weeds and ensure that the management of weeds is an integral component of land management.
<i>Work Health and Safety Act 2011</i>	This Act focuses on the proponent achieving the highest possible standards of occupational health and safety to ensure the elimination of avoidable risks and control and mitigation of unavoidable risks, to the health or safety of workers.

### 3.2 Commonwealth legislation

Commonwealth Acts relevant to the construction of East Arm Wharf are presented in Table 8.

**Table 8** Applicable Commonwealth legislation and relevance to the project

Commonwealth Legislation	
<i>Aboriginal Land Rights (Northern Territory) Act 1976</i>	Provides for the granting of Traditional Aboriginal Land in the Northern Territory for the benefit of the Aboriginal people.
<i>Australian Heritage Commission Act 1975</i>	This Act covers the registration and protection of items and areas of National heritage significance.
<i>Environment Protection and Biodiversity Conservation Act 1999</i>	This Act provides a national framework for environmental and heritage protection. The Act focuses on protecting matters of National Environmental Significance (NES) including listed protected and marine species.
<i>Native Title Act 1993</i>	This Act aims to protect the Native Title rights of indigenous people in relation to land or water and for related purposes.

### 3.3 Other Relevant Documents, Guidelines, Codes and Best Practice

Other Policies and Guidelines relevant to the Project include those outlined below in Table 9.

**Table 9** Policies and guidelines and relevance to the project

Relevant Policies and Guidelines	Relevance
<b>Northern Territory policies and guidelines</b>	
A Northern Territory Approach to ESD Discussion Paper, 2009 (EPA Northern Territory)	This paper discusses the definition of ESD and proposes a number of principles relevant to the Northern Territory circumstance.
A Review of Environmental Monitoring of the Darwin Harbour Region and Recommendations for Integrated Monitoring, 2005, DHAC	This document aims to facilitate the development of an integrated environmental monitoring program for Darwin Harbour Region (in accordance with the Darwin Harbour Regional Plan of Management, 2003a– now replaced by the Framework below).

Relevant Policies and Guidelines	Relevance
A Strategy for the Conservation of Marine Biodiversity in the Northern Territory of Australia, Parks and Wildlife Commission of the NT (PWCNT), 2000	This document outlines strategies for the conservation of marine biodiversity.
Darwin Harbour Regional Management Strategic Framework 2009 – 2013 (draft), DHAC	This policy framework provides guidelines for the management of environment, social, cultural and economic values and uses of the Darwin Harbour. Goals and guidelines for the Harbour waters are outlined.
Darwin Harbour Water Quality Protection Plan, 2009 (draft)	This plan identifies and addresses key water quality risks to values of Darwin Harbour and its catchments. The document follows the Commonwealth <i>Framework for Marine and Estuarine Water Quality Protection: A Reference Document</i> (SEWPaC 2002)
Darwin Port Corporation (DPC) Environmental Management System (EMS), Environment Policy and OH&S Policy 2002	These policies and procedures provide the basis on which DPC manages and operates the whole of the Port of Darwin with due regard to safety and the environment.
DPC Cyclone Procedures 2009-2010	These procedures detail the actions to be undertaken during cyclone warning and threat.
Stormwater: Draft Management Strategy for the Darwin Harbour Catchment, Environment Protection Authority (EPA), 2006	This document details the overarching guidelines for the management of stormwater in Darwin Harbour Catchment. Key steps for the development of Stormwater Management Plans are outlined.
Environmental Guidelines for Reclamation in Coastal Areas, NT EPA, 2006	These guidelines have been developed by the NT EPA to provide practical environmental advice to developers planning to undertake reclamation work in coastal regions of the Northern Territory. They apply to activities such as foreshore filling, in coastal areas and along rivers, marina and port developments, and development occurring on coastal floodplains. The document includes guidelines for the management of acid sulfate soils and removal of mangroves.
Mangrove Management in the Northern Territory, Department of Infrastructure, Planning and Environment (DIPE), 2002	This document provides direction for the research and management of mangrove ecosystems.
Guidelines for Preventing Mosquito Breeding Associated with Construction Practice Near Tidal Areas in the NT, Department of Health and Families (DHF), 2005	This document provides a checklist for planners, engineers or any supervisory officers, responsible for the planning, impact assessment or implementation of any construction activity near tidal areas, in order to prevent the creation of mosquito breeding sites.
Constructed Wetlands in the Northern Territory- Guidelines to Prevent Mosquito Breeding, DHF, undated	This document details the guidelines for the siting and design of constructed wetlands to reduce potential for mosquito breeding. The document includes urban stormwater systems as they are considered to be wetlands.
Erosion and Sediment Control Guidelines; built environment, service corridors, transport corridors, rehabilitated old infrastructure, (undated), NRETAS.	This document details guidelines to inform activities that may impact on surface stability and sediment movement. Advice on developing Erosion and Sediment Control Plans (ESCP) is provided within the document.
<b>National policies and guidelines</b>	
The Environment Protection Policy (Air Policy), 2004 National Environment Protection Measure (NEPM) for Ambient Air Quality, 2003	These guidelines, developed by the National Pollution Inventory (NPI), provide air quality goals for maximum permissible levels of pollutants in ambient air.

Relevant Policies and Guidelines	Relevance
Australia and New Zealand Environment Conservation Council (ANZECC) Guidelines for Fresh and Marine Water Quality (2000) National Water Quality Management Strategy (1992), (Department of Environment, Water, Heritage and the Arts (SEWPC) The Framework for Marine and Estuarine Water Quality Protection (no date), SEWPaC	These authoritative guides set water quality objectives to sustain environmental values. The documents provide specific water quality for each environmental value and the context in which it should be applied.
Australian Ballast Water Management Requirements, Australian Quarantine and Inspection Service (AQIS), 2001	This document details mandatory ballast water management requirements to reduce the risk of introducing harmful aquatic organisms into Australia's marine environment through ships' ballast water.
AS 1289 Method for testing soils for engineering purposes series	This Australian Standard comprises over 60 methods for: soil sampling and preparation; soil moisture content tests; soil classification tests; soil chemical tests; soil strength and consolidation tests; and soil reactivity tests.

### 3.4 Permits and licence approvals

Approvals licenses and permits relevant to the Project may include the following:

- Approval of the project under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act).
- Approval of the Project under *NT Environmental Assessment Act 1994*, incorporating requirements of other relevant NT legislation, such as *Territory Parks and Wildlife Conservation Act 2009* and *Waste Management and Pollution Control Act 2009*.
- Ministerial consent for any development covered by the East Arm Control Plan.
- DPC consent for any coastal development below high tide in Darwin Harbour.
- Marine Branch, DLP consent for any coastal development above low tide in NT Coastal Waters.
- NRETAS and EPA consent for any dredging operations.
- Approval to disturb heritage items and archaeological artefacts, as located, through the Heritage Conservation Division of NRETAS.
- Waste Discharge licence under *Water Act 2008* (NT).
- Aboriginal Areas Protection Authority (AAPA) Authority Certificate for Sacred Site clearance.

## 4.0 Environmental management process and responsibilities

This section contains the sub-plans that describe the management actions and preventative measures that will be implemented during construction works at the East Arm Wharf, in order to protect environmental and heritage values and minimise impacts from construction activities. The sub-plans also outline specific objectives and performance indicators that can measure the relative success of an implemented plan.

These sub-plans also specify a framework for specific monitoring and reporting requirements associated with the potential environmental impacts and associated risks. The results of the monitoring will be used to assess the effectiveness of management actions and site compliance with performance indicators. The Project Manager will be required to report regularly on environmental performance, including incidents/complaints and corrective actions.

The management outlined in this section may be subject to change following, for instance, environmental assessment and condition setting by governing bodies, consideration of additional site specific information and appointment of a dredger. Responsibilities allocated are indicative only and may change depending on the company structure of the construction contractor and/ or final proponent.

### 4.1 Regulatory bodies

The following regulatory bodies maintain responsibilities for administrative processes (Table 10) which may be triggered by dredging and dredge disposal at East Arm Wharf.

**Table 10 Regulatory bodies and the regulatory processes they administrate with respect to dredging**

Regulatory Body	Process
NRETAS	A Commonwealth Sea Dumping Permit is not required as placement of material will occur onshore. NRETAS assess dredging proposals within the limits of Northern Territory under the EA Act.  The proposed activity lies wholly within Northern Territory and as such Commonwealth legislation is not applicable for sea dumping
Department of Resources – Fisheries	Under the NT <i>Fisheries Act</i> dredging activities that may damage any fishery, fisheries management area, aquaculture lease or fisheries habitat require a permit from the Department of Resources – Fisheries to proceed. Fisheries management areas within the Darwin Harbour include East Point and Doctor's Gully.
Aboriginal Areas Protection Authority	Location of registered sites obtained from the NT Aboriginal Areas Protection Authority. Inspection of the Register are made in person or in writing on a standard form from the Authority
Heritage Conservation Services	Registered sites may include Aboriginal archaeological sites, shipwrecks or sites of natural conservation value. Macassan and Aboriginal sites are automatically protected.
Department of Land and Planning	Dredging or dredge spoil disposal may constitute a land use requiring consent under a land use control plan. The Development Consent Authority or Minister for Lands and Planning are responsible for provisionally approving developments under the <i>Planning Act</i> .
Department of Land and Planning	This licence allows for the removal of non-metalliferous materials from Crown Lands under the NT <i>Crown Lands Act 1992</i> .
NT Worksafe	NT WorkSafe will regulate the proposed activity under the <i>Workplace Health and Safety Act</i> and the Workplace Health and Safety Regulations.
Marine Safety Branch	Maritime Safety and navigational aspects of dredging operations are the responsibility of the Marine Safety Branch (MSB) of DLP (DLP)

### 4.2 Proponent

DLP (or its representative) is responsible and accountable for the effective implementation of this DMP. DLP will ensure that all contractors and persons engaged in the dredging and disposal works comply with the DMP and Territory approval requirements. The dredging and disposal works will be managed by a construction team under



the leadership of the DLP Project Manager and/or the Technical Advisory Group (TAG) who will oversee the dredging works.

Roles and responsibilities of the proponent are summarised in Table 11.

**Table 11 Proponent personnel environmental roles and responsibilities**

Proponent DMP stakeholder	Roles and Responsibilities
DLP (or their representative)	<p>The DLP is responsible for the successful execution of the Dredging and Disposal Works. In terms of environmental management the team will be responsible for:</p> <ul style="list-style-type: none"> <li>- Implementing the dredging program.</li> <li>- Ensuring compliance with statutory requirements and commitments.</li> <li>- Ensuring the timely and efficient transfer of relevant information amongst the involved parties.</li> <li>- Establish the Technical Advisory Group to advise on environmental monitoring and dredge performance.</li> <li>- Communication with the dredging contractor(s).</li> <li>- Advising the dredging contractor(s) on exceedences of coral threshold limits and the appropriate reactive management measures that will be implemented.</li> <li>- Review and approval of contractor's environmental management plans and methods statements.</li> <li>- Ensuring all staff and contractors are aware of their responsibilities under the DMP and provide adequate training and resources to fulfil these obligations.</li> </ul>
DLP Environmental Co-ordinator Representative	<p>The DLP representative will be responsible for the environmental performance of the dredging and disposal works and reporting environmental monitoring performance. Responsibilities include:</p> <ul style="list-style-type: none"> <li>- Implementation of the DMP.</li> <li>- Management of the monitoring and reporting contractor.</li> <li>- Conducting regular compliance audits against the DMP, ministerial conditions.</li> <li>- Ensure implementation of the water quality, sediment deposition and ecological condition.</li> <li>- Reporting on the results of the monitoring programs to the DLP and advising on exceedences of threshold limits and reactive management measures.</li> <li>- Advising the DLP on appropriate actions and management measures to be implemented.</li> </ul>
Technical Advisory Group (TAG)	<p>The TAG will be responsible for providing technical advice on all aspects of dredging and disposal works. The role of TAG will be to provide DLP with advice, including but not limited to:</p> <ul style="list-style-type: none"> <li>- the marine management plans</li> <li>- the marine monitoring program</li> <li>- overall dredging method and plans</li> <li>- the management of turbidity generating activities and marine works</li> <li>- impacts on marine fauna and flora, including benthos and mangroves</li> <li>- reporting</li> <li>- new management measures</li> </ul>
All DLP personnel involved with work	<ul style="list-style-type: none"> <li>- Duty of Care to the environment</li> <li>- Reporting of all environmental incidents to NRETAS, DLP or SEWPaC as needs be.</li> </ul>

### Contractor Supervision

Supervision of the contractor's environmental performance will be the responsibility of the DLP or their representative. The supervision will be implemented via:

- day to day monitoring of the operations including cross checking of methods proposed in the approved method statements
- regular environmental audits relating to environmental performance
- regular meetings to discuss environmental performance and possible improvement.

## **Auditing**

Environmental performance and compliance with the requirements of the approvals, and this DMP, and the various policies and management plans associated with the project will be assessed via a comprehensive auditing procedure. The following audits will be undertaken throughout the life of the project:

Pre-start audits to be completed by the Project Manager prior to the commencement of work by any major piece of dredging equipment include:

- Project auditing as per DLP Procedure
- Compliance auditing
- The need to sight certificates for all vessels used including the dredges.

Prior to the commencement of works by any piece of major dredging equipment, a pre-start audit inspection will be undertaken. This self-audit will include the inspections of the vessels equipment (e.g. oil spill response equipment) and records (e.g. environment induction records). In the event of non-compliances, an instruction will be given by the DLP with respect to the actions required to resolve the issue, including required timing. In the event of non-compliance that presents significant risks to the environment are discovered, the vessel will be required to rectify the non-compliance before commencing dredging operations.

Records of the pre-start audit inspection will be maintained. Any actions resulting from this audit process will be ranked and tracked for closeout by the project action tracking system Internal project auditing will be undertaken in accordance with the East Arm Wharf dredging project audit schedule and the DLP project auditing procedure.

The outcomes of the internal audits will form a subset of DLP's annual environmental report and audit reports will be sent for external audit.

## **Complaints Management**

All environmental complaints/queries will be received by DLP. All necessary information will be collected and recorded including:

- details of the person/group making the complaint (if available)
- the times and dates of the incident
- details of the complaint
- witness details.

A complaint register will be completed and an investigation into the complaint will occur as soon as practicable. Any corrective or preventative action taken will be documented on the complaint register. The DLP project manager, will receive a copy of the complaint register. A complaint register, including close out date and signature, will be kept.

### 4.3 Contractor

Roles and responsibilities of the contractor are summarised in Table 12.

**Table 12 Contractor personnel environmental roles and responsibilities**

DMP stakeholder	Roles and responsibilities
Dredging Contractor (DC)	<p>The dredging contractor(s) will be responsible for undertaking the dredging works to the requirements of the DLP. The dredging contractor(s) report to the DLP and will be responsible for:</p> <ul style="list-style-type: none"> <li>- Prepare and submit a DMP for approval by NRETAS (the Final DMP)</li> <li>- Development of the CEMP in accordance with the requirement of this DMP.</li> <li>- Execution of the works in accordance with the approved CEMP.</li> <li>- Implementing the reactive management measures as directed by the DLP.</li> <li>- Preparing and implementing work method statements.</li> <li>- Ensuring that all environmental management measures are implemented and that all equipment is regularly inspected and tested to minimise the risk of an environmental incident.</li> <li>- Ensure all staff and sub-contractors are aware of their responsibilities under the DMP and provide adequate training and resources to fulfil these obligations.</li> </ul>
Monitoring and Reporting Contractor	<ul style="list-style-type: none"> <li>- Implementation of the water quality, sediment deposition and ecological health monitoring programmes.</li> <li>- Reporting the results of the monitoring programmes to DLP Environmental Coordinator.</li> </ul>
All contracting personnel involved in dredging works	<ul style="list-style-type: none"> <li>- Duty of Care to the environment.</li> <li>- Reporting of all environmental incidents to the NRETAS, DLP or SEWPaC as needs be.</li> </ul>

The environmental performance of the contractor(s) will be managed through requirements set during the tendering and contracting process as well as an ongoing auditing process. Before the commencement of works, contractor(s) will be required to provide evidence of vessel compliance and have in place an approved Contractors Environmental Management Plan (CEMP) consistent with this DMP.

The contractor(s) will be required to develop Contractor Method Statements (CMS) before undertaking any major works including dredging and disposal, floating pipeline installation, surveying etc. These CMSs will be required to address the environmental aspects of the proposed activity and provide suitable management measures to minimise identified potential environmental impacts. The CMSs will be required to be consistent with the requirements of this DMP. The CMSs will require approval by the DLP prior to the commencement of works.

#### 4.3.1 Preparation of approvals

The CEMP will be required to provide specific information regarding the overall and day to day environmental management of the dredging and disposal works. This plan will address at a minimum:

- specific operational procedures and work methods relating to managing environmental impacts
- equipment and materials available with regards to environmental management
- roles and responsibilities of staff
- environmental training and inductions
- communication and reporting structures
- inspection and record keeping procedures.

The requirements for each specific management area of the CEMP are shown in Table 13.

Table 13 Management area and associated requirements

Management area	Requirements
Waste Management	<ul style="list-style-type: none"> <li>- Implement a waste hierarchy: reduce, reuse, recycle and recover waste.</li> <li>- Address the management of solid waste, sewage, putrescible waste and hazardous waste.</li> <li>- Apply to all onshore and offshore activities.</li> <li>- Document the procedures for the containment; handling and disposal of wastes.</li> <li>- Identify suitable waste disposal sites and methods.</li> <li>- Outline an induction programme on waste management requirements</li> <li>- Detail record keeping / reporting procedures including a waste disposal catalogue</li> <li>- Ensure that no waste substance is discharged onto the ports facilities or waters as required by the Port Authority.</li> </ul>
Noise and Vibration Management	<ul style="list-style-type: none"> <li>- Specify the implementation requirements for noise and vibration management</li> </ul>
Hydrocarbon Management	<ul style="list-style-type: none"> <li>- Include implementation of the hydrocarbon management measures</li> <li>- Outline the hydrocarbon storage areas, storage methods and handling procedures.</li> <li>- Sign in and out procedures for hydrocarbons including from the dredge and service boats</li> </ul>
Oil Spill and Response	<ul style="list-style-type: none"> <li>- Outline the procedures and safe work method statements to be undertaken in the event of a hydrocarbon spill.</li> <li>- Specify the type and quantities of oil spill equipment that will be available, where it will be stored and how equipment stocks will be managed.</li> <li>- Define the roles, responsibilities of response personnel in the event of an oil spill</li> <li>- Describe any training and induction procedures relating specifically to oil spill response.</li> <li>- Outline the communication and reporting structure to be implemented with regards to oil spill response</li> <li>- Ensure spill kits are available</li> </ul>
Marine Quarantine Management	<ul style="list-style-type: none"> <li>- Include implementation of the Quarantine management measures.</li> <li>- Include the implementation of requirements of a marine quarantine management plans applicable to Darwin Port</li> </ul>
Vessel operations Management	<ul style="list-style-type: none"> <li>- Specify vessel operation requirements and mitigation measures.</li> </ul>
Inspection and auditing	<ul style="list-style-type: none"> <li>- Outline the planned inspection and auditing of environmental management systems including roles and responsibilities and reporting of contractor's activity.</li> </ul>
Complaints and Non-Compliance Management	<ul style="list-style-type: none"> <li>- Detail actions to be taken and reporting requirements in the event of environmental complaints or non compliance.</li> </ul>

### Contractor Method Statements (CMS)

The contractor(s) will be required to develop method statements before undertaking any major works including dredging and disposal, floating pipeline installation, boost stations, surveying etc. These will be required to address the environmental aspects of the proposed activity and provide suitable management measures to minimise identified potential environmental impacts consistent with the requirements of the DMP. The CMS will require approval by the DLP prior to the commencement of works.

### **Hazard Identification and Management**

The contractor(s) will be required to undertake Hazard Identification Studies (HAZIDs) prior to the commencement of any works or any significant variation to the dredge methodology. The HAZIDs will be required to identify the potential environmental hazards associated with the proposed activities as well as mitigation and contingency measures. The HAZIDs will require approval from the DLP Project Manager before the commencement of the activities.

### **Cyclone Management**

The contractor(s) will be required to prepare a cyclone management plan prior to any works being undertaken. The cyclone management plan will be required to identify safety precautions, dredge plant security, evacuation plans, cyclone response stages linked to cyclone intensity and link to the Darwin Port Corporation Cyclone Management Plan. The cyclone management plan will require approval from the DLP Project manager before the commencement of activities.

#### **4.3.2 Operation and monitoring**

##### **Monitoring Program**

The Monitoring and Reporting Contractor will implement an environmental monitoring program and report the findings to the DLP Environmental Representative who in turn reports to and advises the DLP Project Manager who, in turn, inter-relate to the TAG. The TAG may provide advice regarding management measures.

During the dredging operations, monitoring results will be provided to the TAG on a weekly basis. In addition, pre and post dredging monitoring will also be undertaken.

##### **Incident Management**

Environmental incidents will be reported and managed in accordance with the Development Reporting Procedures. Any actions resulting from investigations into environmental incidents will be tracked for closeout by the project action tracking system. Regulatory reportable environmental incidents and non-compliances such as unauthorised discharges or significant (listed) fauna mortality/injury will be reported to the DLP, TAG and SEWPaC as required.

#### **4.3.3 Reporting**

The contractor will be required to report regularly (weekly) on the dredging and disposal activities to the DLP Project Manager. This reporting will be in the form of:

- daily operational logs including approximate dredged quantities, vessel track logs / track plots
- environmental incident reports including fauna sightings and injury
- weekly reports including details of any activities that relate to environmental performance such as reports on the condition, effectiveness of the environmental management measures and details of any environmental complaints or non compliances and any relevant corrective actions taken
- summary reports in accordance with the contracted requirements.

#### **4.3.4 Review, update and improvement of DMP**

Review, update and improvement of the DMP will be undertaken in consultation with the DLP Project Manager and Environmental Coordinator, and the TAG with approval for any recommended update and improvement approved in writing by the DLP Project Manager prior to update of DMP.

#### **4.3.5 Competence, Training and Awareness**

The contractor will be required to prepare a training and induction programme that covers, at a minimum, each employees:

- duty of care with respect to the Environment
- DLP's and contractors environmental policies
- roles and responsibilities
- regular tool box meetings
- First Aid Station location and kit

- Emergency Evacuation Plan
- monitoring requirements (e.g. fauna monitoring)
- waste management requirements for all waste streams
- reporting requirements (including the reporting of environmental incidents, fauna sightings). The training and induction programme will require approval from the DLP prior to its implementation. Records relating to the implementation of the programme will be maintained. The contractor will be responsible for ensuring all employees and sub contractors are inducted.

## 5.0 Environmental and coastal management issues

### 5.1 Assessment of impacts

Dredging activities, using either of the methods outlined in the previous sections, results in a number of impacts on the marine environment. In some cases, impacts may be more relevant to particular dredging methods. Environmental issues that are typically relevant for dredging and reclamation projects include the following:

- changes to water quality
- changes to coastal processes (waves and currents)
- effects on marine ecology (flora and fauna)
- mobilisation of sediment and pore water contamination
- introduction of marine pests
- impacts on cultural heritage values
- nuisance environmental effects (noise and air emissions).

Many of these issues relate to the removal of marine sediments or disturbance of the seabed, and on that basis apply equally, regardless of the particular dredging method. Conversely, the nature of impacts on water quality, mobilisation of sediment contaminants, impacts to marine ecology and the introduction of marine pests are more intrinsic to particular dredging methods. These issues, along with changes to coastal processes, are often the most relevant impacts to the natural environment from dredging and spoil management activities. Table 14 (below) provides a summary of the performance of common dredging methods against key environmental aspects that may be affected differently by different dredging techniques.

**Table 14 Matrix of dredge method performance against environmental aspects**

Environmental Aspect	Mechanical Dredging	Cutter-suction Dredging
Water Quality	Mechanical dredges allow <b>minimal disturbance</b> of dredged material. Mechanical dredging maintains much of the structure of consolidated sediments during dredging. This limits the generation and release of sediment-laden water. <b>Localised turbidity</b> will occur during excavation. In unconsolidated sediments, mechanical dredging produces <b>considerable, but localised turbidity</b> .	CSD's generate a <b>large volume of sediment-laden water</b> at the discharge location because of the fluidisation of the dredged material transport via pipeline.  The cutter-head also causes <b>suspension of sediments</b> at the dredging location, but this effect is limited because of the suction effects at the head of the dredge.
Sediment Contamination	In consolidated sediments, where the consolidated structure on sediments is maintained during dredging, <b>liberation of chemical contaminants from sediments and pore-water is limited. Liberation of chemical contaminants would be greater</b> in unconsolidated sediments, but is not likely to be as significant as with methods that use fluidisation to pump dredged material.	Chemical contamination of sediments and pore-water within the soil matrix can be <b>liberated by the processes of fluidisation</b> . Contaminants may become dissolved within the water used for transportation of dredged material via pipeline. Release of contaminants would occur at the discharge location.

Environmental Aspect	Mechanical Dredging	Cutter-suction Dredging
Marine Ecology	Mechanical dredging will result in <b>direct physical disturbance to sessile marine organisms</b> within the dredging area. Indirect disturbance to non-mobile marine organisms may occur in close proximity to dredging and spoil placement as a result of turbid plume dispersion and sedimentation. <b>Mobile marine fauna are unlikely to be significantly affected</b> by mechanical dredging.	Cutter-suction dredging will result in <b>direct physical disturbance to sessile marine organisms</b> within the dredging area. Indirect disturbance to non-mobile marine organisms may occur in close proximity to <b>dredging and spoil placement as a result of turbid plume dispersion</b> and sedimentation. <b>Mobile marine fauna are unlikely to be significantly affected</b> by cutter-suction dredging, which is effectively stationary plant.
Marine Pests	Introduction of marine pests is <b>unlikely to be relevant for mechanical dredges</b> , because they are typically barge-mounted and do not carry ballast.	Cutter-suction dredges can be self-propelled ocean-going vessels and may carry ballast. Management of <b>introduced marine pests may be relevant</b> for cutter-suction dredges. Provide vessel certification and compliance information.

### 5.1.1 Material extraction

The major environmental effects resulting from material extraction are the direct and indirect effects on water quality from the turbid plume generated from mobilised sediments and subsequent sedimentation of that sediment on the marine benthic environment. Mobilisation of these sediments may disturb, disperse and release contaminants currently held *in situ* at East Arm Wharf.

#### Metocean conditions, coastal processes and currents

Material extraction at the dredging site may affect metocean conditions coastal processes and currents through the alteration of bathymetry by deepening. There are potential effects on coastal processes.

Preliminary modelling results undertaken by WRL (2010) indicate that there will be little effect on currents in the area due to the presence of the project.

The effect of dredging on the metocean conditions is the subject of hydrodynamic modelling (URS Scott Wilson 2011).

#### Water quality

Water quality will be affected within and surrounding East Arm Wharf during both mechanical and cutter-suction dredging operations described in Section 5.1.

Mechanical dredging of the soft surface sediments and offshore disposal of the dredged material may result in the following water quality impacts:

- Minor and localised increase in suspended solids concentration-turbidity at the dredge site, due to disturbance during excavation and overflow from hopper barges used to transport dredged material
- Increased sedimentation as a result of the above influences
- Potential mobilisation of chemical contaminants notably arsenic, lead, zinc and nickel from the dredged sediment and/or pore water at the dredge site and at the offshore disposal site

Cutter-suction dredging of the firm subsurface material and placement of material to reclamation may result in the following water quality impacts:

- Minor and localised increase in suspended solids concentration/turbidity at the dredge site, due to disturbance of seabed sediments caused by the dredge head
- Increase in suspended solids concentration/turbidity at the discharge from the zone of the dredge activity
- Increase sedimentation as a result of the above influences



- Potential mobilisation of chemical contaminants notable arsenic, lead, zinc and nickel from the dredged sediment and/or pore water at the dredge site and at the discharge from the reclamation areas.

Subsequent sedimentation of dredged material from the water column are likely to have effects on marine ecology particularly benthic habitat and benthic dwelling organisms. These are discussed in the following sections.

The extent of the effect on water quality from dredging at East Arm Wharf has been the subject of hydrodynamic modelling (URS Scott Wilson 2011).

### **Marine ecology**

Material extraction around East Arm Wharf is likely to affect the marine ecology of the area through direct and indirect impacts. Direct impacts are likely to include physical disturbance to the benthic habitat and sessile marine organisms within the dredging area, while indirect disturbance to the benthos is likely to occur in close proximity to dredging as a result of turbid plume dispersion and sedimentation. Marine megafauna are unlikely to be significantly affected by turbidity given the turbid nature of Darwin Harbour; however, there is a risk of entrainment and vessel strike.

An increase in turbidity levels and sediment deposition in the surrounding marine environment may occur during dredging. The main potential impact of increased sedimentation and turbidity is on the growth of primary producers such as seagrass, coral and macroalgae, which are light limited. No seagrass beds were observed in the area surrounding East Arm Wharf, however, the following benthic habitats were recorded (BMT WBM 2010):

- Scleractinian reefs
- Moderate to high density sponge and soft coral beds
- Sand with low density of other taxa
- Sand with *Macrorhynchia* and soft coral.

A map of benthic habitat in the vicinity of dredging is presented in Figure 9.

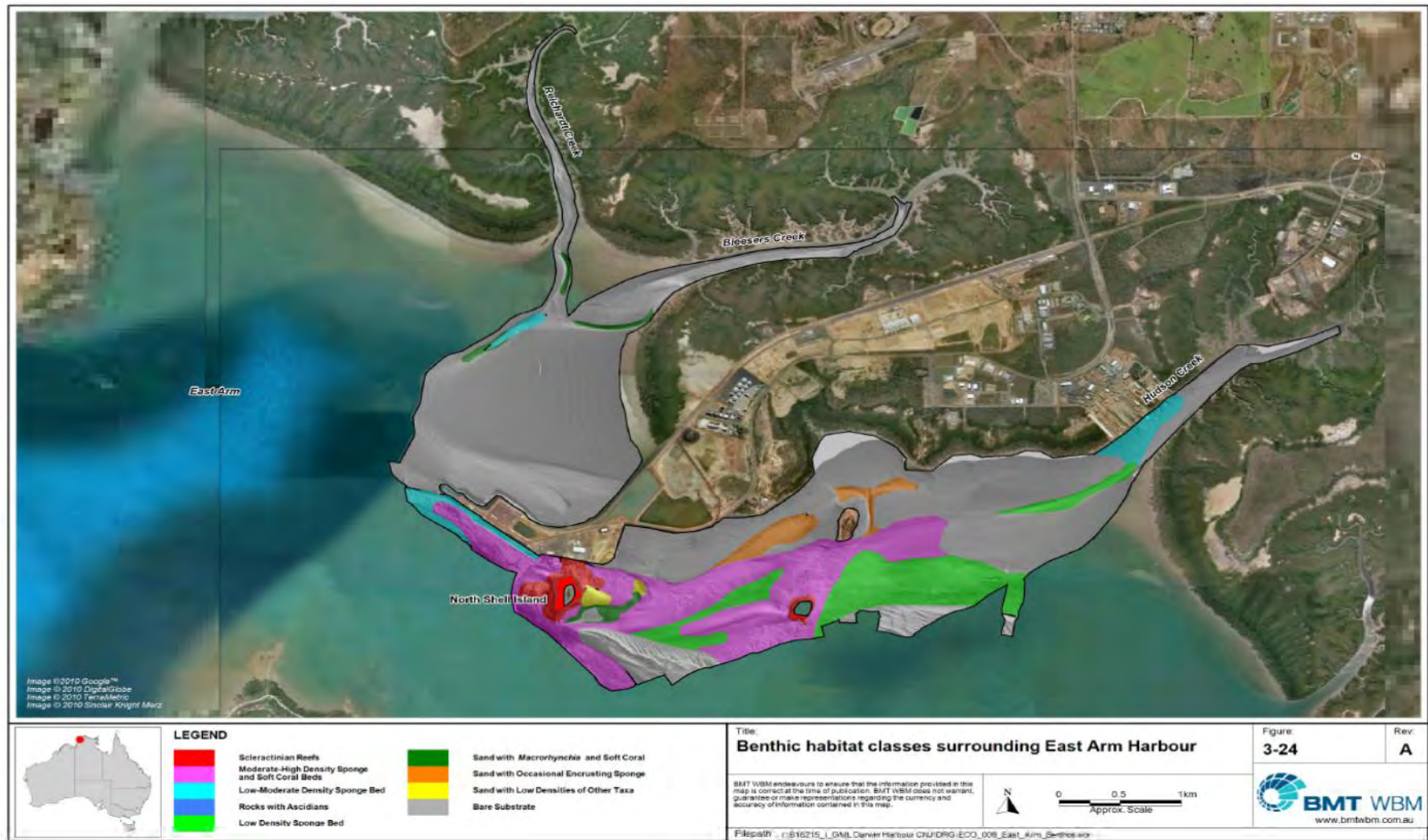


Figure 9 Benthic habitat classes surrounding East Arm Harbour dredging locations (Source: BMT WBM 2010)

### **Benthic Primary Producers (BPP)**

All BPPs are sensitive to removal of their habitats, as this eliminates the substrate on which they grow. Recolonisation is only possible when the removed substrate is replaced with similar substrate. BPPs that colonise hard substrates are therefore less resilient to the effects of dredging as hard substrate is usually replaced with soft substrate. Many coral species, as well as many macroalgae, require hard substrates for settlement. Of all the BPPs, hard corals are considered most sensitive receptors both with respect to their resilience and potential to recover as well as their susceptibility to impacts such as smothering and shading. High levels of sediment deposition results in corals exhibiting symptoms of stress from energies required for mucus production therefore leading to bleaching (Rogers 1990). However extreme levels of sedimentation are likely result in coral mortality from direct smothering (Rogers 1990, Stoddart and Anstee 2004). Where corals occur in mixed habitats with other BPPs, this is often termed mosaic Benthic Primary Producer Habitat (BPPH) and impacts are assessed against this heterogeneous habitat using the most sensitive receptor, hard coral, to assess such impacts.

BPP are dependent upon light as a source of energy, and are sensitive to change in light, temperature, sediment loads and wave exposure. In order for BPP to be impacted by turbidity, the duration of decrease in light attenuation from turbidity is required to deprive BPP of photosynthetic energy (Stoddart and Anstee 2004). Increased sediment loads, decreased light penetration or increased wave action would have the potential to change or damage the existing BPP communities in the area. Dredging would result in diminished light levels which would reduce the density or health of the BPP. Recovery would be expected but the timescale is dependent on the reduction in density of turbidity which could be within several growing seasons.

Benthos may be affected:

- directly, by an acute physiological or biochemical effect on organisms that live associated with the substrate including BPPs, and
- indirectly, through loss and/or reduction of productivity such as planktonic organisms that provide a food source to benthic organisms, such as filter feeders, or sedimentation.

### **Macroalgae, seagrass and microphytobenthos**

Macroalgae, seagrass and microphytobenthos are considered less sensitive to turbidity and sedimentation than hard corals.

### **Hard corals**

Light-dependent photosynthetic activity of the zooxanthellae is a key influence on coral growth and survival (Muscatine 1990). Reduced light, such as that induced by increased turbidity, is known to reduce photosynthesis by zooxanthellae, leading to lower carbon gains, slower calcification and thinner tissues in corals (Anthony and Fabricius 2000, Fabricius 2005, Telesnicki and Goldberg 1995). Furthermore, reduced light is typically paralleled by a reduction in lipid production (Crossland et al. 1980) which may result in a reduction of fecundity (Kojis and Quinn 1984). It has been shown that corals require a minimum amount of light corresponding to approximately 2-8% of surface irradiance (for example Cooper et al. 2007, Tityanov and Latypov 1991). Although such a limit allows the maintenance of corals, it might be insufficient to support active reef growth (Cooper et al. 2007).

Corals, therefore, are sensitive to increases in suspended sediment and the corresponding reduction in light penetration. Through settling of suspended particles on their surfaces, corals are impacted from dredging operations by the need to actively remove particles to avoid smothering and clogging of their feeding apparatus. The rejection mechanisms of sedimentation come at an energetic expense to the coral through loss of carbon from mucus release and enhanced respiration (Anthony and Fabricius 2000) and associated reduced growth rate (Crabbe and Smith 2005) which may vary depending on the quantity and quality of deposited particles (Philip and Fabricius 2003, Weber et al. 2006). Deposition of particles in excess of what may be actively removed by the coral may cause elevated mortality rates (Fabricius 2005). Furthermore, sedimentation also negatively affects rates of survival and settlement of coral larvae.

### **Epifauna and endofauna**

Filter feeders and infauna will suffer mortality when their habitat is removed. The recovery potential from mobile fauna appears to be higher than that of sessile organisms because recolonisation can occur more easily. These organisms are also sensitive to burial by sediment deposition and exposure to marine discharges that change their environment, such as increase salinity or temperature and expose them to toxic substances. In the worst case this causes mortality. As material settles out of the water column over rocky substrates suitable substrate

may be lost. Suitable substrate may also be lost in the direct dredging footprint as exposure of previously buried substrata may leave the area.

Marine invertebrates may be impacted by material extraction by the sedimentation and settlement of water column dredge plume material. This is particularly relevant to sessile invertebrates which are attached to the bed and will not be able to move away from the sedimentation zone.

### Marine Megafauna

Increased turbidity and sedimentation from material extraction may affect marine megafauna through loss of foraging habitat and behavioural disturbance. As marine mammals are dependent on sight for feeding and navigation, foraging efficiency and predator avoidance may also be affected.

Marine mammals are susceptible to injury or mortality resulting from interaction with vessels, particularly when they rise to the surface to breath, rest or forage in shallow waters. Although dugongs typically move to deeper water to avoid approaching vessels, this response may be maladaptive, as dugongs may seek shelter within the shipping channel where they may experience increased risks. Dugongs while vulnerable to shallow draft vessel impact are unlikely to be present as shallow near-shore seagrass beds are not known to be present near the dredger operations

The main factor to consider in the assessment of strike risk is whether marine megafauna can detect boats at a distance that allows them to evade collision, with detection determined by hearing ability and the propagation of vessel noise. Boat strike (from swift and/or manoeuvrable vessels) is a primary cause of anthropogenic mortality in turtles accounting for up to 60 percent of reported human caused deaths. In response to this risk, GBRMPA has imposed speed and size restrictions on certain protected waters relating to vessels greater than ten metres and travelling faster than twenty knots as a balance between the reasonable use of the area and the risk of fatal boat strike and noise disturbance. However, in this situation where vessels will be present for relatively short periods (weeks→months) and the dredgers will be very slowly moving, the risk is extremely low. Marine megafauna are known to be entrained in TSD and these will not be used on this development.

### Fish

Suspended sediment and sedimentation caused by material extraction has the potential to adversely affect marine benthic habitats including seagrass, coral, macroalgae and filter feeding communities. The potential magnitude of impact on fish, particularly those with sedentary or territorial habits, relates to the loss or reduction in productivity of the habitat. Loss of light through suspended sediment in the water column or by sedimentation can reduce primary and secondary production rates resulting in less abundant foodstuff. Reduced fish biomass is an indirect effect associated with the loss of BPPH and may be deleterious, particularly if the loss of foraging grounds was sustained over a large area for a long period of time. Such an event is very unlikely to occur.

### Policy Assessment

Policies and plans relevant to material excavation are presented in

**Table 15 Policies and plans relevant to material extraction**

Policies and Plans	Relevance
Territory 2030 Strategic Plan (Northern Territory Government 2009)	In the Economic Sustainability section of this plan of particular relevance is Objective 3; Growing local industry. The expansion of East Arm Wharf will require dredging within Darwin Harbour to provide for effective and efficient vessel access and manoeuvring. This will improve access for prospective wharf users, including commercial users and the Department of Defence, thus impacting positively on the growing local industry.
Northern Territory Environmental Guidelines for Dredging Management (Northern Territory Government; NRETAS, Draft)	These guidelines outline the legislative and administrative requirements for dredging in the NT. They also highlight some important issues for consideration in relation to the dredge monitoring and management. Issues raised for consideration will be addressed in studies and EIS and relevant environmental and operational plans.
Building Northern Territory industry participation (Northern Territory Government 2006)	This framework consists of a nationally agreed set of objectives, principles and strategies that will strengthen industry participation and build on existing arrangements. The contractor, as part of its plan will develop operational and management plans recognising the importance of industry participation and the engagement of local businesses.

Darwin Harbour regional plan of management (Northern Territory Government; NRETAS 2003)	The main goal of this plan is to protect the environment of Darwin Harbour through key outcomes such as improving water quality, managing development appropriately, protecting biodiversity and supporting recreational use of the Harbour. The contractor as part of its plan will develop operational and environmental management plans to monitor and protect water quality and biodiversity in the Harbour; these will be outlined in the EIS.
Darwin Harbour Regional Management Strategic Framework 2009-2013 (DHAC draft)	This policy framework provides guidelines for the management of environment, social, cultural and economic values and uses of the Darwin Harbour. The EIS will address issues relating to environment, social, cultural and economic values associated with the activities of dredging.
ANZECC Guidelines for Fresh and Marine Water Quality (2000) National Water Quality Management Strategy (1992), The Framework for Marine and Estuarine Water Quality Protection (no date), SEWPaC	These authoritative guides set water quality objectives to sustain environmental values. The documents provide specific water quality for each environmental value and the context in which it should be applied. The contractor will comply with these water quality guidelines where applicable, and ensure that management procedures are put in place to minimise impacts to water quality to meet the requirements under the <i>Water Act</i> .
Australian Ballast Water Management Requirements, AQIS, 2001	This document details mandatory ballast water management requirements to reduce the risk of introducing harmful aquatic organisms into Australia's marine environment through ships' ballast water. The contractor will comply with these management requirements to ensure that no harmful aquatic organisms are introduced to the marine environment from the vessels ballast water or hull.

### 5.1.2 Dredge material placement

There is no effect on the marine environment as dredged material is to be placed onshore.

## 5.2 Environmental management

This section contains the sub-plans that describe the specific management actions and preventative measures that will be implemented during construction works at the East Arm Wharf, in order to minimise the risk of harm on environmental and heritage values and minimise impacts from dredge related activities.

The sub-plans outline specific objectives and performance indicators that can measure the relative success of an implemented plan. These sub-plans also specify specific monitoring and reporting requirements associated with the potential environmental impacts and associated risks. The results of the monitoring will be used to assess the effectiveness of management actions and site compliance with performance indicators. The DLP Project Manager will be required to report regularly on environmental performance, including incidents/complaints and corrective actions to NRETAS.

The management procedures outlined in this section may be subject to change following environmental assessment by governing bodies. Responsibilities allocated are indicative only and may change depending on the company structure of the construction contractor and/ or final proponent.

The location of construction works close to marine waters enhances the potential for adverse impacts upon the marine environment. Impacts could potentially originate from petroleum, oil and lubricant (POL) spills, stormwater discharges or sediment dispersal from dredging and reclamation. It should be noted that the works are intended to be completed prior to the onset of the wet season resulting in a far lower likelihood of contamination occurring as a result of surface water runoff. Impacts from contamination from spills of hazardous materials (POL) are described further in Section 5.2.6.1.

Dredging activities may also release existing contaminated sediments into the water column if they are present in the dredging area. Impacts of dredging on marine water turbidity are described further in Section 5.2.1.

Disturbance of acid sulfate soils can result in local reductions in pH (increase in acidity) which can directly impact upon marine and estuarine waters through reductions in water quality, as well as result in indirect impacts through the mobilisation of heavy metals.

### 5.2.1 Mitigation and management of effects on physical receptors

Liberation of particles from the dredge head into the water column will occur which will cause an increase in turbidity and with consequent sedimentation of settleable particles adjacent to the source of dredging.

Sub-plan 1: Water quality	
Factor – Ambient estuarine water quality	
Aspect – Generation (and migration) of Turbidity and Sedimentation Fields at the Dredging source	
Management Objective	<ul style="list-style-type: none"> <li>- To minimise the generation of extensive, prolonged and / or intense turbidity plumes and sedimentation during dredging activities within the designated Zone of Moderate Impact.</li> <li>- To manage water quality and sedimentation effects in order to limit undue effects on benthic habitats and nearby aquaculture facilities as a result of the dredging and materials disposal campaign.</li> </ul>
Statutory Requirement or Guidance	<ul style="list-style-type: none"> <li>- <i>National Water Quality Management Strategy: Guidelines for Fresh and Marine Water Quality</i> (ANZECC 2000)</li> <li>- <i>Darwin Harbour Water Quality Protection Plan, 2009</i> (draft)</li> <li>- <i>Developing Water Quality Objectives for the Darwin Harbour Region, 2009</i> (draft)</li> </ul>
Performance Criteria	Within the Zone of Moderate Impact (outside of each of the Zone of High Impact and Zone of Influence, refer to Section 5.3.2), water quality thresholds are to be developed and assessed as proposed in Section 5.4.
Implementation Strategy	<p>Prior to dredging, develop the following:</p> <ul style="list-style-type: none"> <li>- Water Quality and Sedimentation Monitoring Program</li> <li>- Under advisement of TAG, a monitoring and management plan (including thresholds levels and any adaptive management) in relation to human and ecological receptor sensitivities.</li> </ul> <p>Prior to dredging:</p> <ul style="list-style-type: none"> <li>- establish baseline (before) existing conditions in order to detect unacceptable levels of change associated with dredge operations (use already existing information where possible)</li> <li>- confirm the areas and delineate the Zones of impact (High and Moderate) and Zone of Influence for each of the dredging and disposal activities</li> <li>- assess water quality (eg. turbidity) at “core” regional monitoring sites – for example South Shell Island; NE Wickham Point; Channel Island and Weed Reef to be consistent with previous and/or other ongoing assessments. Adopt other sites within “Zone of Moderate Impact” as required in consultation with TAG and NRETAS.</li> <li>- characterise the sediments to be dredged in order to segregate potentially contaminated sediment (destined for onshore disposal) and clean materials</li> <li>- devise a treatment and tailwater release strategy from onshore emplacements</li> <li>- review this DMP and approve the Dredge Contractors EMP and Final DMP.</li> </ul> <p>During on-water dredging:</p> <ul style="list-style-type: none"> <li>- adopt relevant technology to minimise overflows in dredging areas to limit cumulative turbidity effects</li> <li>- apply mitigations, where fines content is elevated and/or closest to sensitive receptors</li> <li>- use tidal exchange and current flows to direct location of dredgers, and subsequent plume migration</li> <li>- routinely monitor levels of turbidity (and other selected water quality indicators) prior to, during and post dredging campaign and the “core” sites (and as needed at temporary sites nearer to dredge areas)</li> <li>- establish and operate TAG to seek independent, project related advice and adaptive management practices.</li> <li>- if turbidity levels exceed agreed monitoring and management frameworks then the TAG will advise on what actions may alleviate effects.</li> </ul>

Sub-plan 1: Water quality	
Factor – Ambient estuarine water quality	
Aspect – Generation (and migration) of Turbidity and Sedimentation Fields at the Dredging source	
	<p>During land-side works and dewatering:</p> <ul style="list-style-type: none"> <li>- maximise construction activities during the dry season to reduce potential for erosion, sedimentation and acid leachate emissions</li> <li>- for wet season preparedness and activities, for instance: <ul style="list-style-type: none"> <li>• divert stormwater away from the construction site through the implementation of a temporary bund wall</li> <li>• install fencing within or gravel/rock any temporary drainage channels created during the construction phase of the development to reduce stormwater velocity</li> <li>• apply measures such as gross pollutant traps, temporary cut off drains and bunding are to be installed where suitable to capture gross pollutants, POL, sediment and other contaminants generated by near shore activities</li> </ul> </li> <li>- visually inspect stockpiled fill to identify any areas of major wind/water soil erosion (Refer to Soil Erosion and Sediment Control Plan)</li> <li>- inspect the condition and operability of site diversionary drains and erosion control measures (silt traps, sediment fences other measures).</li> </ul> <p>Post dredging:</p> <ul style="list-style-type: none"> <li>- monitoring to determine ongoing effects resulting from dredging and system recovery.</li> <li>- comparison of results with previous dredge monitoring results.</li> </ul>
Monitoring	<ul style="list-style-type: none"> <li>- TAG and the Proponent to develop the requirements of Section 5.4.1</li> <li>- Monitoring contractor to apply the requirements of Section 5.3.4, Table 17 Condition 2</li> <li>- Dredging contractor to apply the Final DMP and CEMP and monitor for incidents</li> </ul>
Auditing and Reporting	<ul style="list-style-type: none"> <li>- Data to be evaluated daily by Dredge contractor and DLP project manager during the active dredging schedule.</li> <li>- Determine course of action against monitoring and management framework</li> <li>- Apply reporting and responsibilities described in Section 4.0.</li> </ul>
Corrective Action	<ul style="list-style-type: none"> <li>- Refer to Section 5.3.</li> <li>- Refer to East Arm Wharf DEIS/SEIS</li> <li>- Consider advice from TAG</li> </ul>
Responsibility	TAG; with advice to Proponent
Timing	Continuous monitoring, daily assessment and routine reporting

## 5.2.2 Mitigation and management of effects on ecological receptors

### 5.2.2.1 Benthic and coastal habitats

Management and protection of benthic and mangrove habitats will control the risk of undue effects on primary production rates and fauna using these areas as habitat.

Sub-plan 2: Benthic and coastal habitats	
Factor: Estuarine ecological community receptors	
Aspect – Shading / sedimentation / erosion of Flora and sessile Fauna adjacent to the dredging area	
Management Objective	<ul style="list-style-type: none"> <li>- To minimise the loss of sub-tidal benthic habitat within the Zone of Moderate Impact.</li> <li>- To prevent the temporary (or greater) loss of sub-tidal benthic habitat within the Zone of Influence.</li> <li>- To minimise the impact on the environment that forms habitat for listed protected species or areas of environmental significance including loss of mangroves and other inter-tidal and supratidal vegetation.</li> </ul>

Sub-plan 2: Benthic and coastal habitats	
Factor: Estuarine ecological community receptors	
Aspect – Shading / sedimentation / erosion of Flora and sessile Fauna adjacent to the dredging area	
Statutory Requirement or Guidance	<ul style="list-style-type: none"> <li>- <i>National Environment Protection Council (NT) Act 1994</i></li> <li>- <i>Policy on the Protection of Darwin Harbour and its Coastline (TOPROC, 1999)</i></li> <li>- <i>Darwin Harbour Regional Management Strategic Framework 2009-2013 (DHAC draft)</i></li> <li>- <i>EPBC Act and Environment Protection and Biodiversity Conservation Regulations 2000</i></li> </ul>
Performance Criteria	<ul style="list-style-type: none"> <li>- No measurable loss of estuarine habitat extent within or beyond the Zone of Moderate Impact.</li> <li>- Recovery from any temporary reduction in ecological health within two years of completion within the Zone of Moderate Impact.</li> <li>- No permanent loss of key species from within areas outside of the approved Zone of High Impact.</li> </ul>
Implementation Strategy	<p>Prior to dredging, develop the following:</p> <ul style="list-style-type: none"> <li>- Benthic Habitat thresholds in accordance with the requirements of Section 5.4.2.</li> <li>- Under advisement of TAG, monitoring and management plan (including thresholds levels and any adaptive management) in relation to 'Water Quality and Sedimentation' be linked to ecological receptors to address Section 5.4.</li> </ul> <p>Prior to dredging:</p> <ul style="list-style-type: none"> <li>- establish baseline (before) existing conditions in order to detect unacceptable levels of change associated with dredge operations (use already existing information where possible)</li> <li>- assess regional "core" monitoring sites – for example, these may be South Shell Island; NE Wickham Point; Channel Island and Weed Reef to be consistent with previous and ongoing assessments. Adopt other sites within Zone of Moderate Impact as required in consultation with TAG and NRETAS.</li> <li>- confirm the areas and delineate the Zones of impact (High and Moderate) and Zone of Influence for each of the dredging activities</li> <li>- review this DMP and approve the Dredge Contractors EMP and the Final DMP.</li> </ul> <p>During on-water dredging and onshore disposal:</p> <ul style="list-style-type: none"> <li>- adopt relevant technology to minimise emissions in dredging areas to limit cumulative turbidity, sedimentation or other effects from potential toxicants</li> <li>- apply mitigations, where fines content is elevated and/or closest to sensitive receptors</li> <li>- use tidal exchange and current flows to direct location of dredgers, and subsequent turbid plume migrations. For instance, dredging may not be able to continuously occur close to the South Shell Island benthos during ebb tides</li> <li>- routinely monitor benthic health (selected indicators) prior to, during and post dredging campaign and the "core" sites</li> <li>- if benthic habitat loss exceeds agreed monitoring and management framework thresholds then dredging operations need be altered</li> <li>- establish and operate TAG to seek independent, project related advice and adaptive management practices.</li> </ul> <p>During associated land-side works:</p> <ul style="list-style-type: none"> <li>- check reclamation areas and discharge to onshore in approved or existing footprint</li> <li>- adopt the requirements for water quality, sedimentation and acid leachate management (Sub-plans 1 and 2)</li> <li>- clearly mark the boundaries of any areas to be cleared</li> <li>- revegetate or, if conditions allow, promote re-colonisation of native vegetation in the areas surrounding the development upon completion of the project</li> <li>- provide protective fencing and/or signage for sensitive habitat areas in proximity to works areas</li> </ul>



Sub-plan 2: Benthic and coastal habitats	
Factor: Estuarine ecological community receptors	
Aspect – Shading / sedimentation / erosion of Flora and sessile Fauna adjacent to the dredging area	
	<ul style="list-style-type: none"> <li>- apply buffer areas between works and intact habitat to minimise disturbance and degradation.</li> </ul> <p>Post dredging:</p> <ul style="list-style-type: none"> <li>- monitoring and reporting requirements are outlined in Section 5.3.4, Table 17, Condition 3.</li> </ul>
Monitoring	<ul style="list-style-type: none"> <li>- Adopt/adapt the requirements of Section 5.3.4, Table 17, and assess performance against monitoring and management framework as set out in Section 5.4.</li> <li>- Monitoring contractor to apply the requirements of Section 5.3.4, Table 17, Condition 3.</li> <li>- Dredging contractor to apply the Final DMP and CEMP and monitor for incidents</li> </ul>
Auditing and Reporting	<ul style="list-style-type: none"> <li>- Data from “Water quality and sedimentation monitoring program” (Table 17; Condition 2) to be evaluated by dredge contractor and TAG during the dredging schedule according to the monitoring and management framework as set per Section 5.4.</li> <li>- Data from benthic habitat survey to be evaluated by the monitoring contractor and DLP project manager.</li> <li>- Depending on findings in relation to Table 17 Conditions 2 and 3, determine course of action (depending on any monitoring and management framework).</li> <li>- Apply reporting and responsibilities described in Section 4.0.</li> <li>- Incidents are to be reported and records retained.</li> <li>- Record any fish kills and immediately report to DLP Project Manager and NT Department of Resources - Fisheries.</li> </ul>
Corrective Action	<ul style="list-style-type: none"> <li>- Review routine and scheduled monitoring data and findings to determine need for corrective action</li> <li>- Implement preventative actions as above.</li> <li>- Refer to Section 5.3</li> <li>- Refer to East Arm Wharf DEIS/SEIS</li> <li>- Use advice from TAG</li> <li>- Investigate incidents and implement preventative actions as required</li> <li>- Undertake remedial action, such as revegetation.</li> </ul>
Responsibility	TAG; with advice to Proponent
Timing	<ul style="list-style-type: none"> <li>- Routine monitoring, assessment and routine reporting (Table 17, Condition 2)</li> <li>- Adapt to more frequent monitoring and reporting, if needed, based on Water Quality and Sedimentation Monitoring program findings and adopted thresholds.</li> </ul>

#### 5.2.2.2 Vessel – marine animal co-occurrence

Species such as dolphins, dugong and turtles all inhabit or occasionally occupy the waters of Darwin Harbour. Dredgers and vessels will be present on the Darwin Harbour for the course of several months and likely to be working at times when such animals are present both night and day.

The CSD's are relatively immobile vessels working close to shore, or in small footprint areas, and as such have a low risk of colliding with fauna as they transit though the harbour.

In addition, the relatively large intake rate of bed sediments by CSD's, are unlikely to entrain swimming animals such as fish and turtles into the cutting mechanisms.

Sub-plan 3: Marine animal co-occurrence	
Factor – Marine vertebrates	
Aspect – Vessel operations and interaction with aquatic megafauna	
Management Objective	- Adopt practices to minimise the risk of harm to listed protected marine species.
Statutory Requirement or Guidance	- <i>EPBC Regulations 2000, Regulation Part 8</i>
Performance Criteria	- Animal observations made, recorded and reported - No harm or injury to native marine vertebrate fauna
Implementation Strategy	<p>During on-water works:</p> <ul style="list-style-type: none"> <li>- Prior to, and during daily dredging operations, visually assess the surrounding area to identify the presence of any aquatic vertebrates in the vicinity of the proposed dredge work activity. Prior to the commencement of any noise-intensive activity, a marine fauna exclusion zone extending 500 m in all seaward directions from the noise source should be established.</li> <li>- If listed marine animal species, including dolphins, turtles or dugongs are identified in the vicinity of the dredger path, the dredger will re-position to avoid interactions.</li> <li>- Before beginning daily activities, one hour prior to commencement of any noise-intensive activity, vessel and/or land based observers should monitor the exclusion zone to check for the presence of listed marine fauna. Activities may commence if no marine fauna have been sighted within the exclusion zone 30 mins prior to the commencement of the activity.</li> <li>- Should animal entrainment occur, alternative equipment or operational procedures will be considered.</li> <li>- Vessel crew will be given training on sea turtle and marine mammal observation.</li> </ul>
Monitoring	<ul style="list-style-type: none"> <li>- Any collisions or whale sightings are to be recorded (as described in Implementation Strategy) and reported immediately and the dredge contractor work is to halt until notification is given to proceed by the DLP Project Officer. The marine monitoring procedure is presented in Figure 10.</li> <li>- Action: Constant watch to be maintained during dredging activities with personnel allocated as spotters.</li> </ul>
Auditing and Reporting	<ul style="list-style-type: none"> <li>- The dredging contractor is to document any incidents involving dredgers (dredging, manoeuvring, transiting or disposal) that result in injury or death to any marine megafauna, such as whales and dolphins, dugongs and/or marine turtles. The time and nature of each incident, and the species involved, if known, must be recorded and reported to the DLP project manager and thence to NRETAS and SEWPaC within 72 hours.</li> <li>- Detailed reports of cetacean sightings are reported using the DSEWPC Cetacean Sightings Application (database) (<a href="http://data.aad.gov.au/aadc/ammc/index.cfm">http://data.aad.gov.au/aadc/ammc/index.cfm</a>)</li> <li>- Routine updates on sightings shall be reported to the Approval agency and TAG.</li> </ul>
Corrective Action	<ul style="list-style-type: none"> <li>- Activities may commence if marine fauna have not been sighted within the exclusion zone 30 minutes prior to the commencement of the activity.</li> <li>- If collision or entrainment occurs, DLP Project Officer must liaise with NRETAS immediately to identify animal rescue options and develop future corrective strategy.</li> <li>- If animals are regularly recorded in close proximity to dredge operations report to the DLP Project Officer to investigate any necessary modification to operations.</li> </ul>
Responsibility	Dredge Contractor – vessel operations DLP Project Manager - reporting to Approval agency
Timing	Monitoring and assessment as above Routine reporting in accordance with the CEMP

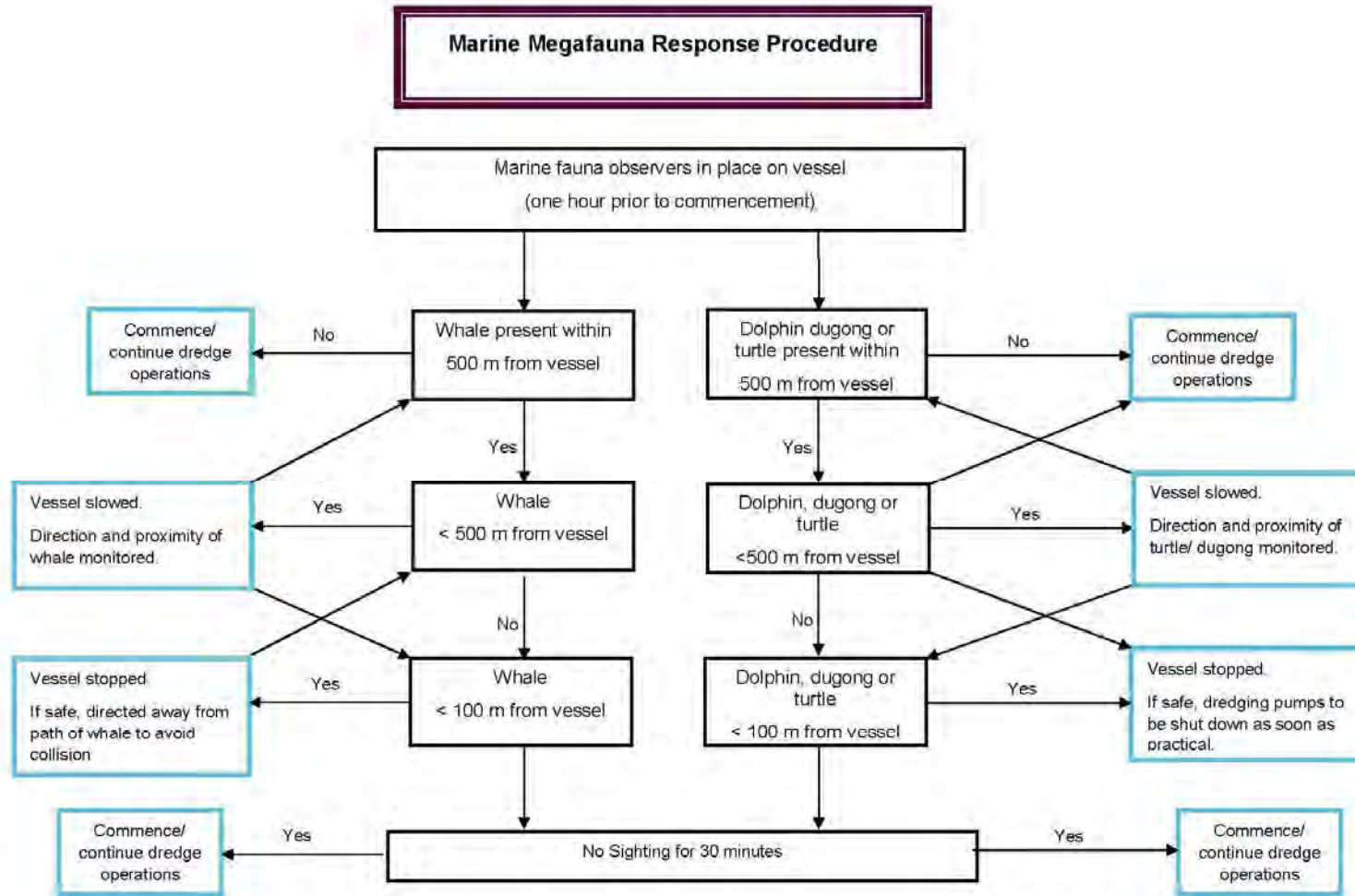


Figure 10 Indicative marine megafauna monitoring procedure (subject to revision based on conditions of approval)

### 5.2.3 Noise

The Port of Darwin is a working industrial area, with loading conveyors, marine vessel noise, transportation vehicles and processing plants dominating the existing noise climate. It is estimated that noise associated with localised wharf activities would fluctuate approximately between  $L_{A90}$  55 to 65 dB throughout daytime hours and a minimum of  $L_{A90}$  45 to 50 dB in the early morning (DIPE, 2004). Monitoring for the Darwin City Waterfront Redevelopment found that idling vessels on the wharves produced a noise level of  $L_{eq}$  55 dB(A) at the foreshore and operation of the crane produced levels of  $L_{eq}$  55 dB(A) approximately 100 m inland from the foreshore (DIPE 2004). Noise generated during dredging increases background noise. Vessel movements cause lower intensity sound; however, these are continuous and generally increase background noise levels. Long-term noise exposure to fish could effectively cause effects such as temporary hearing loss and/or stress leading to physiological effects or immediate effects such as fish moving away from feeding sites (Popper and Hastings 2009).

Sub-plan 4: Noise	
Factor – Human amenity; ecological health	
Aspect – Noise and Hours of Dredger Operation	
Management Objective	<ul style="list-style-type: none"> <li>- To minimise disturbance and injury to marine reptiles, marine mammals and fish, particularly listed marine species.</li> <li>- To ensure minimal or no impacts to public amenity from construction noise generated during dredging and disposal activities.</li> </ul>
Statutory Requirement or Guidance	<ul style="list-style-type: none"> <li>- <i>Workplace Health and Safety Act 2007</i></li> <li>- EPBC Act</li> </ul>
Performance Criteria	<ul style="list-style-type: none"> <li>- No avoidable injury to marine megafauna as a result of noise and vibrations generated during dredging and spoil placement operations.</li> <li>- No marine megafauna mortalities as a result of noise and vibration.</li> <li>- No unreasonable disturbance to public amenity as a result of noise and vibration generated during dredging activities.</li> </ul>
Implementation Strategy	<p>Prior to dredging, develop the following:</p> <ul style="list-style-type: none"> <li>- Noise and Vibration Management Program.</li> <li>- Under advisement of TAG, monitoring and management plan (including thresholds levels and any adaptive management) in relation to Noise and Vibration should be linked to ecological receptor thresholds for marine species.</li> </ul> <p>Prior to dredging:</p> <ul style="list-style-type: none"> <li>- Investigate potential noise impacts on sensitive receptors from dredging.</li> <li>- Review current activities near the Project Area which may contribute to background levels of noise and vibration.</li> <li>- Establish existing background and ambient noise levels for the day, evening and night time periods in order to detect unacceptable levels of change associated with dredging and disposal activities.</li> <li>- Review this DMP and approve the Dredge Contractors EMP and Final DMP.</li> </ul> <p>During dredging and onshore material placement:</p> <ul style="list-style-type: none"> <li>- Ensure that all equipment is maintained in good operating order and is switched off when not required.</li> <li>- Ensure that all equipment on board the dredger will be operated in a safe and efficient manner.</li> <li>- Adopt relevant technology to minimise generation of noise and vibration.</li> <li>- Routinely monitor noise and vibration levels prior to and during dredging campaign.</li> <li>- If marine megafauna injury or mortality occurs then dredging operations must be ceased immediately.</li> <li>- Operate TAG for project related advice and adaptive management practices.</li> </ul>
Monitoring	<ul style="list-style-type: none"> <li>- Dredging contractor to apply the Final DMP and CEMP and monitor for incidents</li> </ul>
Auditing and Reporting	<ul style="list-style-type: none"> <li>- Data transfer to be evaluated daily (when available) by Dredge contractor and TAG during the active dredging schedule.</li> <li>- Apply reporting and responsibilities described in Section 4.0.</li> </ul>

Sub-plan 4: Noise	
Factor – Human amenity; ecological health	
Aspect – Noise and Hours of Dredger Operation	
Corrective Action	<ul style="list-style-type: none"> <li>- Review routine and scheduled monitoring data and findings to determine need for corrective action.</li> <li>- Investigate incidents and implement preventative actions as required.</li> </ul>
Responsibility	TAG
Timing	Routine monitoring, assessment and routine reporting.

#### 5.2.4 Air emissions

The main source of atmospheric emissions will be engines and vehicles, particularly heavy vehicles necessary for the transport of construction materials. Electricity use is another main source of greenhouse gas emissions.

Sub-plan 5: Air Emissions	
Factor – Human amenity and airshed load	
Aspect – Air Emissions for dredger	
Management Objective	<ul style="list-style-type: none"> <li>- To ensure minimal or no impacts to human receptors from air emissions generated during dredging and disposal activities.</li> </ul>
Statutory Requirement or Guidance	<ul style="list-style-type: none"> <li>- <i>Ozone Protection and Synthetic Greenhouse Gas Management Act 1989</i></li> <li>- <i>Ozone Protection and Synthetic Greenhouse Gas Management Regulations 1995</i></li> <li>- <i>Public Health Act 1952</i></li> <li>- <i>Workplace Health and Safety Act 2007</i></li> <li>- <i>Workplace Health and Safety Regulations</i></li> <li>- <i>National Environment Protection Measure for Ambient Air Quality – Monitoring Plan for the Northern Territory (LPE, 2001)</i></li> <li>- <i>National Environment Protection (Ambient Air Quality) Measure 1999</i></li> </ul>
Performance Criteria	No unreasonable disturbance to human receptors as a result of air emissions generated during dredging activities.
Implementation Strategy	<p>Prior to dredging, develop the following:</p> <ul style="list-style-type: none"> <li>- Air Management Program</li> </ul> <p>Prior to dredging:</p> <ul style="list-style-type: none"> <li>- establish baseline (before) existing conditions in order to detect unacceptable levels of change associated with dredging and disposal activities</li> <li>- review this DMP and approve the Dredge Contractors EMP and Final DMP.</li> </ul> <p>During dredging:</p> <ul style="list-style-type: none"> <li>- ensure that engines and equipment on board the dredger are properly maintained and in good working order</li> <li>- ensure emission controls on engines and machinery are in place and working</li> <li>- adopt relevant technology to minimise generation of air emissions</li> <li>- routinely monitor air emission levels prior to and during dredging campaign</li> <li>- operate TAG to seek independent, project related advice and adaptive management practices.</li> </ul>
Monitoring	<ul style="list-style-type: none"> <li>- Dredging contractor to apply the Final DMP and CEMP and monitor for incidents</li> </ul>
Auditing and Reporting	<ul style="list-style-type: none"> <li>- Data transfer to be evaluated daily (when available) by Dredge contractor and DLP project manager during the active dredging schedule</li> <li>- determine course of action depending on TAG advice</li> <li>- apply reporting and responsibilities described in Section 4.0.</li> </ul>
Corrective Action	<ul style="list-style-type: none"> <li>- Review routine and scheduled monitoring data and findings to determine need for corrective action.</li> <li>- Investigate incidents and implement preventative actions as required.</li> </ul>

Sub-plan 5: Air Emissions	
Factor – Human amenity and airshed load	
Aspect – Air Emissions for dredger	
Responsibility	DLP Project Manager TAG
Timing	Routine monitoring, assessment and routine reporting.

### 5.2.5 Maritime safety

The operation of the dredgers will be managed to minimise risk of incursion on port shipping movements, vessel collision or foundering thereby managing the risk of impact to the marine environment. UXO are known to be within the harbour region, however have been cleared as described in the DEIS.

Sub-plan 6: Maritime Safety	
Factor – Human safety; waterway use and ecological health	
Aspect – Vessel Navigation and Maritime Safety	
Management Objective	<ul style="list-style-type: none"> <li>- Avoid vessel collisions or unsafe vessel operations.</li> <li>- No impedance to planned port operations and shipping movements.</li> <li>- Manage UXO risk</li> </ul>
Statutory Requirement or Guidance	<ul style="list-style-type: none"> <li>- <i>Darwin Port Corporation Act 1983</i></li> <li>- <i>Workplace Health and Safety Act 2007</i></li> <li>- Policy on the <i>Protection of Darwin Harbour and its Coastline</i> (TOPROC, 1999)</li> <li>- EPBC Act</li> </ul>
Performance Criteria	<ul style="list-style-type: none"> <li>- No time lost to human injury or vessel access to port.</li> <li>- No incidents or spills to marine environment.</li> <li>- UXO's identified and cleared (NB: refer to other sources of that harbour has been cleared of UXOs).</li> </ul>
Implementation Strategy	<ul style="list-style-type: none"> <li>- The DLP Maritime Branch will make available suitably qualified masters at all times within port limits for vessel over specified gross register tonnage.</li> <li>- Dredging operations will be conducted, so as to minimise the effect on port operations and port users and to ensure the safe work execution.</li> <li>- Dredger operations will be carefully coordinated with the DPC.</li> <li>- Adopt existing DPC procedures, utilising long-term and day-to-day planning, and implementing a cyclone management plan.</li> <li>- In consultation with DPC, the dredging contractor will advise the expected dredging locations, shipping routes, dredge log and schedule and anchoring or berthing locations.</li> <li>- In consultation with DPC and Department of Defence, review the information on the location of UXO and agree on clearance protocol.</li> <li>- DPC will issue a Notice to Mariners to advise other port users of the dredging vessels movements and adjust as conditions change</li> <li>- During shipping movements, the DPC will advise incoming / outgoing vessels of the location and operations of the dredgers.</li> <li>- The dredging contractor will develop and implement a Cyclone Management Plan which will be based upon DPC Cyclone Procedures. This plan will address safe locations for anchorage either within or beyond the Port limits.</li> <li>- Existing designated anchoring locations will be used where possible.</li> <li>- The anchors of any CSD will only be set within the dredging area limits.</li> </ul>
Monitoring	<ul style="list-style-type: none"> <li>- DLP to inspect DC operations</li> <li>- Notice to Mariners, records of DPC communications including pilotage certificates</li> <li>- Routine (weekly) operations reports by DC to DLP</li> </ul>
Auditing and Reporting	<ul style="list-style-type: none"> <li>- Vessel Logs kept by DC</li> <li>- Audit by DPC and/or AMSA representatives</li> <li>- Routine monthly updates shall be reported to the Approval agency and TAG.</li> </ul>

Sub-plan 6: Maritime Safety	
Factor – Human safety; waterway use and ecological health	
Aspect – Vessel Navigation and Maritime Safety	
Corrective Action	Refer to Dredging contractors CEMP
Responsibility	Dredge Contractor – vessel operations DLP Project Manager - reporting to Approval agency
Timing	Monitoring and assessment as above Routine reporting in accordance with the CEMP

### 5.2.6 Risk management and contingency planning

Aspects of operation require dedicated systems planning, plant and equipment maintenance and response training to avoid or limit the risk of environmental harm.

#### 5.2.6.1 Petroleum, Oil and Lubricants management

The handling, transport, storage and use of Petroleum, Oil and Lubricants (POL) will be managed to minimise the risk of accidental spillage and the subsequent impacts on the marine environment. The contingency actions to be taken in response to a leak or spill will be outlined in the Dredge Contractors Oil Spill Contingency Plan (OSCP) and Ship Board Oil Pollution Emergency Plans (SOPEPs). Both of the plans will be required to meet the requirements of the port authority.

Sub-plan 7: POL Management	
Factor – Human safety, health; waterway use and amenity; ecological health	
Aspect – Emergency Preparedness including Oil Spill Response	
Management Objective	<ul style="list-style-type: none"> <li>- Prevent accidental release, leaks or spills of POL and chemicals to marine waters or the natural environment.</li> <li>- Rapid and complete response to any accidental release, leaks or spills of POL and chemicals.</li> </ul>
Statutory Requirement or Guidance	<ul style="list-style-type: none"> <li>- Accordance with the requirements of MARPOL 73/78</li> <li>- <i>Marine Pollution Act (NT)</i></li> <li>- <i>Waste Management and Pollution Control Act (NT)</i></li> <li>- <i>Public Health Act 1952</i></li> <li>- <i>Workplace Health and Safety Act 2007</i></li> <li>- <i>Workplace Health and Safety Regulations</i></li> <li>- <i>Northern Territory Oil Spill Contingency Plan (1998)</i></li> <li>- <i>NT Marine Pollution Contingency Plan (which supports the National Plan to Combat Pollution of the sea by Oil and other Noxious and Hazardous Substances).</i></li> <li>- <i>Environmental Protection (National Pollution Inventory) Objective (NT)</i></li> <li>- <i>Marine Pollution Act 1999</i></li> <li>- <i>Marine Pollution Regulations 2003</i></li> <li>- <i>Environmental Offences and Penalties Act 1996)</i></li> </ul>
Performance Criteria	<ul style="list-style-type: none"> <li>- preparation, review and readiness of Contractor's plans, OSCP and equipment</li> <li>- evidence of crew training and preparedness</li> <li>- Hazmat registers and records created and retained</li> </ul>
Implementation Strategy	<p>Storage and handling:</p> <ul style="list-style-type: none"> <li>- oils, greases and chemicals will be securely stored onboard in minimum volumes on dredge vessels in marked containers.</li> <li>- hydrocarbons stored above deck will be bunded with 110% capacity of the total POL volume being stored.</li> </ul> <p>Vessel operations:</p> <ul style="list-style-type: none"> <li>- high quality, well maintained hydraulic system components</li> <li>- draining and refilling of the hydraulic oil system during maintenance will be done in accordance with the vessel SOPEP procedures</li> <li>- no bilge water will be discharged into the water at any time. This includes any bilge water treated via oily water separators</li> <li>- on arrival at site, all vessels will have bilge water outlets tagged and closed</li> </ul>

Sub-plan 7: POL Management	
Factor – Human safety, health; waterway use and amenity; ecological health	
Aspect – Emergency Preparedness including Oil Spill Response	
	<ul style="list-style-type: none"> <li>- all bilge water will either be contained onboard or discharged onshore and disposed of via a licensed waste management contractor</li> <li>- inventories of hydrocarbon and chemicals on and off vessels to ensure no unaccounted for losses (spills)</li> <li>- contaminated drainage waters will be contained (eg. diverted to a sump) or will be cleaned to prevent overboard discharge</li> <li>- communication with DPC in relation to operational areas and known UXO hazards</li> </ul> <p>Refuelling:</p> <ul style="list-style-type: none"> <li>- procedure developed, documented and implemented by the DC</li> <li>- within Port limits will be conducted in accordance with all DPC requirements</li> <li>- undertaken in port at suitable facilities</li> <li>- conducted by experienced personnel, using well maintained equipment</li> <li>- appropriate couplings will be used where practical</li> <li>- takes place during daytime and not to be undertaken during adverse weather conditions (that is, high swell, bad visibility, strong winds).</li> </ul> <p>Spill response:</p> <ul style="list-style-type: none"> <li>- any fuel and oil spills within Port limits will be managed in accordance with DPC's oil spill arrangements and procedures</li> <li>- dredge vessel master maintains a SOPEP for each dredge vessel. This plan will contain procedures and identify all resources available in the event of a spill</li> <li>- kits will be provided and located in close proximity to storage and operational areas</li> <li>- disposal of all including minor spill waste via a licensed contractor.</li> </ul> <p>Information and training:</p> <ul style="list-style-type: none"> <li>- Material Safety Data Sheets will be available for all POLs and chemicals</li> <li>- work instructions will be developed by the dredging contractor that will outline practical procedures for crew members</li> <li>- instructions will address safety, spill avoidance and spill response</li> <li>- training and drills will be undertaken.</li> </ul> <p>Spill response coordination:</p> <ul style="list-style-type: none"> <li>- oil spills to marine waters are regulated under the by the Marine Safety Branch NT Department of Lands and Planning</li> <li>- Northern Territory OSCP supports the National Marine Oil Spill Contingency Plan developed by AMSA. AMSA are responsible for coordinating, investigating and cleaning up marine oil spills of national significance.</li> </ul>
Monitoring	<ul style="list-style-type: none"> <li>- Equipment, including hoses and fuel tanks, will be checked prior to and during refuelling activities. These checks will be recorded in the vessel log books and will be made available as requested.</li> <li>- Regular inspections will be undertaken to ensure that the bilge outlets have not been opened.</li> <li>- Storage and operational areas will be checked as secure on a daily basis</li> <li>- Record (by photograph &amp; document), sample and investigate any discoloured soil or oil sheens detected during routine visual inspections of marine waters nearest to the construction area whether sourced from land or seas.</li> </ul>
Auditing and Reporting	<ul style="list-style-type: none"> <li>- Any spill will be reported using the incident reporting system.</li> <li>- On deck spills greater than 1 litre will be reported to the DLP.</li> <li>- Bilge disposal receipts will be kept on-board as evidence of compliance.</li> <li>- DLP and DPC inspections with 24 hours notice.</li> <li>- Routine performance reports shall be reported by DC to DLP and thence, as required, to the Approval agency and TAG</li> </ul>
Corrective Action	<ul style="list-style-type: none"> <li>- Apply SOPEP and OSCP for any spills or emergency situations</li> </ul>



Sub-plan 7: POL Management	
Factor – Human safety, health; waterway use and amenity; ecological health	
Aspect – Emergency Preparedness including Oil Spill Response	
Responsibility	Dredge Contractor – vessel operations DLP Maritime Safety Branch Port Authority / AMSA DLP Project Manager - reporting to Approval agency
Timing	Monitoring and assessment as above Routine reporting in accordance with the CEMP

### 5.2.6.2 Introduced marine species

The proximity of Darwin Harbour to Asia makes marine pest incursions a particular concern. Marine pests have previously been found in the Port of Darwin.

Sub-plan 8: Introduced marine species	
Factor – Human use and amenity; ecological health	
Aspect – Marine Quarantine Management	
Management Objective	<ul style="list-style-type: none"> <li>- Minimise the probability of additional weeds, pests and diseases entering and/or becoming established in the harbour.</li> <li>- Detect and eradicate any introduced species that occurred by the project vessels or equipment.</li> </ul>
Statutory Requirement or Guidance	<ul style="list-style-type: none"> <li>- <i>Quarantine Act 1908 (C'wealth)</i>; Quarantine Regulations 2000.</li> <li>- <i>Australian Ballast Water Management Requirements, AQIS 2001</i></li> </ul>
Performance Criteria	<ul style="list-style-type: none"> <li>- Adoption of screening mechanisms for DC vessels and equipment</li> <li>- Identification of IMS that occur.</li> <li>- Avoidance of incursion and spread of IMS due to dredge activities.</li> </ul>
Implementation Strategy	<p>Within three days after entry of the dredging contractors vessels and in-water equipment and/or other vessels associated with dredging into the Port of Darwin, the contractor will:</p> <ol style="list-style-type: none"> <li>1) for vessels originating from ports outside of NT waters, arrange for an inspection (in-water or dry-dock) and clearance by appropriately qualified marine scientists; or</li> <li>2) for vessels originating from ports within NT waters, provide evidence of: <ul style="list-style-type: none"> <li>• the vessel being fully cleaned of fouling organisms and sediments immediately prior to departure for the Port of Darwin; or</li> <li>• inspection of the vessel at the point of departure for the Port of Darwin immediately prior to departure; or</li> <li>• a risk assessment based on the history of the vessel and in-water equipment, its characteristics and use during the implementation of the proposal.</li> </ul> </li> </ol> <p>To achieve clearance (of containing marine species of concern) all vessels and equipment will undergo at least one of the three clearance options being inspection, cleaning or risk assessment prior to mobilisation.</p> <p>Ballast water management for vessels from international waters according to IMO and AQIS requirements.</p>
Monitoring	<ul style="list-style-type: none"> <li>- Pre-entry vessel and in-water equipment monitoring and reporting by DC</li> <li>- Routine DPC infrastructure routine monitoring</li> <li>- The Introduced Marine Species Monitoring Procedure in accordance with AQIS requirements</li> </ul>
Auditing and Reporting	Vessel risk assessment reporting to government agencies

Sub-plan 8: Introduced marine species	
Factor – Human use and amenity; ecological health	
Aspect – Marine Quarantine Management	
Corrective Action	IMS management upon positive identification: <ul style="list-style-type: none"> <li>- Appropriate cleaning at local haul out facility or dry dock</li> <li>- Mobilisation out of Australian waters</li> <li>- Waste collection and destruction and quarantine waste management</li> </ul> Reporting, inspection and assessment by State and Commonwealth agencies of DC vessels and equipment.  Quarantine and eradication upon future detection by DPC.
Responsibility	DC - for clearance of vessels and equipment AQIS and NRETAS – for response to positive identification DPC – for future detections
Timing	Prior to DC entry; ongoing

## 5.3 Dredge performance requirements and impact monitoring criteria

### 5.3.1 Dredging assessment framework

The following is presented as an approach to the dredge activity in order to:

- Manage short term dredge operations through monitoring and adaptive management.
- Assess associated marine ecological health.

The framework presented establishes an approach for generating and managing predictions of *the likely range* of environmental impacts which, in turn, provide the basis for facilitating approval conditions, environmental monitoring and dredge management strategies.

The content of the framework is derived from *Environmental Assessment Guideline for Marine Dredging Proposals* (WAEPA 2011), known as EAG7. This guideline typically represents the most current approach and policy towards managing near-shore dredging impacts on sedentary biota in Australia's tropical north-west.

### 5.3.2 Context for identifying impacts

Direct impacts occur predominantly within and immediately adjacent infrastructure footprints such as excavated seabeds. Direct impacts usually involve irreversible loss of benthos and communities, including soft corals and sponges (*irreversible* is defined as 'lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less' (WAEPA, 2009). The corollary is that reversible impacts prevail for less than five years).

Indirect impacts arise from effects of dredge-generated sediments and generally extend over areas surrounding infrastructure dredging areas when sediment deposition and/or elevated turbidity exceed the natural tolerance levels of benthic organisms. These indirect effects of dredge-generated sediments may restrict or inhibit key ecological processes and cause impacts that range in severity and duration from irreversible to readily-reversible.

If required, the proponent will seek authority for the direct permanent loss of benthos (typically over a limited footprint area) comprising what is identified by EAG7 as the Zone of High Impact.

The spatial relationship between the Zone of High Impact, Zone of Moderate Impact and Zone of Influence as established by EAG7 (WAEPA, 2011) is described in Table 16 and Figure 11 as follows.

**Table 16 Framework methodology for Impact Zonation Scheme for seabed areas (based on benthic habitat and occurrence of turbidity)**

Zone	Direct Effects	Indirect Effects	Description
Zone of High Impact	<p>Area of seabed removal at the EAW by dredging plus an area adjacent to the dredge source where there is elevated turbidity and sedimentation.</p> <p>The Zone of High Impact extent referred to in the DEIS, SEIS or through subsequent analysis (prior to dredging)</p>	<p>Area affected by sedimentation Concentrated, light attenuating turbidity levels.</p> <p>Refer to East Arm Wharf DEIS and SEIS for details of effect areas.</p>	<p>The <b>Zone of High Impact</b> is the predicted (near) permanent direct and indirect loss of seabed and associated habitat in the near field.</p> <p>This impact is sought to be authorised by Ministerial approval, development consent &amp;/or dredging licence.</p>
Zone of Moderate Impact	N/A	<p>Moderate detectable reduction of marine benthos, non permanent</p> <p>Frequent turbid plumes with occasional light attenuation and/or highly visible occurrences. Temporary reduction in benthos.</p>	<p>The <b>Zone of Moderate Impact</b> is the predicted "mid field" zone with temporary (recoverable) indirect effects. Such effects can be minimised by mitigations and adaptive management such as those required by Ministerial approval, consent &amp;/or dredging licence and the contents of this DMP (and subsequent versions).</p>
Zone of Influence	N/A	<p>Detectable changes in environmental quality associated with dredge plumes and anticipated during dredging, but not result in a detectable impact on benthos.</p> <p>Occasional visible turbid plumes transit the zone.</p>	<p>The <b>Zone of Influence</b> is the predicted, far-field zone with no direct and likely small very temporary indirect effects. Such effects must be minimised by mitigations and adaptive management such as those required by Ministerial approval, consent &amp;/or dredging licence and the contents of this DMP (and subsequent versions).</p>

Notes:

- The net change in marine benthic habitat loss is determined by subtracting the baseline extent of marine benthic habitat from the extent of marine benthic habitat measured on a sampling occasion, moderated for temporal variability at reference sites.

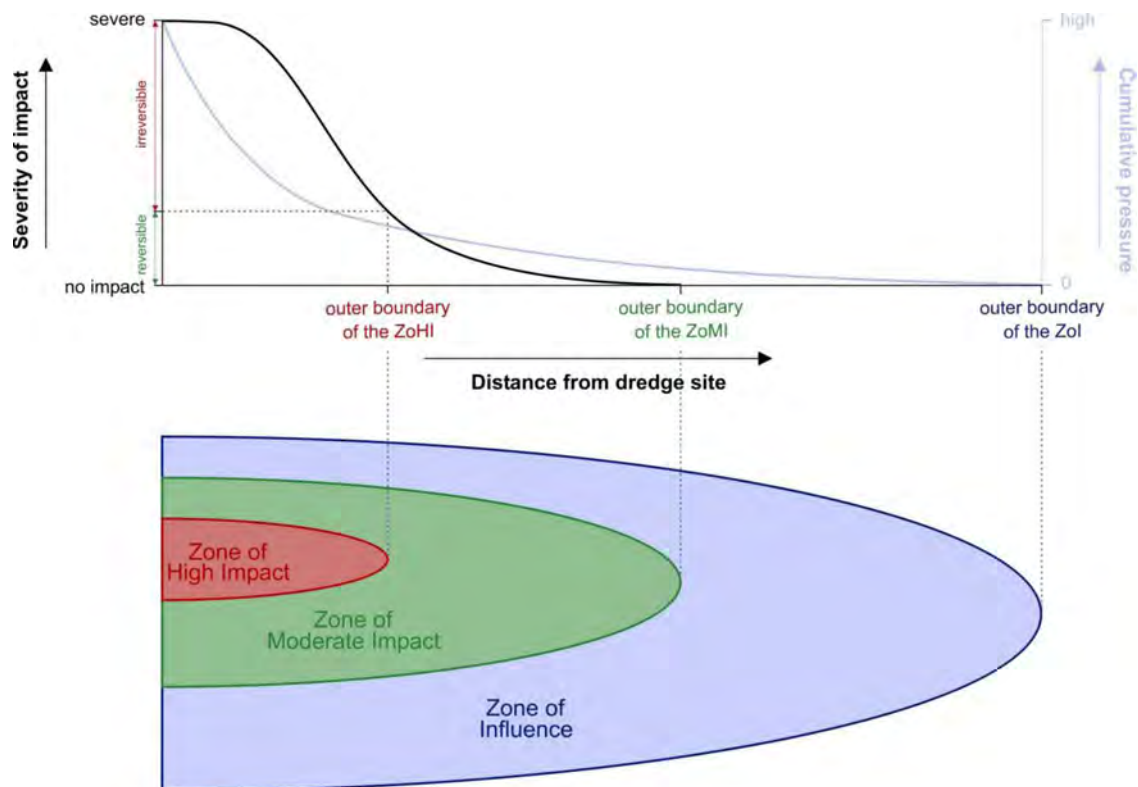


Figure 11 Schematic drawing showing ecological impact associated with Dredging (source; WA EPA, 2011)

Figure 11 provides a schematic drawing showing the change in environmental quality associated with dredging (grey line) and level of resultant impact (black line) extending away from the dredging site to the outer extremity of the Zone of Influence. The location of the outer boundaries of the Zone of High Impact (ZoHI), Zone of Moderate Impact (ZoMI) and Zone of Influence (ZoI) are shown relative to these predicted changes in environmental quality and impacts on biota (source: WAEPA 2011).

Ecological impact associated with dredging generally attenuates with distance from the dredge as depicted above. For the Zone of High Impact, this means that no irreversible impacts would be predicted to occur outside of this zone - not all impacts on all benthos within this zone are predicted to be irreversible.

### 5.3.3 Further information needs

To create an informed, appropriate spatially-based dredge assessment framework, it is important to establish:

- the range of likely impacts on different inhabitant benthos immediately outside the dredged seabed area
- up-to-date data and mapping of sensitive benthos types in that area and the region
- predict the extent of sediment “pressure” fields.

Such information needs to be assembled and interpreted sufficiently prior to dredging to ensure:

- Data on current and relevant field conditions is being utilised.
- Effects from other independent activities and occurrences are being considered (for instance, cyclones, floods and/or planned Inpex development works).
- Proposed applicable dredge technologies (methods and cycles) can be analysed and adapted.

These antecedent conditions necessarily require that the DMP is revised prior to the commencement of the dredge program.

The likely “best case” predictions from assessment of those issues listed above will be used in setting appropriate ‘management’ objectives (i.e. targets). WA EPA (2011) identifies that this approach:

“.....allows a distinction to be made between monitoring requirements for informing management of dredge operations and monitoring requirements for demonstrating compliance. This should allow a more efficient allocation of resources between the various monitoring and management tasks. In simple terms, proponents can expect that the frequency and extent of compliance monitoring during the dredging programs will be inversely proportional to the overall confidence in the predictions of environmental impact, the environmental significance of the impacts and the effectiveness and responsiveness of the proposed environmental monitoring and management strategies.”

#### 5.3.4 Dredging commitments

At this stage, in the absence of the necessary information to complete the additional analysis required to address the information needs (refer to section 5.3.3), developing the proposed monitoring to inform adaptive management and determine if management targets are being achieved is a future task for the proponent and their dredger. They will also seek support and contributions from regulators and an independent Technical Advisory Group (TAG).

Furthermore, in support of this approach, EAG7 (WA EPA 2011) recommends that:

*“when developing proposed environmental monitoring programs, proponents should consider monitoring required for adaptive management purposes and that necessary to demonstrate compliance and any efficiencies that could be realised. The overarching objective of the assessment framework, outlined in the preceding sections, is to enhance the linkage between the environmental impact predictions made for EIA and the data generated through monitoring and management programs implemented post-approval. This should generate validation data which will further increase confidence over the prediction – management continuum.”*

The commitments to create and implement a suitable dredge framework can be stipulated as follows based on:

- An area of approved impact within a Zone of High Impact (refer Table 17, Section 1 – *Direct and indirect seabed disturbance*)
- A proposed dredge performance assessment framework utilising:
  - Suitable *water quality and sedimentation indicators, monitoring, assessment and reporting* (refer Table 17, Section 2)
  - Suitable *benthic habitat indicators, monitoring, assessment and reporting* (refer Table 17, Section 3)
- Monitoring for Table 17 Sections 2 and 3, to provide data for decisions on adaptive dredge management, would be designed around the application of indicators that signify progressively greater risk of unacceptable impact (WA EPA, 2011) (as further described in Section 5.4).

**Table 17 Elements of dredging framework with a subordinate assessment program**

<b>1 - Direct and Indirect Seabed disturbance</b>	
1-1	The proponent shall not cause permanent loss of seabed supporting actual or potential benthic habitat in excess of the Zone of High Impact areas (described in Table 16) and identified based on EAW DEIS and SEIS findings and any subsequent predictions.
1-2	Beyond the Zone of High Impact around the direct dredge areas in the Zone of Moderate Impact, if benthic ecology or water quality indicator thresholds are exceeded (based on an unacceptable extent, intensity and duration derived from Section 5.4), the proponent shall notify the approval agency, provide proposed actions being undertaken to reduce turbidity and/or sediment-generating activities which are affecting water quality and provide an assessment of the anticipated effect on the marine environment once the new management action(s) is implemented.
1-3	The proponent, under advisement from TAG, shall review dredging, excavation and disposal activities that generate conditions that are in excess of thresholds (derived from Section 5.4) within the Zones of Moderate Impact and/or Zone of Influence.
<b>2 – Water quality indicators, monitoring, assessment and reporting: assessment of dredging effects</b>	
2-1	Dredge operations management and corrective actions shall be in accordance with the Dredger’s CEMP and the Final DMP.

2-2	Zones of High Impact, Zone of Moderate Impact and Zone of Influence and the areas to be stipulated in <b>Table 16</b> shall be determined and specified by maps and coordinates, accordingly.
2-3	<p>Prior to commencement of any site development works, the proponent shall prepare and submit a "Water Quality and Sedimentation Monitoring Program" to the approval agencies. The program shall address the following:</p> <ol style="list-style-type: none"> <li>1) statistical design for comparative analysis describing spatial and temporal trends in ambient water quality and sedimentation rates near the dredge source</li> <li>2) identify key parameters for monitoring including turbidity and sedimentation rates but also, depending on sediment content, potential contaminants and aquatic health indicators</li> <li>3) propose rapid and reliable methods for data collection, acquisition and interpretation to enable adaptive management for future dredge activity</li> <li>4) establishment of monitoring sites within Zone of High Impact and Zone of Moderate Impact areas</li> <li>5) treatment of monitoring data to establish dredge effects.</li> </ol>
2-4	<p>The proponent, with the agreement of the approval agencies, shall institute a <b>Technical Advisory Group</b> to act in accordance with its role described in the DMP including:</p> <ol style="list-style-type: none"> <li>1) verify the planned activities for the "Benthic Habitat Survey" and "Water and Sediment Quality Monitoring Program".</li> <li>2) consider the findings of monitoring and assist in establishing risk based pressure-response pathways (refer Section 5.4)</li> <li>3) advice on the Final DMP monitoring and management framework, as required</li> <li>4) develop and utilise a risk based monitoring and management framework (derived from Section 5.4).</li> </ol>
<p><b>3 – Benthic habitat indicators, monitoring, assessment and reporting: assessment of dredging effects</b></p>	
3-1	<p>Prior to commencement of site works, the proponent shall prepare a <i>Benthic Habitat Survey</i> to establish ground conditions and for the information of the approval authorities.</p> <p>The survey shall address the following:</p> <ol style="list-style-type: none"> <li>1. establish thresholds for ecological receptor sensitivities (linked to select "lead" impact indicators for water quality)</li> <li>2. monitoring design to enable comparative analysis identifying target benthic parameters, duration for monitoring and the relationship to short term water quality monitoring</li> <li>3. methods for surveys following commencement and completion of dredging to identify effects outside the Zone of High Impact</li> <li>4. location and establishment of survey sites in Zones of Moderate Impact and Zone of Influence</li> <li>5. timing and frequency of monitoring and treatment of survey data</li> <li>6. identifying unacceptable impacts.</li> </ol> <p>Note: "Benthic habitats" contain live hard and soft coral communities, sponge and other filter feeding and marine plant communities.</p>
3-2	<p>If other recent and relevant data do not exist, the proponent shall commence and conduct monitoring described in the <i>Benthic Habitat Survey</i> and provide an initial report to the approval agencies:</p> <ol style="list-style-type: none"> <li>(1) on the findings of the pre-dredging conditions, and</li> <li>(2) a plan for repeat monitoring in areas of predicted dredging effects.</li> </ol>
3-3	<p>Following commencement of any dredging works, the proponent shall apply the Benthic Habitat Survey and provide the results to the approval agencies following commencement of any dredging works which shall:</p> <ol style="list-style-type: none"> <li>1. show the locations and spatial extent of the different marine benthic habitat types and parameters such as percentage cover of each dominant taxa.</li> <li>2. record the abundance and health of benthic taxa observed within the indicator communities.</li> <li>3. compare results to baseline (pre-development) results.</li> <li>4. develop and utilise a risk based monitoring and management framework (derived from Section 5.4).</li> </ol>
3-4	<p>Following completion of the dredging program, the proponent shall, if any significant ecological effect is detected outside of the approved Zone of High Impact, conduct field survey within 2 years and submit the findings of that survey to the approval agencies. Any initial need or further continuation of this monitoring (after dredging is completed) will be based on whether compliance with criteria has been made.</p>

## 5.4 Water quality and benthos monitoring and management framework

Monitoring activities will be undertaken throughout the dredging in relation to the identified performance objectives and target. Benthos at South Shell Island have been identified as potential target receptors and will need to be assessed in relation their situation in an "Impact Zonation Scheme" (Figure 11) and the degree of resilience of biota to exposure to sedimentation and elevated turbidity.

EAG7 (WA EPA, 2011) suggests that the framework around which to design environmental monitoring programs should be risk-based using understanding of pressure-response pathways for key biota in the benthic communities to be monitored. In summary, this presents a framework where:

- Exceedence of a primary indicator (e.g. specified turbidity level or sedimentation rate criteria) will require a Tier 1 management action (e.g. investigating the cause of the exceedence and increasing monitoring to include biota).
- Exceedence of a secondary indicator (e.g. a measure of biotic stress) will require a Tier 2 adaptive management to reduce dredge-related pressure.
- Exceedence of a tertiary indicator (e.g. a measure that is an immediate precursor to unacceptable impact) will require strong management action to alleviate dredge-related pressure.

Such a framework will need to take account of other regional activities, under way at the time or just before, that may be major sources of sediment, such as the Inpex development.

### 5.4.1 Water quality

Thresholds for dredge operations will be developed to enable compliance assessment and adaptive dredge management. Note the proposed turbidity levels and/or sedimentation rates must be verified according to tabled predictions and be able to be adapted or modified by the TAG based on emergent data.

Other key considerations will be:

- use of water quality "early indicators" of light attenuation (turbidity or PAR) and/or sedimentation effects. These pressures necessarily must be created as a precedent to any undue effects on ecological health, so serve well as early indicators of potential stress
- baseline water quality prior to the commencement of dredging activities including turbidity, salinity, dissolved oxygen and temperature, potentially by in situ data loggers
- data analysed for intensity (range of NTU values), duration (range of hours), and frequency (the number of times that NTUs fall within each range for each duration)
- water quality thresholds as a spatio-temporal matrix of:
  - conservative turbidity levels and sedimentation rates
  - periods of exposure of benthos to those "pressure" levels
  - the sensitivity of adopted benthic receptors to those "pressure" levels for ecologically meaningful periods of time
- criteria/thresholds should be reviewed by the TAG once the actual turbidity and sedimentation rates are known by virtue of precedent routine monitoring
- the initiation and implementation of management responses will be based on monitoring and other event based records.

### 5.4.2 Benthos

The benthic baseline monitoring programme will be used to develop monitoring and thresholds that can be used to guide management responses of the TAG during the dredging program.

Other key considerations will be:

- use of indicator benthic taxa (eg. sponges, hard corals) located within Zone of Moderate Impact, Zone of Influence (and reference locations)
- baseline and dredge program assessments of the benthic communities in relation to the "Impact Zonation Scheme" (refer to Figure 11)

- inter-relate to water quality thresholds established as a spatio-temporal matrix of:
  - conservative turbidity levels and sedimentation rates
  - periods of exposure of benthos to those “pressure” levels
  - the sensitivity of adopted benthic receptors to those “pressure” levels for ecologically meaningful periods of time
- criteria/thresholds should be reviewed by the TAG once the actual results known by virtue of reactive campaign monitoring
- the initiation and implementation of management responses based on monitoring results.



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## Appendix A

# Ecological values and marine habitat

## Appendix A Ecological values and marine habitat

## Benthic habitats

Smit (2003) describes the composition of harbour floor habitats. Intertidal soft sediments consist of muddy to sandy mud substrates. Species diversity within the substrate is low but it does hold large numbers of an individual species. The habitat is dominated by polychaetes (marine worms) such as capitellids and nereids. Intertidal soft sediments are important feeding areas for shorebirds at low tide and fish during an upcoming high tide.

Smit (2003) describes subtidal soft sediments as consisting of varying degrees of mud and sand fractions grading into coarser sediments in the channel. The habitat is dominated by marine worms, crustaceans, echinoderms and sponges. Subtidal soft sediments play an important role in the food chain of the harbour as they provide a feeding ground for pelagic sharks and fish species migrating from mangroves and reefs.

Channel sediments consist of mainly coarse sand and gravel with the finer sediments becoming detached by current from the substrate. Smit (2003) states, that the role of these substrates in the harbour ecosystem is not known.

Corals and shallow reef communities are an important part of the Darwin Harbour ecosystem. Corals are scattered throughout the harbour although they tend to be restricted to small patches on shallow water rocky reefs. Coral distribution is limited by the availability of suitable substratum and low light penetration due to high natural turbidity. High turbidity in the harbour limits most benthic plant and coral growth to approximately seven metres below mean sea level. Corals and associated flora and fauna are only found in abundance in a relatively narrow zone of three to four metres below the low spring tide mark. Below these depth organisms such as sponges and gorgonians are dominant as they don't require light for photosynthesis (Acer Vaughan Consulting Engineers 1993). It is likely that the coral species that occur in Darwin Harbour are in suboptimal habitats and are naturally stressed (URS 2002).

Coral reefs identified as "impact sites" during dredging activities in East Arm are around South Shell Island, and at Wickham Point (Hanley and Caswell 1997b) including Weed Reef. These coral reefs showed a decrease in health, including bleaching, during previous dredging activities; however these appeared to recover completely within a week of the cessation of the dredging activities. It should be noted that there were very low tides associated with dredging activity.

Hanley and Caswell (1997b) explains that corals are known to be extremely sensitive to and adversely affected by increases in turbidity, suspended solids, and sedimentation rates, as well as increases in temperature and nutrient levels.

A benthic survey using video sampling and diver surveys has been completed to allow for the reporting on the distribution and abundance of such species and species assemblages that may constitute habitat of conservation significance. The biodiversity values of the sites will also be discussed in comparison to reference sites. At least two surveys will be undertaken and linked to seasonal changes in fauna activity.

### **Macroalgae (sea weeds)**

There is very little information available for marine algae in Darwin Harbour. The limited data available includes a species list (Wynne and Luong-Van 1997) and a description of algal assemblages and coral assemblages at Nightcliff reef (Fern 1996).

### **Seagrass**

Although seagrass beds are known to occur near Casuarina Beach, Talc Head and Gunn Point, there is little knowledge of their composition or extent.

### **Mangroves**

Dames and Moore (1994) explain that mangroves occur along most of the Northern Territory Coastline, particularly in estuaries and bays, growing in relatively sheltered areas, where their presence enhances sedimentation processes. The most extensive mangrove forests in the Northern Territory occur in the Darwin-Bynoe Harbour area and in the Arnhem Bay area.

Mangrove communities consist of a variety of growth forms that include trees, palm, shrubs, vines, epiphytes, samphires, grasses and ferns. They form valuable ecosystems along sheltered tropical and sub-tropical coastal environments that are periodically inundated by tidal waters. They perform a vital role in estuarine and coastal ecosystems, and protect the coastline from erosion and storm surge. They form effective, self-repairing barriers against severe storm and tropical cyclones. Their extensive root systems trap and stabilise sediments, making

them important sediment sinks by reducing siltation of waterways and estuaries, improving water quality and protecting reefs from upstream sediment loads (NRETA 2005).

The area of mangroves in Darwin Harbour is 27,350 hectares (ha), which constitutes approximately 5% of the total mangrove area of the Northern Territory, and are amongst the most diverse in Australia. The most common species are *Rhizophora stylosa*, *Ceriops tagal*, *Sonneratia albam*, *Bruguiera exaristata*, *Avicennia marina* and *Camptostemon schultzei* (NRETA 2005).

## Marine invertebrates

A summary of marine invertebrate communities was provided by Smit (2003) during the Proceedings of Darwin Harbour public presentations. Smit (2003) noted that despite the extensive data sets that exist for marine invertebrates few of these have been derived from systematic surveys. Certain habitats are not well represented and the number of listed invertebrate species probably represents only a fraction of what actually exists within the harbour.

### Plankton

Limited information exists on the species composition of Phytoplankton in Darwin Harbour. Padovan (1997) collected three samples from Darwin Harbour and found that cell densities were dominated by epifluorescent picoplankton and diatoms of the genus *Chaetoceros* and *Rhizosolenia*. Bolch (1999) examined dinoflagellate cysts in Darwin Harbour sediments and found that assemblages were dominated by Peridinioid species, particularly of the genus *Scrippsiella*.

More information exists on phytoplankton abundance through the measurement of chlorophyll-a. Studies have shown maximum concentrations to be present in harbour inlets while concentrations in the main harbour are uniformly low throughout the year (Padovan 1997). Chlorophyll-a concentrations in Darwin Harbour are generally similar to those found in other north Australian waters (Padovan 2003).

Zooplankton biomass in Darwin Harbour is generally high. Studies in Middle Arm (Caldwell Connell Engineers 1983) found that there is significant exchange between the harbour and the Arafura Sea, with zooplankton communities of the larger channels being characteristic of open ocean waters. Duggan *et al.* (2008) studied zooplankton composition within the harbour over a two year period and found significant seasonal as well as yearly differences. A total of 35 species were found, 32 of which were copepods. The harbour was found to have higher species richness than nearby rivers, and zooplankton biomass was found to be highest during the monsoon season.

### Foraminifera

Michie (1987) studied the distribution of foraminifera in the Port of Darwin. The number of species listed was 86 comprising of three distinct biotopes. A collarine biotope was identified comprising of 52 different species and found at small reef areas of Nightcliff, East Point and Lee Point. A tidal flat biotope comprising of five species was identified from East Arm. Also listed was a subtidal biotope found in reworked sediments in channels, shallow subtidal areas and the offshore comprising of 29 species.

### Sponges

Hooper (1984, 1986a, 1986b, 1987) has conducted the majority of research on Sponges in Darwin Harbour. A total of 56 species of sponge are known to occur in the harbour. Darwin Harbour is the type locality for 22 of these species. The known species of sponge is believed to represent only a fraction of those present within the harbour.

### Bryzoans

There is very little information available for species composition of Bryzoa (lace corals). The 1995 Beagle Gulf Benthic Survey was the first systematic survey of north Australian waters to describe bryzoan fauna to species level. The survey resulted in 78 species of bryozoans being recorded (Smit 2003). It should be noted that the survey sites were located in open waters just outside of Darwin Harbour.

### Cnidarians

A total of 29 genera of octocorals, comprising soft corals and gorgonians, have been recorded from Darwin Harbour. Approximately 20-25 species of soft corals are known to exist in Darwin Harbour and they are most abundant on intertidal rock platforms. About 30-40 species of gorgonians are known to inhabit the harbour. The low diversity of octocorals is attributed to the high turbidity of water in the harbour (Russell and Hewitt 2000).



The shallow subtidal reefs of the harbour are rich in hard corals, with 123 recorded species of scleractinian and non-scleractinian corals. The major coral beds of the harbour are thinly distributed across extensive intertidal reef flats (Wolstenholme, Dinesen and Alderslade 1997).

Recent work by Watson (1999, 2000) identified a total of 72 hydroid species in Darwin Harbour. Of these species 7 are only found within the Darwin Harbour region.

There is limited information on Scyphozoa (jelly-fish) in Darwin Harbour. Several species of Cubozoan (Box jellyfish) are seasonally abundant in Darwin Harbour (Russell and Hewitt 2000). Among these is the Box jellyfish (*Chironex fleckeri*). These species are most abundant during the wet season when water temperatures are warmer. Wind and currents bring these species closer to shore.

### **Marine worms**

Hodda and Nicholas (1987) recorded 22 genera from small samples of mangrove mud from a tidal creek of East Arm.

Literature on polychaete worms in Darwin Harbour is limited. Recent studies by Metcalfe and Glasby (2008) in mangrove habitats in Darwin Harbour recorded a total of 68 polychaete species. It has been estimated that 600 species of polychaetes occur in Darwin Harbour (Hanley 1988).

Russell and Hewitt (2000) stated that Sipunculida are likely to be common in a variety of marine habitats in Darwin Harbour. Edmonds (1980, 1986) recorded six species of sipunculida in the Darwin Harbour region while Metcalfe and Glasby (2008) recorded three.

### **Crustaceans**

Hanley (1988) estimated the total number of crustaceans in Darwin Harbour to be in the order of 1000. Most studies of crustaceans in north Australia have focused upon decapods, an order comprising of crabs, prawns, shrimp and lobsters. Bruce (1988) listed 65 species of shrimp from East Point. Bruce and Coombes (1997) recorded 121 species of caridean shrimp from Darwin Harbour. LeProvost, Semeniuk and Chalmer (1982) recorded 32 species of decapods crustaceans from mangroves, while Morgan (1987) recorded 11 species of hermit crabs from Darwin Harbour. Studies undertaken by Keable (1997) recorded 24 cirrolanid isopods, increasing the number of known species to 26. The same study also resulted in the discovery of three new species of tanadacean crustaceans.

### **Enchinoderms**

Hanley (1988) estimated the number of species of echinoderms in Darwin Harbour to be in the order of 60, believing that high turbidity restricted diversity. The Beagle Gulf Benthic Survey (BGBS) conducted in 1995 collected 117 species of echinoderms, 26 of which are endemic to northern Australia indicating higher species richness than was previously believed to exist in the harbour.

### **Molluscs**

Le Provost et al. (1982) recorded 31 species of mollusc in the harbour, most of which were gastropods. A list compiled by Dr R Willan of the Museum and Art Gallery of the Northern Territory contained 924 mollusc species for the Darwin Harbour region. Smit (2003) noted that species diversity is considered to be low compared to other nearby regions.

## **Marine vertebrate fauna**

### **Fish**

Larson and Williams (1997) have produced the most recent checklist of known fish species within Darwin Harbour. The checklist provided 415 species ranging from the well known species such as pelagic sharks, Mackerel, Queenfish, Threadfin Salmon, Jewfish and Barramundi to reef species such as Snappers, Coral Trout and Emperors as well as sedentary small fish such as gobies and cardinal fish. Approximately 70 species of gobies and about 20 species of cardinal fish are believed to exist within the harbour. Four species of seahorses are known to inhabit the harbour.

### **Marine reptiles**

Whiting (2003) provided a summary of the reptiles and mammals known to Darwin Harbour during the Proceedings of Darwin Harbour public presentations in 2003.

Four species of sea turtles are known to occur in Darwin Harbour: the green turtle (*Chelonia mydas*), hawksbill turtle (*Eretmochelys imbricate*), flatback turtle (*Natator depressus*) and the Olive Ridley turtle (*Lepidochelys olivacea*). Immature and adult sized green turtles have been observed in both reefal and non-reefal habitats in the harbour while immature and adult sized hawksbill turtles have been reported using rocky reef habitats (Whiting 2003). There are no known nesting sites of green and hawksbill turtles in Darwin Harbour (URS 2002). Flatback turtles are known to nest at Channel Island and Mica Beach as well as Casuarina Beach (URS 2002, Whiting 2003). Olive Ridley turtles have been known to nest in Casuarina Beach (Whiting 2003).

There are three groups of sea snakes in Darwin Harbour, which include:

- ephalophine sea snakes, comprising the Port Darwin Sea Snake (*Hydrelaps darwinensis*) and Mertens' Sea Snake (*Darahydrophis mertoni*)
- aipysurine sea snakes, comprising Dubois's Sea Snake (*Aipysurus duboisii*), the Spine-tailed Sea Snake (*Aipysurus eydouxii*) and the Olive Sea Snake (*Aipysurus laevis*)
- hydrophine sea snakes, including the genera *Acalyptophis*, *Astrotia*, *Disteira*, *Enhydrina* and *Hydrophis* (Whiting 2003).

Saltwater Crocodiles (*Crocodylus porosus*) occur in Darwin Harbour but infrequently nest in the area due to lack of suitable sites. Approximately 110 crocodiles are trapped and removed by the Parks and Wildlife Commission in Darwin Harbour each year (Whiting 2003).

### Marine mammals

Dugongs (*Dugong dugon*) are occasionally sighted in Darwin Harbour. The movements and distribution of dugongs has been considered in Whiting (2008), through a combination of aerial surveys, community sightings and satellite tracking, that has revealed distribution, habitat, relative densities and spatial use of individual dugongs in the Darwin region.

During the surveys (March and August 2002), a total of six dugongs were sighted within Darwin Harbour, out of a total number of thirty sightings across the entire project area, which extended north to the Tiwi Islands and south into Fog Bay. All sightings in Darwin Harbour were of individual dugongs, and the relatively low numbers were believed to be due to the limited amount of seagrass in the harbour (Whiting 2002).

Whiting (2008) concluded that dugongs were often found associated with rocky reefs, with macro-tidal rocky reefs providing important habitat, and small areas of habitat were important for long-term residency of individual dugongs.

Whiting has also published several other reports relating to dugongs in the Northern Territory, including *Conserving Dugongs in Darwin Harbour* (2004), *Rocky Reefs Provide Foraging Habitat for Dugongs in the Darwin region of Northern Australia* (2002), and *Opportunistic Observations of Marine Mammals from the Coastal Waters of Fog Bay, NT* (1997).

A total of seven species of Cetacea have been recorded in Darwin Harbour, including the Indo-pacific Humpback Dolphin (*Sousa chinensis*), Bottlenose Dolphin (*Tursiops truncatus*), Australian Snubfin Dolphin (*Orcaella heinsohni*), the Great Sperm Whale (*Physeter macrocephalus*), Pygmy Sperm Whale (*Kogia simus*), the False Killer Whales (*Pseudorca crassidens*) and Humpback Whale (*Megaptera novaeangliae*) (URS 2002, Whiting 2003). Little is known about the basic ecology and biology of cetaceans in Darwin Harbour.

A survey currently being undertaken by Carol Palmer of the Biodiversity North Unit, NRETAS, has recorded dugongs, Australian Snubfin Dolphins, False Killer Whales, Indo-pacific Humpback Dolphins, and Indo-pacific Bottlenose Dolphins (*Tursiops aduncus*) in Darwin Harbour since 2007.

AECOM have received numerous datasets from NRETAS and the Museum and Art Gallery of the Northern Territory (MAGNT). These include fauna records for the Darwin Harbour dating back to 1876, and current results from the Coastal Dolphin Research Project Survey which has tallied the sightings of dugongs, Australian Snubfin Dolphins, Indo-pacific Humpback Dolphins, Indo-pacific Bottlenose Dolphins, as well as the False Killer Whale. Additionally, lists of species collected from Darwin Harbour are held at the museum.

### Birds

Darwin Harbour supports avifauna such as the endemic or restricted mangrove species Chestnut Rail (*Eulabeornis castaneoventris*), Mangrove Robin (*Eopsaltria pulverulenta*), Mangrove Golden Whistler

(*Pachycephala melanura*) and Great-billed Heron (*Ardea sumatrana*), as well as providing important refuge areas for Radjah Shelduck (*Tadorna rajah*).

## Introduced marine species

In 1997 the Northern Territory Government funded a major baseline study to assess the Port of Darwin regarding the introduction of marine pests. Surveys were conducted in the dry season of 1998 and the wet season of 1999. The report Baseline Survey of the Port of Darwin for Introduced Marine Species, produced for the NT Department of Transport and Works in 2000 (Russell and Hewitt) presented the results of these surveys. The survey focussed on the identification of:

- species listed on the Australian Ballast Water Management Advisory Council's (ABWMAC) schedule of introduced marine pest species
- a group of species which are major pests in overseas ports and which, on the basis of their invasive history and projected shipping movements, might be expected to colonise Australian ports
- those known exotic species in Australian waters that are currently not assigned pest status.

Survey sites were selected in order to increase the likelihood that exotic species in the port would be detected, and therefore concentrated on habitats and sites in the port and adjacent areas that were most likely to have been colonised by the target species, and included active wharves, marina areas, mooring areas, slipways and artificial reefs (Russell and Hewitt 2000). The sites were Fort Hill Wharf, Stokes Hill Wharf, Iron Ore Wharf, Cullen Bay Marina, Francis Bay Marina, Fishermans Wharf, and East Arm Port.

A summary of the results of the survey is provided in Table 18 below.

**Table 18 Summary of introduced marine species survey**

Specimens identified		Comments
Dinoflagellates	Pyrophyta	Dinoflagellates were found at 8 sites. No confirmed harmful or toxic Dinoflagellate species were found.
Foraminifera	Rhizopoda	Unidentified foraminifera were collected at 9 sites. Previous studies did not indicate any exotic species.
Sponges	Porifera	Sponges were collected from 25 sites, all unidentified. Previous studies did not indicate any exotic species.
Coelentrates	Cnidaria	42 species of hydroids were collected from 16 sites. 47 species of anthozoans were collected from 18 sites. None of the species can be considered exotic or cryptogenic.
Nemertean	Nemertea	Unidentified Nemertean worms were collected from 6 sites, and are not considered to be a significant potential pest group.
Nematodes	Nematoda	Unidentified Nematode worms were collected from 5 sites, and are not considered to be a significant potential pest group.
Sipunculids	Sipuncula	Unidentified sipunculid worms were collected from 4 sites, and are not considered to be a significant potential pest group.
Polychaete worms	Phylum Annelida, Class Polychaeta	142 species of polychaete worms were collected from 27 sites. One species, the tubeworm <i>Hydroides elegans</i> is an ABWMAC listed exotic species.
Molluscs	Mollusca	Dry season sampling yielded 429 species and the wet season yielded 103 species. Only one species, <i>Mytilopsis sallei</i> was introduced, and was assumed to have been irradiated shortly after the survey.
Lamp Shells	Brachiopoda	16 species were identified at 10 sites, although Brachiopods are not included in the ABWMAC schedule of known marine pest and other exotic species, and are not considered to be a

Specimens identified		Comments
		potential pest group.
Lace Corals	Bryozoa	Bryozoans occurred at 27 sites. Preliminary examination showed no evidence of any ABWMAC listed marine pest or exotic marine species.
Crustaceans	Crustacea	A total of 27 species were recorded at 23 sites. One species <i>Megabalanus tintinnabulum</i> , is a listed ABWMAC marine pest and other exotic species
Echinoderms	Echinodermata	No listed ABWMAC listed marine species were found.
Ascidians	Phylum Chordata: Ascidiacea	The ABWMAC list of marine pest species do not include and ascidians and known exotic species are mainly temperate.
Fishes	Phylum Chordata:Osteichthys	A total of 42 species were collected during the survey from 8 sites. None of the species collected are ABWMAC listed exotic species.

Russell and Hewitt (2000)

The Black-striped Mussel (*Mytilopsis sallei*) was detected at high densities in the Cullen Bay Marina during the dry season survey of August 1998. Despite not being an ABWMAC designated marine pest species it does have a propensity to cause severe fouling on marine structures and displace native species. Subsequent inspections of other marinas found the species to be present on the hulls of some small pleasure craft. The species is an opportunist with very fast growth, early maturity, high fecundity and wide tolerance to salinity, oxygen and pollution levels. It is well established in Asia where it is a major fouling pest in several ports. The early detection of the Black Striped Mussel led to a massive effort by the NT Government to contain and eradicate it. This effort appears to have been successful.

Earlier discoveries of marine pest species in the Port of Darwin include the discovery of 40 specimens of the Asian Green-lipped Mussel (*Perna viridis*) on the hull of a Vietnamese refugee vessel in December 1991. In September 1999 juveniles of this species were found on the hull of an Indonesian-based charter vessel. This species is widespread in the tropical Western Pacific and poses a potential economic and environmental threat (Russell and Hewitt 2000).