Darwin Port Maintenance Dredging
Darwin Port Operations
22-Jan-2018
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Darwin Port Long Term Dredging Management Plan

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Client: Darwin Port Operations

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Quality Information

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			Name/Position	Signature
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1.0 Introduction

1.1 Darwin Harbour port facilities

Darwin Port Operations Pty Ltd (Darwin Port) operates port facilities within Darwin Harbour, Northern Territory (NT); these include Fort Hill Wharf, East Arm Wharf and the Marine Supply Base (MSB). A brief introduction to these facilities is presented below.

1.1.1 Fort Hill Wharf

Fort Hill Wharf is Darwin Port's cruise ship and defence vessel facility. The precinct includes a purpose-built cruise ship terminal which is capable of handling complete passenger changeovers for smaller cruise vessels whilst providing a transit lounge for more infrequent larger international cruise ships. Frequent naval ship visits to Darwin are catered for at the wharf, with secure and efficient port facilities and services provided. Berthage for tugs and pilot boats used within Darwin Harbour is also provided.

The wharf was originally constructed in during World War II, though bioerosion by *Teredo* worms led to the collapse of some two thirds of the structure. It was partially reconstructed with steel pipes and another two wharves (the Navy Boom Wharf and the Navy Repair Wharf) were added in 1941, the latter to facilitate repairs to Navy vessels.

Over the years the land abutting the wharf has been used for pre-export stockpiling of iron ore and zinc concentrate and a Navy refuelling facility has also operated across the wharf. The current Fort Hill Wharf was commissioned in 1981 (Darwin Port Corporation, undated). The old structure was removed, and some of the seabed in the vicinity of the wharf was dredged, as a part of the Darwin City Waterfront Redevelopment in 2006.

Darwin Port records indicate that the Fort Hill Wharf berths were dredged to 12 m below chart datum (CD) in 1992. Maintenance dredging was last undertaken in 2008/09. During this dredging campaign approximately 7,000 m^3 of sediments were dredged and the spoils were disposed on the seafloor approximately 300 m from the wharf. The current dredging proposal seeks to excavate sediments to a depth of 10 m below CD.

1.1.2 East Arm Wharf and MSB

East Arm Wharf was opened in 2000 and provides facilities for berthing vessels up to 80,000 tonnes. It comprises a:

- Bulk liquids berth which handles regular imports of fuel and is connected via pipeline to a fuel oil facility and a bio diesel refinery. Chemicals such as acids are also piped to adjoining areas.
- Common user facility which is heavily utilised by offshore oil rig tenders. The number of tenders permanently working out of Darwin is increasing as the offshore industry surrounding Darwin expands.
- Container facility served by mobile harbour cranes. This is also used as a common user berth to discharge or load break bulk cargo. Live cattle exports have increased significantly over the past few years with ongoing demand expected.
- Bulk materials handling facility which can cater for Panamax size vessels and is currently used to export iron ore and manganese.

The East Arm Wharf precinct has been progressively developed since 1994; the most recent expansion being the construction of the MSB in 2012-2013 and the Multi User Barge Ramp Facility in 2015-2016. Spoil from the capital dredging campaigns undertaken to develop East Arm Wharf has been disposed within decant ponds within the Darwin Port lease. The ponds have also received spoil from other developments (e.g. the Darwin City Waterfront Redevelopment) and pond management measures have been developed over the years that have proven to be effective in mitigating impacts upon the environment outside of the pond system.

East Arm Wharf has a design depth of 15 m below CD and maintenance dredging undertaken in 2008/09 removed accumulated sediments (approx. 1,000m^3) to a depth of 13 m below CD. Sediments were disposed into Pond F at East Arm Wharf. This pond has now been reclaimed and converted into a hardstand area and refrigerated container terminal.

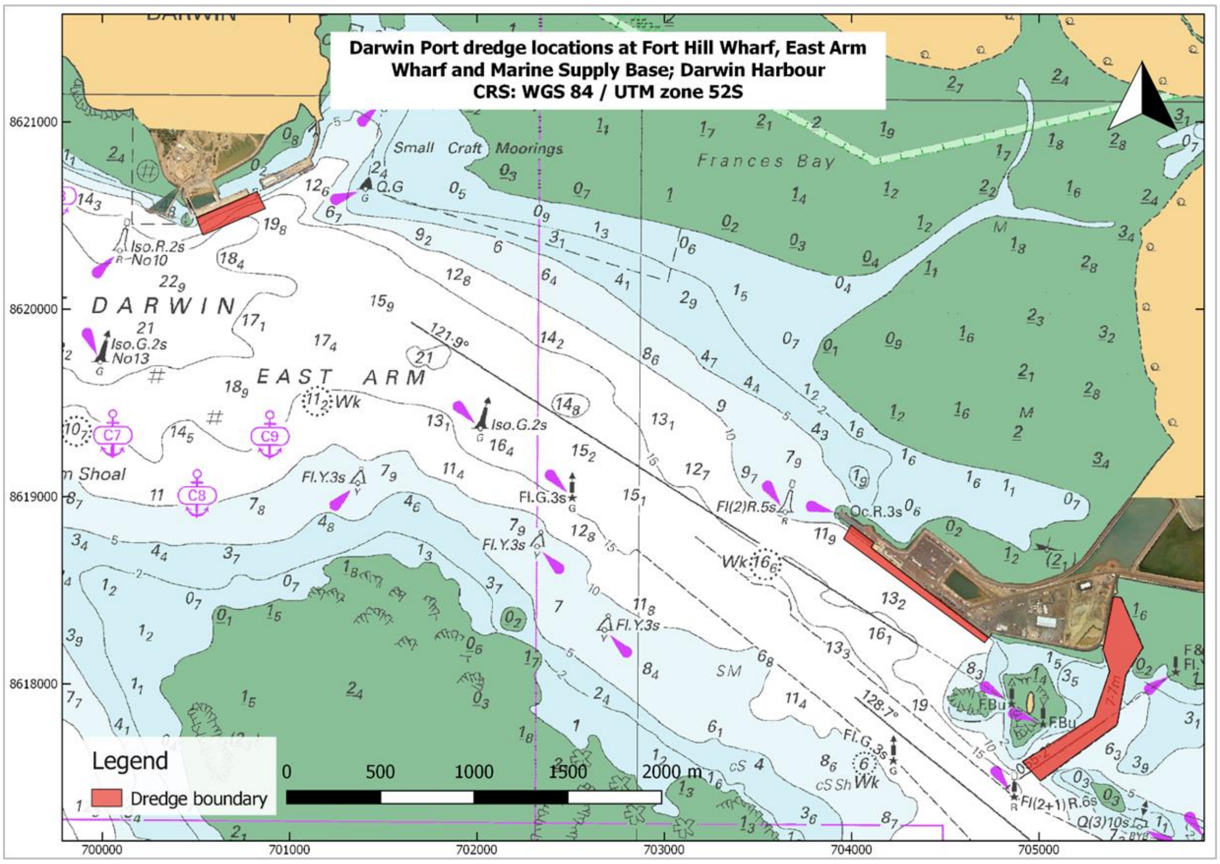
The MSB channel, turning basin and berths 2 and 3 have design depths of 7.7 m below CD and berth 1 has a design depth of 8.7 m below CD. Since the completion of the capital dredging for construction of the MSB in 2014, there has been an accumulation of sediment along the wharf face which now requires removal in order to provide for continued safe berthing for design vessels.

1.2 Maintenance dredging requirements

Darwin Port has a need to periodically undertake maintenance dredging to remove unconsolidated sediment (e.g. clay, silt, sand) that is naturally transported and deposited into existing berth pockets at East Arm Wharf and Fort Hill Wharf, and into the berth pockets, turning basin and channel of the MSB (Figure 1). Coordinates and locations of the potential dredging and harbour spoil disposal sites are provided in Appendix A. This dredging is required to maintain the required depths to provide safe access at all tides for vessels using port facilities and maintain effective operational parameters at the facilities.

The frequency of maintenance dredging will be dependent upon the rates of sediment accumulation at the three locations. In turn, this will be dependent upon factors such as the nature of the seafloor materials adjacent to the port facilities and the degree of their disturbance (e.g. by tidal currents and meteorological events) following the previous dredging campaigns. It is estimated that the berth pockets at East Arm Wharf and Fort Hill Wharf will require maintenance dredging at intervals of no less than six years, and that maintenance dredging at the MSB will be required no more frequently than every three years (Streten, Tsang & Harries 2017).

Figure 1 Maintenance dredging locations



Source: Streten, Tsang & Harries (2017)

1.3 Purpose of this plan

This document is the Long Term Dredging Management Plan (LTDMP) for the required periodic maintenance dredging and spoil disposal activities at East Arm Wharf, Fort Hill Wharf and the MSB. The purpose of the LTDMP is to provide the framework within which maintenance dredging campaigns will be managed and monitored.

The Plan will support the approvals processes for the dredging campaigns (e.g. variations to development permits, waste discharge licence applications). It will also form a part of the documentation released to prospective tenderers to undertake the maintenance dredging works.

1.4 Proponent and dredging contractor

The Proponent for the maintenance dredging works is Darwin Port. For each maintenance dredging campaign, a Dredging Contractor (hereafter 'Contractor') will be appointed; this entity will be required to comply with the LTDMP during execution of the dredging works.

1.5 Legislative framework

Darwin Port operates under the *Ports Management Act*, which was established to provide for the control, management and operation of ports, and for related purposes.

This LTDMP has been prepared to support Darwin Ports' planning applications to vary the development permits attendant to Fort Hill Wharf, East Arm Wharf and the MSB. In reviewing the applications, the Department of Environment and Natural Resources (DENR) identified the need for referral under the *Environmental Assessment Act.* To enable the NT Environment Protection Authority (NT EPA) to decide whether potential environmental impacts arising from the maintenance dredging works have the potential to have a significant effect on the environment, NT EPA requested that Darwin Port prepare a management plan for the dredging projects.

This LTDMP will also support Darwin Port's applications for Waste Discharge Licences pursuant to Section 74 the *Water Act.*

The LTDMP has been prepared with reference to:

- Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA 2013).
- Guideline for the Preparation of a Notice of Intent (NT EPA 2015a).
- Guideline for the Preparation of an Environmental Management Plan (NT EPA 2015b).
- National Assessment Guidelines for Dredging (Commonwealth of Australia 2009).
- Technical Guidance: Environmental Impact Assessment of Marine Dredging Proposals (Western Australian Environmental Protection Authority [WA EPA] 2016).
- International best practice (e.g. PIANC 2006, 2008; CEDA 2011, 2015).
- Current recommendations for monitoring and impact assessments promulgated by the Dredging Node of the WA Marine Science Institution.
- Australian and New Zealand Guidelines for Fresh and Marine Water Quality (hereafter 'ANZECC Guidelines', ANZECC & ARMCANZ 2000).

1.6 Darwin Harbour water quality management framework

The NTG developed the Darwin Harbour Water Quality Protection Plan (WQPP) (DLRM 2014) under the National Water Quality Management Strategy.

Phase 1 of the development of the WQPP was completed in 2009. The overall aim of the WQPP was to ensure that water quality objectives (WQOs) are maintained and that the community's values for waterways are protected. This included identifying key risks to water quality, development of interim

WQOs (based on beneficial use declarations under the *Water Act*), improvements to monitoring activities and evaluation of pollutant loads (NRETAS 2010).

Phase 2 of the WQPP was released in February 2014 and aims to support good management and sustainable development by focussing on a range of management actions including monitoring, assessing and managing the impacts of sediment and nutrient (nitrogen, phosphorus) inputs to Darwin Harbour. It also highlights key considerations for future water quality protection (DLRM 2014).

The proposed maintenance dredging activities fall within the Darwin Harbour Declaration of Beneficial Uses and Objectives of Surface Water. The declared beneficial uses are environment, cultural (aesthetic, recreational and cultural) and aquaculture (NRETAS 2010).

Performance against the Darwin Harbour Region WQOs (Fortune 2016) is assessed on the basis of the annual mean value of the measured parameter. It is noted that the guidelines do not apply during high flow events associated with Wet Season conditions and that the water quality objectives are intended for use in “catchment management and land use planning activities”. Hence the objectives could be considered as representing targets for long-term water quality rather than as limits to be adhered to during dredging operations. However, they have been taken into account during the development of the environmental management frameworks detailed in Section 7.0. The environmental management frameworks have been developed in a manner that is consistent with the risk-based decision framework discussed above.

1.7 LTDMP peer review, acceptance, revision and availability

In preparing the initial LTDMP, an independent peer review of the document was undertaken. The reviewer’s comments were taken into account and the LTDMP was revised accordingly prior to its submission to the NT EPA for acceptance.

Once this LTDMP is accepted by the NT EPA for implementation, Darwin Port will include it within the maintenance dredging tender documentation. The appointed Contractor will be required to comply with the LTDMP during execution of the maintenance dredging works.

Prior to each dredging campaign, a sampling and analysis plan (SAP) will be implemented in order to ascertain the geochemical properties of representative samples of the material to be dredged (refer Section 2.5). The results of these investigations will be taken into account when considering whether or not modifications to this LTDMP are required for the campaign. The NT EPA will be advised of the outcomes and, if necessary, a revised LTDMP will be submitted for acceptance.

A review of the implementation of the LTDMP will be undertaken by Darwin Port at the completion of each dredging campaign. Should circumstances require the LTDMP to be revised this will be undertaken by Darwin Port, with the revised plan submitted to the NT EPA for acceptance. Such circumstances may include the identification of deficiencies in the effectiveness of this LTDMP; modifications to the monitoring regime on the basis of monitoring results from the completed dredging campaigns; changes in environmental risks, business conditions or processes for monitoring environmental performance; or emerging environmental issues that are currently not addressed.

The LTDMP will be publicly available on the Darwin Port website.

2.0 Dredging and Dredge Spoil Placement Activities

2.1 Volumes

The current (September 2017) estimated total volume of material requiring removal by maintenance dredging is approximately 8,000 m³ (based on hydrographic surveys undertaken by Darwin Port in December 2016). Estimated volumes for each site are presented in Table 1.

Table 1 Dredge volumes

Site	Description	Base Level (m LAT)	Volume (m^3)	Surface Area (m^2)
Marine Supply Base				
MSB Berth 1	Southern most berth on the MSB wharf	-8.7	**370**	600
MSB Berth 2 & 3	Two berths immediately to the north of berth 1	-7.7	**570**	490
MSB turning area	Area defined as the navigable area adjacent to both ends of the MSB wharf	-7.7	**135**	172
MSB entrance	Entrance to MSB channel near the East Arm sand bar	-7.7	**250**	400
East Arm Wharf				
East Arm Wharf Berth 1	Berth at the south-east end of the wharf key line	-12.0	**553**	1300
East Arm Wharf Berth 2	In the centre area of East Arm Wharf	-13.0	**153**	580
East Arm Wharf bulk liquid berth	At the north-west end of East Arm Wharf	-12.0	**3100**	2800
Fort Hill Wharf				
Fort Hill Wharf	Area adjacent to the face of, and extending to the north east of the wharf	-10.0	**2820**	1730

2.2 Schedule

As indicated in Section 1.2, the schedule for each maintenance dredging campaign will depend upon the rates of accumulation of material within the areas to be dredged. These rates are expected to differ between areas; hence it is possible that not all three areas will require dredging during each campaign.

Dredging of the volumes of material presented in Table 1 is anticipated to require the dredge to operate for approximately three days at each location. The dredging campaign is expected to be spread over a two to three week period, depending upon the extent to which simultaneous operations occur (e.g. occupancy of wharf berths by ships). This takes account of:

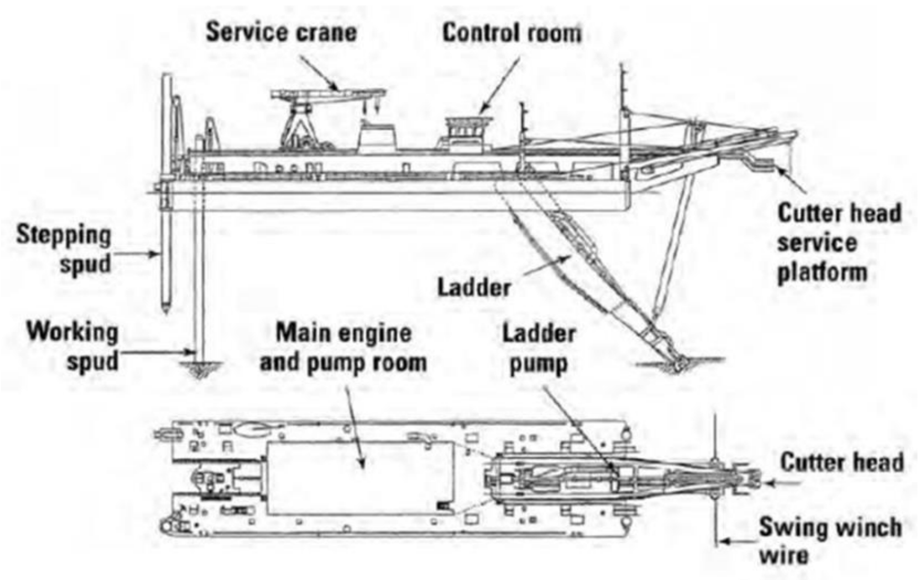
- The need to dredge at reduced production rates when operating around wharf infrastructure (to avoid damage to structures).
- Time taken to relocate the dredge between the three dredging areas.

If the dredging campaign is scheduled for execution during the Wet Season, then cyclonic or otherwise adverse weather conditions could necessitate the temporary cessation of dredging activities, thereby extending the period over which dredging would take place. The Contractor will make ongoing assessments regarding weather conditions to determine if a cessation in dredging was required. If Darwin Port goes into cyclone alert or shut down then, in accordance with the Darwin Port Cyclone Procedure (Darwin Port 2016), the Contractor will comply with all directions from the Darwin Port General Manager Operations.

2.3 Equipment

Dredging will be completed using a cutter suction dredge (CSD, see Figure 2 for typical plant). The CSD would dredge sediment from the seabed, pumping it to the disposal areas (onshore dredge spoil decant ponds or designated disposal sites within the harbour). To achieve the required pumping distances from the dredge footprint to the disposal sites, a booster pump may be required to supplement the pumping capacity of the CSD.

Figure 2 Typical cutter suction dredge



2.4 Summary of work method

Where possible, dredging will be undertaken during the Wet Season; however, should the need arise, dredging during the Dry Season will also need to be permitted.

It is expected that dredging would be undertaken up to 20 hours per day (24-hour operations with four hours down time per day) and, where dredging of all locations is required, would occur over of a period of approximately two to three weeks. Stoppages in dredging may occur for dredge maintenance or to assist in the control of the quality of the water at the designated disposal sites within the harbour.

Dredge rates are anticipated to be between 1,400 m^3 per hour at a water-to-sediment ratio of 19:1 (Streten, Tsang & Harries 2017) and 2,000 m^3 per hour at a water-to-sediment ratio of 9:1 (Williams 2017). A sediment loss rate of 1% at the dredge head is typically applied to modelling of CSD operations. However, the cutter will only be engaged for limited time periods as the majority of dredging will be undertaken in close proximity to wharf infrastructure and the loss rate will therefore be substantially less than this. To mitigate the risk of impact to the cutter head and the infrastructure, the dredge will operate in suction-only mode during these times.

2.5 Sediment characteristics

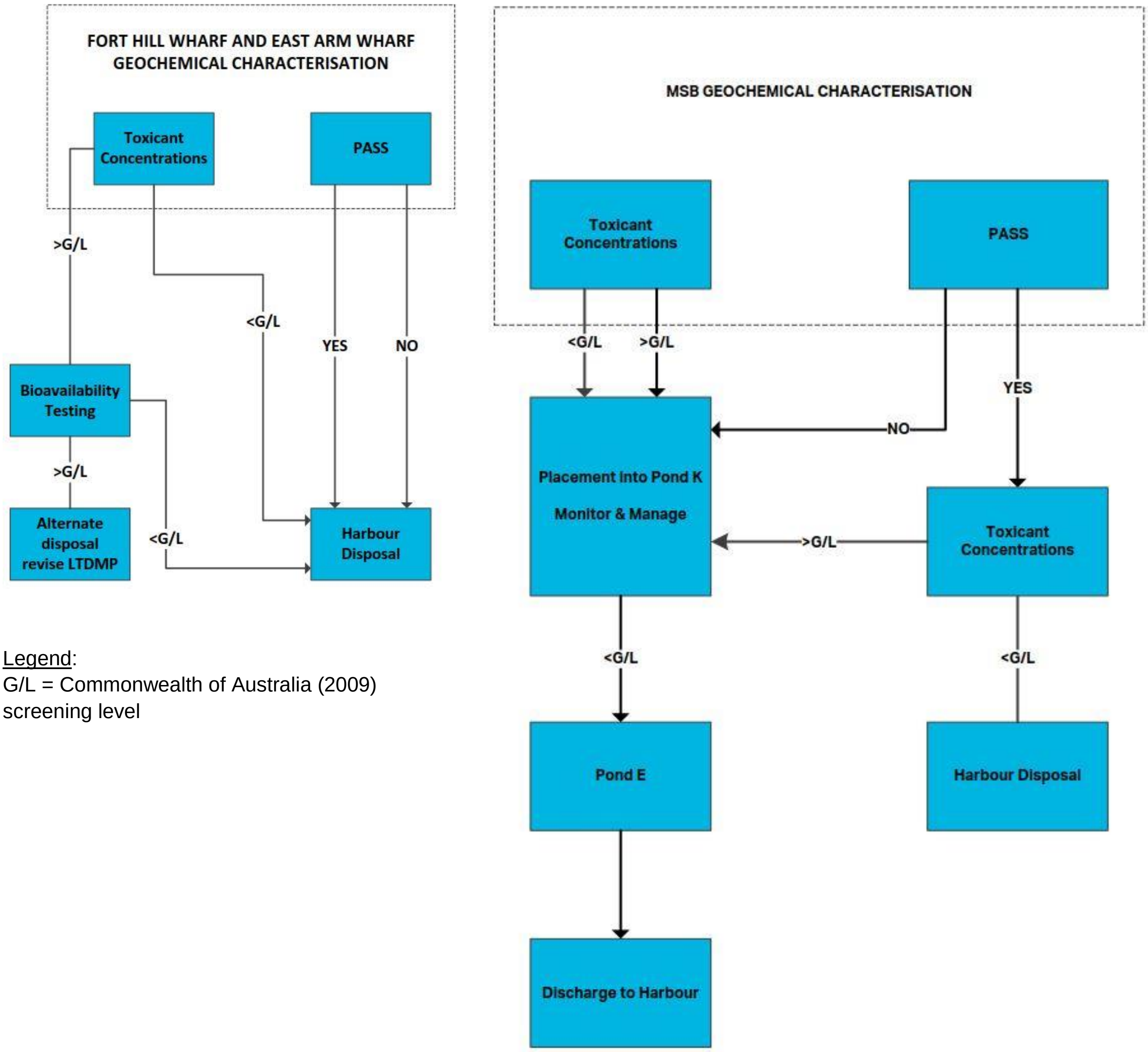
Prior to each maintenance dredging campaign, the geochemical characteristics of representative samples of the material to be dredged will be determined through the implementation of a SAP. The material will be unconsolidated sediments that have accumulated within areas in which capital dredging has been undertaken. The following characteristics of the sediments will be determined:

- Particle size distribution (PSD) to confirm that the sediment to be dredged is of comparable PSD to that used in plume dispersion modelling (Section 5.3).
- Concentrations of contaminants of potential concern (Section 4.2.3.2) to ascertain whether the 95% upper confidence limit of the mean (95% UCL) concentration of any contaminant exceeds the Commonwealth of Australia (2009) screening level for that contaminant.

- Acid sulfate soil potential (Section 4.2.3.3) to ascertain whether potential acid sulfate soils (PASS) are present in the areas to be dredged. This will only be required for sediments from the MSB berths for which disposal into the decant ponds at East Arm Wharf is proposed (Section 2.6.2); the sediments to be disposed into harbour waters (Section 2.6.1) will not be exposed to air, hence there will be no potential for oxidation and acid generation.

The outcomes of the geochemical assessment will guide the selection of the location for the disposal of dredge spoil from each dredging site, as per Figure 3.

Figure 3 Spoil disposal flowcharts



Legend:
G/L = Commonwealth of Australia (2009) screening level

2.6 Dredge spoil placement areas

Dredge spoil placement will occur either onshore within the existing decant ponds in the East Arm Wharf area or in Darwin Harbour, nearby the dredge footprints. The proposed spoil disposal locations are shown in Figure 4.

Figure 4 Dredge spoil disposal locations

2.6.1 Harbour disposal

Dredge spoil from East Arm Wharf and Fort Hill Wharf will be disposed of into areas around 500 m from the wharves. Spoil will be pumped through a floating pipeline by the CSD to the disposal location where it will be discharged through the submerged end of the pipeline. To prevent mounding of the dredged material, the spoil will be disposed across areas that are 100 m wide and 800 m long, aligned along the tidal axes which are parallel to the wharf faces.

The spoil from maintenance dredging at the MSB will be disposed onshore until such time as the decant ponds have insufficient remaining capacity. Thereafter, maintenance dredge material will need to be disposed into the harbour at a location approximately 600 m east of the MSB. In the unlikely event that PASS is detected during the geochemical assessment of dredge material, dredge spoil will be placed at this alternative location to avoid exposure of PASS to oxidising environments (provided the concentrations of all toxicants are below Commonwealth of Australia [2009] screening levels).

2.6.2 Onshore disposal

2.6.2.1 Justification

Placement into the existing decant ponds at East Arm Wharf is the preferred option for material dredged from the MSB due to the ready accessibility of the ponds without impacting upon shipping movements and other operations at East Arm Wharf. These ponds have been used to dispose of dredge spoil from a number of dredging programs in East Arm Wharf precinct, including the dredging associated with the construction of the MSB.

Maintenance material dredged from the East Arm Wharf berth pockets cannot be safely, economically or practically disposed into the decant ponds as disposal pipelines would cross shipping channels and/or critical wharf operational areas.

2.6.2.2 Dredge spoil placement and tailwater flow path

If the geochemical assessment of the material to dredged from the MSB berths (Section 2.5) indicates that PASS is not present, then the spoil will be pumped into the East Arm Wharf decant ponds, with tailwater stored for sufficient time to allow for settling of fine suspended sediments (residence time) prior to discharge of the tailwater back into Darwin Harbour. Water quality management and monitoring is discussed in detail in Section 7.3 of this plan.

Whenever possible, dredge spoil will be pumped ashore through a temporary pipeline from the dredge area into Pond K. Once the physico-chemical properties of the tailwater within Pond K are deemed acceptable for release (Section 7.3.3), it will flow into Pond E (North) via a reclamation box in the bund wall, through Pond E (South), then out of the permeable section of the railway bund wall (Figure 5).

Figure 5 East Arm Wharf pond system

Transfer points from ponds K to E (North) and ponds E (North) to E (South) (Figure 5) have reclamation boxes with adjustable height weirs. The weir boards are designed to be sufficiently watertight to contain sediment, thus managing turbidity levels within ponds K and E (North) and decreasing the likelihood of turbidity levels in Pond E (South) becoming unacceptably high. The reclamation boxes and associated weir boards are the same as those approved and used for previous dredging programs utilising the ponds for spoil disposal and tailwater management, including the capital dredging for construction of the MSB.

If it is necessary to place spoil directly into Pond E (North) (e.g. in the unlikely event that PASS is detected in the material to be dredged from the MSB and spoil cannot be placed at the designated harbour location [Section 2.6.1], or Pond K reaches capacity), then this would only occur when the chance of a large stormwater flow is low (i.e. during the Dry Season).

During dredging works, regardless of the initial dredge spoil deposition location (i.e. Pond K or Pond E [North]), the tailwater will be returned to the environment through the permeable section of the railway bund wall located in the south-west corner of Pond E (South) (Figure 5).

2.6.2.3 Available pond volumes

A survey of the pond capacities was undertaken by Douglas Partners (2014) following the capital dredging of the MSB. The survey showed:

- Pond K: Volume to Relative Level (RL) 6.5 m is 105,000 m^3 with available volume for dredge spoil to RL 6.0 m of 57,000 m^3.
- Pond E (North): Volume to RL 5.0 m is 460,000 m^3 with an available volume for dredge spoil to RL 4.0 m of 374,000 m^3.

Based on the above, the pond system had a storage capacity of 431,000 m^3 for solids utilising both Ponds K and E (North). While the storage capacity would have been reduced marginally during the disposal of material from the capital dredging of the multi-user barge ramp facility (estimated volume of 16,000 m^3), it is apparent that there will be adequate capacity to receive the maintenance material from the MSB berth dredging (estimated in situ volume of 1,325 m^3, refer Table 1).

It may also be possible to stockpile some dredge spoil within the ponds to achieve greater available volume should it be required (as was done during the MSB capital dredging campaign). The capacity of Pond K will be used as a priority.

2.6.2.4 Pond water levels

The maximum water height in Pond K will be 6.0 m AHD or a minimum of 0.5 m freeboard (whichever is higher). Pond E (North) will operate with a water level between 3.5 and 5.0 m AHD and be controlled by a reclamation box with an adjustable weir.

The water level in Pond E (South) will be controlled to ensure at least 0.5 m freeboard at all times; tailwater input can be managed such that, if necessary, the rate of flow out through the permeable section of the railway bund (at the south-west corner of Pond E [South]) matches or exceeds the rate of tailwater input.

At the reclamation boxes between ponds K and E (North), and between ponds E (North) and E (South), the flow can be stopped by adding drop boards and raising the height of the weir. In both instances flow can be stopped within an hour as a corrective action, if required (Table 12) and subject to the need to retain stormwater flows (Section 2.6.2.5).

2.6.2.5 Stormwater and landform

Stormwater from the pond network and adjacent Darwin Port land ultimately flows into Pond E (South) for return to the harbour via the permeable section of the railway bund wall (refer Figure 6). During MSB dredging operations, particularly if dredging is undertaken over the Wet Season, consideration will be given to possible storm events and the Contractor will ensure that a flow path is always available for stormwater to find its way through the ponds.

Stormwater from the Pond K road bund and a catchment area near the gatehouse, estimated to be 20,000 m^2, is now diverted into a new stormwater channel in place along the boundary between Pond K and the former Pond C area, instead of flowing into Pond K. Stormwater from the highpoint on the road to the south of Pond K now flows along a stormwater channel and through a culvert into Pond E (North).

The runoff from Darwin Port land to the north of the ponds passes through Pond D and into Pond E (North). Importantly, stormwater does not flow into Pond K, allowing greater control over water exiting from this primary spoil disposal pond.

Figure 6 Stormwater flow paths through the East Arm Wharf pond system

If, during the Dry Season, it is necessary to dispose of sediment from the MSB berths into Pond E (North) (Section 2.6.2.2), then this will only be filled with solids to a level which will allow sufficient capacity for stormwater and tailwater management.

The pond network has the ongoing function of stormwater management beyond the duration of maintenance dredging operations and will be maintained during and after the completion of dredging activities. Therefore, the pipe connections between ponds will be retained for ongoing stormwater management. When the dredging is complete a surface survey will be completed and a surface profile developed to minimise the risk of ponding against the access road causeway or in areas not forming part of the stormwater system, and the final landform will be effective in directing surface water through Pond E (North) before entering into Pond E (South), then returning to the receiving environment through the permeable portion of the railway bund wall.

3.0 Environmental Project Management and Resourcing

Maintenance dredging will be undertaken in accordance with the Darwin Port Environmental Policy (Figure 7); this requires that Darwin Port develops and maintains an Environmental Management System (EMS), provides sufficient resources to achieve its environmental targets and seeks to prevent pollution from its activities.

Figure 7 Darwin Port Environmental Policy

LANDBRIDGE DARWIN PORT

ENVIRONMENTAL
POLICY STATEMENT

Darwin Port (DP) manages aspects and operates within the Port of Darwin. DP recognises the environmental, social and economic importance of operating in an environmentally sustainable and responsible manner. We will ensure a high level of environmental performance is achieved and are committed to continual improvement.

To achieve environmental performance consistent with this Policy, DP will:

- Develop and maintain an environmental management system, consistent with its activities, services and environmental impacts, that includes planning, setting objectives and targets, implementation and operation, monitoring performance, review and continuous improvement.
- Provide sufficient resources and training to achieve the targets defined in its environmental management system.
- Implement risk management techniques to assess impacts of DP's activities and to introduce appropriate mitigation measures.
- Comply with all applicable environmental laws, regulations, policies and standards which relate to its activities and services in a transparent manner.
- Seek to prevent pollution resulting from port activities and services.
- Communicate to employees and stakeholders this policy and DP's progress in meeting the objectives and targets defined in its environmental management system.
- Continually improve its environmental management and environmental performance.

The Chief Executive Officer and the Port Management Group are responsible for the effective implementation of this policy and all employees, tenants, licensees, service providers, other persons and those otherwise engaged at the workplace are expected to reasonably comply with requirements of this Policy.

Publicly available from: www.darwinport.com.au

Terry O'Connor
Chief Executive Officer

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Financial Services Manager

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Landbridge HSE&R Manager

Alastair Black
Engineering Manager

October 2017

Work Safe. Live Safe.

3.1 Environmental Management System and Procedures

The Darwin Port EMS is based on the requirements of ISO14001:2015 (International Standard for Environmental Management Systems) and provides a framework for the achievement of continual environmental improvement. The EMS is underpinned by 12 procedures (EMSPs) that explain the operation of the EMS.

The Darwin Port EMS and procedures will guide all maintenance dredging operations. On appointment, the Contractor will develop any additional project-specific detailed plans required as bridging documents to the Darwin Port EMS and procedures. These plans will be approved by Darwin Port before dredging commences.

3.2 Key roles and responsibilities

Key roles and responsibilities will be identified by the Contractor on appointment and a project-specific organisational chart will be developed and maintained by the Contractor.

Site management responsibilities will be defined and documented by the Contractor before dredging commences; these will include reporting and communication pathways between the Contractor and Darwin Port personnel.

Key roles to be identified include (but are not limited to):

- Project Manager
- Health Safety Environment and Quality (HSEQ) Advisor
- Supervisors / engineers
- Employees and subcontractors

3.3 Inductions and training requirements

Inductions and training requirements will be determined by Darwin Port and the Contractor on appointment and will be in accordance with Darwin Port and the Contractor's policies and procedures. All relevant inductions will be completed by all personnel before they begin work on the project. A training and inductions register will be maintained by the Contractor.

3.3.1 Environmental general and work program specific inductions

The Darwin Port Environmental Policy commits to providing sufficient resources and training to achieve the targets defined in its EMS. Darwin Port will fulfil this commitment by:

- ensuring all persons involved with the maintenance dredging complete the Darwin Port General Induction
- appointing Contractor(s) to perform the maintenance dredging works with complementary environmental policies (through the Contractor prequalification process) and provision of advice to the Contractor on required work program specific environmental inductions.

Dredging work program specific environmental inductions may include, but not be limited to, the following environmental topics:

- overview of key environmental issues and personnel responsibilities
- promoting awareness of significant environmental issues and personnel responsibilities
- reporting of environmental incidents - which will include how an event is reported and to whom the event is reported (all incidents are to be reported, including near misses)
- emergency procedures - which will cover the procedure for an emergency and for evacuation of the site in the event of a catastrophic situation arising
- contingency plans - e.g. for hydrocarbon or chemical spills.

3.3.2 Environmental awareness

Daily prestart / toolbox meetings will be conducted by the Contractor, with input from Darwin Port, and will be primarily aimed at operational staff. All Contractor and subcontractor personnel (if any) will be required to attend. Toolbox meetings will focus on environmental and safety items relevant for the project during that time, and will be used as the main tool to further increase awareness of significant environmental and safety issues, and to communicate the relevant items contained in the Environmental and Safety Management Plans.

Typical items discussed in these toolbox meetings include environmental items such as new procedures or reinforcement of existing procedures relating to erosion control, handling of hazardous chemicals, management of waste/ recycling, need to report all incidents and hazards/near misses, etc.

3.3.3 Training

Only suitably qualified and experienced personnel will be engaged on the project. All personnel will have appropriate qualifications and experience for their role on the project. Training and qualifications are to be demonstrated to Darwin Port by the Contractor(s) prior to the commencement of the dredging work programs.

3.4 Environmental documents and records management

The Contractor appointed will have in place, or will develop before the start of dredging, a document management system that fulfils requirements to operate under the Darwin Port EMS.

Project records, including subcontractor project records, will be maintained to provide evidence of conformity to Darwin Port requirements and commitments in this LTDMP.

Such records include, but are not limited to:

- correspondence to/from the Darwin Port and interested parties
- permits, licenses and approvals
- induction training records
- inspection and test documentation (including calibration)
- non-conformance and corrective action / complaints
- environmental incidents
- audits and inspections
- monitoring records
- delivery / waste dockets.

3.5 Performance management

Performance management includes activities to ensure that goals are consistently being achieved in an effective and efficient manner. A key component of the environmental management process is the development and implementation of dredging work program specific measures to ensure that the environmental risks arising from the dredging and dredge spoil disposal activities are minimised. The success of these objectives is to be measured with key performance indicators (KPIs) defined for environmental management. Environmental performance measures are to be developed by Darwin Port and committed to by the Contractor(s) prior to the commencement of each specific dredging work program.

3.5.1 Environmental objectives

The environmental objectives of dredge operations management are to:

- Limit impacts of dredging and dredge spoil management operations on marine life and water quality.

- Ensure that protected marine species, including dolphins, dugongs, turtles and sawfish are not significantly adversely affected by dredging activities.
- Reduce the potential impacts from noise generated by dredging equipment.
- Limit sediment (turbid plume) mobilisation to an extent consistent with protecting the viability of specified communities.
- Ensure migratory bird species that use the dredge spoil deposition ponds are not directly adversely affected by dredge activities.
- Ensure that dredging and dredge spoil placement are undertaken in accordance with regulatory approvals, licenses, permits or authorisations.

3.5.2 Performance criteria

This LTDMP is the key reference document which identifies actions and commitments to be followed by the Contractor and subcontractor personnel throughout dredging operations. The broad performance criteria of the LTDMP are as follows:

- Compliance with the LTDMP by all project personnel and activities.
- Adherence to discharge water quality parameters as identified in the Water Quality Monitoring Plans (Sections 7.2.3 and 7.3.3 of this Plan).
- No net adverse impacts on corals, mangroves, dolphins, dugongs, turtles or sawfish.
- No injuries to protected marine species.
- No complaints received in relation to noise or vibration and no impacts on protected species from these sources.
- Response to all registered complaints and completion of Complaint Record and / or Incident Report; appropriate corrective actions taken within the timeframe stipulated by Darwin Port.

Where performance criteria are not met, this will form a trigger for review of the Plan, in addition to initiating corrective actions specific to the scenario.

3.5.3 Environmental management KPIs

In the environmental management frameworks detailed in Section 7.0 of this Plan, specific objectives and targets are set for each significant environmental aspect. KPIs related to the objectives and targets for each of the environmental management frameworks can be found in Section 7.0.

General objectives and targets are:

- all personnel working on site have undergone a work program specific environmental induction
- internal audit score of 100% compliance with the LTDMP (refer to Section 3.6)
- Darwin Port conducted audit score of 100% for compliance with the LTDMP (refer to Section 3.6)
- no activity in breach of the provisions of any environmental legislation
- 100% investigation and reporting of any environmental incident at the site
- 100% compliance required for management measures relating to dredging and dredge spoil management.

3.5.4 Environmental incident reporting

All Contractor and subcontractor site personnel will be required to report all environmental incidents immediately to the appropriate supervisor in accordance with their incident reporting procedures. The Contractor engaged will have (or will develop prior to the start of dredging) an Incident Reporting and Investigation Procedure.

Incidents shall be tracked through to close-out using an incident tracking system or register. Complaints will be investigated by the Project Manager and action taken to enable satisfactory closeout. Any incidents that have caused environmental harm, or that have the potential to cause environmental harm, will also be reported to the Darwin Port representative and to the NT EPA Pollution Hotline (1800-064-567) within 24 hours. When in any doubt as to the seriousness of the event, the Contractor will notify the authorities, in liaison with Darwin Port. Darwin Port will be notified of any notices received from authorities.

3.6 Management review

3.6.1 Inspections

Daily inspections of the work operations will be conducted by the Contractor’s site supervisors. Any corrective actions resulting from inspections will be recorded and the progress tracked for completion.

3.6.2 Internal audits

Where dredging work programs are planned to be conducted over several days, internal audits of this LTDMP will be undertaken during the work program to assess the effectiveness of the Plan in the field, to ensure that the Contractor’s monitoring and management regimes are aligned with those in the LTDMP, and to identify any opportunities for improvement.

3.6.3 Darwin Port audits

Darwin Port may audit the Contractor(s) implementation of this LTDMP at any time during the work program to assess the effectiveness of the Plan in the field, to ensure that the Contractor’s monitoring and management regimes are aligned with those in the LTDMP, and to identify any opportunities for improvement.

3.6.4 External audits

External audits may be conducted by NTG departments if any given department considers there may be an issue in relation to environmental compliance. Darwin Port will assist with any external audit.

Results from any external audits will be reviewed by Darwin Port, with any necessary corrective actions assigned to Project personnel to ensure appropriate and timely closeout. Any corrective actions will be recorded and the progress tracked for completion.

3.6.5 Project corrective actions register

Any environmental non-conformance (e.g. incidents, audit-related non-conformance, complaints, NTG notices, etc.) will be recorded in a Project corrective actions register, or similar, to be developed by the Contractor. The corrective actions register will detail the non-conformance, the corrective action(s) required, the person(s) responsible for the action(s), timeframes within which each action is to be completed, and the actual completion date. Each non-conformance will be reviewed by Darwin Port and it will be established if there are any actions available to reduce the severity or likelihood of re-occurrence.

3.6.6 Continuous improvement

The Contractor will have in place mechanisms to review performance and to identify opportunities for improvement. Records will be kept and reporting will be done according to Contractor procedures for managing documentation. Observations will be detailed in Project reporting to Darwin Port.

Mechanisms may include, but will not be limited to:

- prestart meetings
- toolbox meetings
- progress reports.

4.0 Existing Environment and Relevant Studies

4.1 Regional Setting

This section of the Plan provides a brief overview of those components of the existing environment that are pertinent to the consideration of impacts from dredging and spoil placement during maintenance dredging at Fort Hill Wharf, East Arm Wharf and the MSB. This information provides the context for determining the monitoring programs and management strategies detailed in Section 7.0.

The Darwin Harbour region extends from Gunn Point in the east, to Charles Point in the west, covering an area of over 3200 km^2 comprising 65% terrestrial and 35% marine habitats (at high tide) (Fortune 2016). The Darwin Harbour region includes the catchments 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. Within the harbour, shores are characterised by extensive intertidal mud flats and mangroves.

4.2 Existing Physical Environment

4.2.1 Meteorological conditions

Darwin Harbour lies in the monsoonal (wet–dry) tropics of northern Australia and experiences two distinct seasons; a hot Wet Season from November to March (when winds are predominantly westerly) and a warm Dry Season from May to September (when winds vary from south-easterly through to northerly). The months of April and October are transitional.

Maximum temperatures are defined as hot all year round, but November is the hottest month with a range of 25°C minimum to 33°C maximum, while the lowest average daily temperatures (19°C minimum to 31°C maximum) are normally experienced in July (Bureau of Meteorology [BoM] 2017). The mean annual rainfall for Darwin is 1723 mm, with rain falling on an average of 113 days, mainly from December to March (BoM 2017).

Cyclone activity occurs intermittently in the Darwin region, mainly between November and April, with cyclones typically causing the most damage within a distance of 50 km from the coast. Aside from the impacts of strong winds, storm surges can be of concern to vessels and coastal developments surrounding Darwin Harbour. Storm surges result from strong onshore winds and reduced atmospheric pressure, and can cause flooding and damage through raised tidal levels and increased wave heights. The height of a storm surge is influenced by many factors, including the intensity and speed of winds within the associated cyclone, the angle at which the cyclone crosses the coast, the speed and direction of tidal flows and the bathymetry of the affected area (NT Emergency Service 2011).

4.2.2 Coastal geomorphology and bathymetry

Darwin Harbour is a large ria system, or drowned river valley, formed by post-glacial marine flooding of a dissected plateau. The harbour was formed by rising sea levels about 6000–8000 years ago. Since the formation of the harbour, surface erosion from the adjoining terrestrial environment has carried substantial quantities of sediment into the harbour. This sediment now forms much of the intertidal flats that which overlie bedrock around the harbour margins.

The harbour extends for more than 30 km along a north-west to south-east axis. The main channel of the harbour is around 15-25 m CD deep, with a maximum depth of some 36 m. The channel favours the eastern side of the harbour and continues into East Arm, at water depths of more than 10 m CD. The bathymetry in this area has been modified by dredging for the development of East Arm Wharf and the INPEX LNG processing facilities located at Bladin Point.

4.2.3 Marine sediments

4.2.3.1 Darwin Harbour seafloor

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).

The typical geological profile of the Darwin Harbour seafloor comprises Quaternary age intertidal marine alluvium comprising mud, silt, sand and coral remnants, underlain by the Proterozoic metasediments of the Burrell Creek Formation, consisting of meta-siltstone, meta-sandstone and phyllite. The rocks strike close to north-south and are steeply dipping either to the east or west. Quartz veins are widespread within the Burrell Creek Formation.

Sediments in the river catchments are predominantly fine-grained, mainly clay and silt. Creeks and rivers may transport coarser material (e.g. sand) into the estuary during the wet season, though much is trapped by coastal vegetation, both riparian and mangrove (McKinnon et al. 2006). The fine sediment delivered to the upper arms of the harbour settles out of suspension and is then eroded and re-deposited mainly by tidal currents, especially at spring tides (Munksgaard 2013).

Hydrodynamic modelling of the fate of suspended sediment plumes has shown that substantial sediment fluxes are directed up-estuary where fine sediments are trapped; the sediment fraction exported to the ocean is relatively small (Williams, Wolanski & Spagnol 2006).

4.2.3.2 Contaminants of potential concern

Land uses in the Darwin Harbour catchment represent potential sources of contaminants that may accumulate in the berths to be dredged. Skinner, Townsend and Fortune (2009) estimated the diffuse annual contaminant loads contributed to the harbour during typical Wet Season rainfall (1,670 mm); the loads from catchments that may influence the maintenance dredging locations are presented in Table 2.

Table 2 Diffuse annual pollutant loads

Catchment	Suspended Sediment	Nitrogen	Phosphorus	Aluminium	Arsenic	Cadmium	Chromium	Copper	Nickel	Lead	Zinc
	tonnes				kg						
EEA	3100	72	3.56	142	54.2	18.6	202	576	98.8	428	2300
Mi	737	14.2	0.9	40	11.7	3.49	44.8	169	19.3	156	616
PS	339	5.36	0.43	20.9	4.9	1.23	19.3	90.6	7.18	93.7	312
My	116	1.76	0.15	7.28	1.64	0.4	6.51	31.6	2.35	33.2	108
Hu	1010	14.4	1.32	65.8	14	3.17	55.9	287	19.2	308	969
Bl	473	6.82	0.61	30.5	6.56	1.51	26.2	133	9.08	143	451
Re	310	4.42	0.4	20.2	4.29	0.97	17.1	88.1	5.88	94.6	297
Sa	342	5.14	0.44	21.6	4.83	1.16	19.2	94	6.87	99.1	321
CBD	446	5.87	0.59	30	5.96	1.25	24.1	132	7.77	145	438
Total	**6873**	**130**	**8.4**	**378**	**108**	**31.8**	**415**	**1601**	**176**	**1501**	**5812**
Catchment codes: EEA=Elizabeth East Arm; Mi=Mitchell; PS=Palmerston South; My=Myrmidon; Hu=Hudson; Bl=Bleesers; Re=Reichardt; Sa=Sadgroves; CBD=Darwin Central Business District											

Approximately 6 km upstream of East Arm Wharf, the Palmerston Wastewater Treatment Plant discharges treated effluent into Myrmidon Creek, which enters the lower reaches of the Elizabeth River where it enters East Arm. The mass loadings of the release from the Plant in 2005/06 (the most recent data available) were 181 tonnes of suspended sediment, 40 tonnes of ammonia, 69 tonnes of nitrogen and 18 tonnes of phosphorus (Power and Water Corporation [PWC] 2006).

Potential contaminants in the three dredging areas pertaining to port operations over the years include metals (e.g. arsenic, cadmium, chromium, copper, iron, mercury, manganese, nickel, lead, uranium, zinc), hydrocarbons, nutrients (from fertilisers) and organotins (i.e. tributyltin from ship anti-foulant coatings). Whilst the latter substance is no longer permitted to be applied to ships that would enter Darwin Harbour (as per the International Convention on the Control of Harmful Anti-fouling Systems on Ships) it is a persistent contaminant that may remain within sediments for many years (Okoro et al 2011), often associated with paint flakes (Commonwealth of Australia 2009).

As indicated in Section 2.5, the geochemical characteristics of the material to be dredged in each campaign will be ascertained through analysis of representative samples during the planning phase.

4.2.3.3 Potential acid sulfate soil

In the Darwin region, PASS has been identified in association with mangrove sediments (e.g. Hill & Edmeades 2008). As PASS is formed under anaerobic conditions, it is considered unlikely that it will occur in the sediments that accumulate at the maintenance dredging locations, which will be deposited under aerobic conditions (i.e. in the presence of dissolved oxygen within the water column). Nonetheless, the presence of PASS in the material to be dredged in each campaign will be ascertained through analysis of representative samples during the planning phase (Section 2.5).

4.2.4 Metocean Conditions

Darwin Harbour has semidiurnal macro-tides (two highs and two lows per day) with a strong diurnal inequality. The highest astronomical tide is 8 m CD. 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 within the harbour with tidal fluctuations.

The large tidal ranges in the harbour produce strong currents that peak at speeds of up to 2–2.5 m/s. Tidal flows are also large; peak spring-tide flows have been measured along a line from East Point to Mandorah and are in the order of 120 000 m^3/s. Over a spring tide up to 1000 GL/s can pass through this area (Williams & Wolanski 2003).

Modelling by Li et al (2014) indicated that total sediment transport in the harbour was predicted to be seaward in the main harbour channel, and landward at the entrance to East Arm. The model also suggested that mangroves and tidal flats played key roles in redistributing suspended sediments and affected total sediment transport by modulating tides and tidal asymmetry.

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 (Williams, Wolanski & Spagnol 2006).

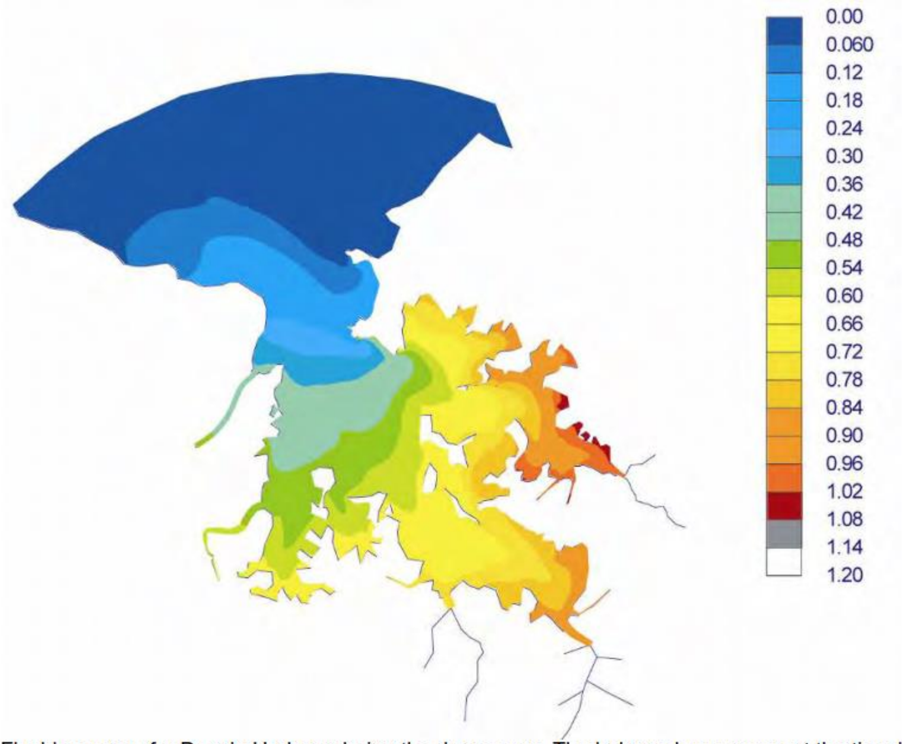
The East Arm Wharf and MSB sites are located in an area where the Dry Season flushing is estimated to be around 40 days (Figure 8), hence it is defined as being in the Upper Estuary Zone. The flushing time at Fort Hill Wharf is estimated to be around 25 days; hence it is defined as being in the Middle Estuary zone (Fortune 2010).

4.2.5 Marine water quality

Water quality in Darwin Harbour is generally high, although naturally turbid most of the time. Water quality parameters vary greatly with the tide phase (spring versus neap; flood versus ebb), location (inner versus outer harbour), and with the season (Wet Season versus Dry Season). Duggan (2006) conducted research on the water quality of Darwin Harbour from 2002 to 2004. Seasonal aspects, rather than spatial or tidal aspects, were found to be the most important determinant of water quality within the harbour in general, with rainfall considered to have the greatest impact on water quality (increasing nutrients, suspended solids and chlorophyll a).

Tidal movement can play an important role in re-suspending material from the harbour floor into the water column and water quality in the dredging areas is predominantly impacted by suspended sediments resulting from fast moving currents.

Figure 8 Dry season flushing zones in Darwin Harbour



Flushing zones for Darwin Harbour during the dry season. The index values represent the time in days it takes for a conservative constituent to be removed from the harbour by advection / diffusion. Multiply the index values by 60 for the time in days. (*Source: David Williams, in 'Water Quality Guidelines for the Protection of Environmental Beneficial Use of the water resources of the Darwin Region': EMG Paper 1, Dec 2007*).

Source: Fortune (2010)

Water quality is typically higher in outer harbour waters than within the inner harbour, though turbidity at the harbour mouth can be elevated in shallow areas due to re-suspension of sediments from intertidal flats, especially during spring tides.

A typical Darwin Wet Season extends from November to April and is characterised by warm air temperatures, convective storms and monsoonal weather which brings heavy rain and strong north-westerly winds and, in some years, cyclonic weather (Fortune 2016). These Wet Season conditions affect harbour water quality due to high surface runoff from the land (URS 2011).

There is no evidence of widespread water or sediment pollution in the Harbour (DENR 2016, Fortune 2016), although there some localised pollution has been identified in the past (e.g. Padovan 2003, Water Monitoring Branch 2005, Drewry et al 2011). Anthropogenic influences to Harbour water quality include the East Arm Wharf port operations, historic industrial activities at Darwin Waterfront, Sadgroves Creek and wastewater outfalls (URS 2004); however, there has been no evidence of widespread or persistent hydrocarbon or pesticide pollution in the harbour (Darwin Harbour Advisory Committee 2007).

The harbour may be subject to occasional pollution events such as hydrocarbon spills, from potential sources such as:

- seasonal stormwater inflow from Darwin and Palmerston stormwater drainage networks
- creeks with industrial developments in their catchments (e.g. Hudson Creek, Sadgroves Creek)
- bulk hydrocarbon storage (e.g. at East Arm Peninsula, Darwin LNG plant and Channel Island Power Station)
- inventories in recreational vessels and commercial ships
- refuelling locations (e.g. *HMAS Coonawarra*, Cullen Bay, Fishermans Wharf).

4.2.6 Water quality baseline data

Between 2008 and 2011, a number of water quality investigations were undertaken by URS on behalf of INPEX to characterise the existing conditions in East Arm (URS 2009, 2011). Table 3 presents summary statistics for Dry and Wet Season water quality, as recorded at a site off the southern tip of South Shell Island (URS 2011).

These data were collected every 15 minutes over a year-long program. Data were grouped and averaged based on tidal cycle and seasonal variation, allowing seasonal means, medians and percentiles to be calculated. This gives a robust body of data to compare background levels of turbidity with potential increases associated with various natural and artificial turbidity-generating events in the harbour.

Water quality data from South Shell Island are relevant to the maintenance dredging locations as this site has the nearest sensitive receptors (coral communities) to them, although modelling does not predict that the communities are at risk of irreversible impacts from the dredging works (refer to Section 5.0).

Table 3 Summary of water quality parameters at South Shell Island

	Dry Season			Wet Season		
	Mean	Minimum	Maximum	Mean	Minimum	Maximum
Temperature (°C)	28.1	25.3	32.1	30.4	28.1	32.0
Conductivity (mS/cm)	48.7	40.2	52.9	46.2	36.7	49.8
Depth (m)	6.3	2.4	11.0	6.7	2.5	11.3
pH	8.0	7.7	8.5	8.0	7.6	8.2
DO (%)	93.5	73.4	121.1	88.5	67.3	106.4
Turbidity (NTU)	4.4	0.1	46.4	8.3	0.2	68.0
Suspended sediment concentration (SSC) (mg/L)*	10.8	7.1	46.4	14.1	7.2	64.7

* Calculated from NTU using relationship in URS (2011): SSC = 0.848 * NTU + 7.0477
Source: URS (2011)

4.3 Environmental receptors

4.3.1 Marine communities

Darwin Harbour has a complex assemblage of marine ecological communities, including rocky shore biota, hard corals, filter feeders (primarily soft corals and sponges), macroalgae, seagrasses, soft sediment biota, mangroves and fish communities. Smit, Penny and Griffiths (2012), in their summary of previous benthic habitat mapping of Darwin Harbour, suggest that the benthic habitats present in the inner and outer harbour differ significantly and are typically characterised as follows:

- Outer harbour:
  - extensive seagrass communities occur in shallow waters
  - corals and algae dominate on hard substrates in shallow waters.
  - deeper waters are characterised by filter-feeder communities (e.g. sponges, soft corals).
- Inner harbour:
  - hard substrates in shallow and deeper waters consist of mixed communities or are dominated by sponge communities
  - no seagrass communities are present.

The environmental receptors that will be exposed to potential impacts from the maintenance dredging works are those within the inner harbour, hence seagrass communities are not considered within this Plan.

DENR is the custodian for comprehensive habitat mapping datasets accrued over surveys for many projects within Darwin Harbour (e.g. Geo Oceans 2011, 2012a,b; Siwabessy et al 2015). Habitats that are relevant to this Plan (i.e. those that could potentially be impacted by maintenance dredging) are shown in Figure 13.

4.3.1.1 Hard coral communities

Hard coral communities occur in Darwin Harbour where the substrate is rocky in the lower intertidal and shallow subtidal zones and where hydrodynamic conditions permit. A total of 123 species of corals have been recorded in Darwin Harbour (Wolstenholme, Dinesen & Alderslade 1997). Hard coral communities are typically dominated by colonies with massive (e.g. Faviidae, *Porites* spp.), foliose (e.g. *Turbinaria* spp.) or encrusting (e.g. Faviidae) growth forms (INPEX 2010).

Hard corals are dominant within some of the benthic communities around South Shell Island, mainly on the western side of the island. A reduction in hard coral cover was recorded at South Shell Island monitoring sites during the INPEX capital dredging campaign conducted between 2012 and 2014; this was concluded to be as a result of a combination of elevated turbidity and increased sedimentation (Cardno 2014). Reductions in hard coral cover at South Shell Island monitoring sites were also detected during the MSB capital dredging campaign that was undertaken within the same period as the much larger INPEX campaign (Macmahon 2013, Department of Infrastructure [DoI] 2014). Sediment plume modelling for the maintenance dredging works covered in this Plan (Section 5.4) predicts that the South Shell Island coral community is sufficiently distant from the works to not be at risk of irreversible impact.

Other well-known hard coral communities in Darwin Harbour include the following:

- Off the north-east shore of Wickham Point.
- Weed Reef, Plater Rock and Kurumba Shoal, on the western side of the harbour, and Dudley Point at the northern end of Fannie Bay.
- Channel Island coral community in Middle Arm, on the intertidal platform between Channel Island and the mainland. This is listed on the Register of the National Estate and is a declared Heritage Place under the NT *Heritage Conservation Act 1991*.

All of these communities are sufficiently remote from the dredging and proposed spoil disposal locations that there is no credible risk of impact to them.

4.3.1.2 Filter-feeder communities

Filter-feeder communities are those that primarily comprise sponges, gorgonians (sea fans and sea whips) and other soft corals. They primarily occur on intertidal or subtidal hard substrates and may co-occur with hard corals, giving rise to “mixed species” communities. However, they also occur at depths shallower than, and deeper than, those at which hard corals thrive and can be the dominant component of the benthic community in some areas.

It is recognised that filter-feeder communities around South Shell Island and Old Man Rock may contain species that could be of importance to bio-prospecting. However, it is also recognised that large areas of filter-feeder communities are present both within East Arm and across the broader harbour (Geo Oceans 2011, 2012a,b; Siwabessy et al 2015).

Benthic habitat monitoring during the MSB capital dredging campaign (undertaken in 2012 and 2013) found no statistically significant changes in filter-feeder communities across the three surveys (Macmahon 2013, DoI 2014). This is somewhat unsurprising as these communities are generally less sensitive than corals to the physiological pressures of reduced benthic light availability and sedimentation associated with dredging activities or natural environmental conditions. Filter-feeder communities were not monitored as part of the INPEX dredging campaign that was conducted within the same period as the MSB dredging (INPEX 2013).

4.3.2 Protected marine species

4.3.2.1 Cetaceans

Three species of coastal dolphin inhabit the Darwin Harbour region: the Australian humpback (*Sousa sahulensis*; formerly known as the Indo-Pacific humpback), Indo-Pacific bottlenose (*Tursiops aduncus*) and Australian snubfin (*Orcaella heinsohni*) dolphins. All three species are listed under the EPBC Act as marine migratory species and are therefore designated as Matters of National Environmental Significance.

Brooks and Pollock (2014) undertook the most extensive and recent study of the abundance, movements and habitat use of coastal dolphins in the Darwin region (Darwin Harbour, Bynoe Harbour and Shoal Bay) between 2011 and 2014, a program initiated as part of the environmental approvals for the Ichthys LNG project. Their study revealed that together, these three species are more commonly observed in Shoal Bay, while in Darwin Harbour, dolphins are more commonly seen in East Arm and West Arm than other parts of Darwin Harbour.

Brooks and Pollock (2014) analysed the results of the first six primary samples from dolphin surveys undertaken between October 2011 and March 2014, concluding:

- Australian humpback dolphins were the most abundant at all three sites monitored with the number estimated across the six surveys in Darwin Harbour remaining relatively consistent at between 37 and 49 individuals.
- Bottlenose dolphin numbers in Darwin Harbour were more abundant than at Bynoe Harbour and Shoal Bay with numbers varying between 13 and 30 across the surveys. Temporary emigration between sites is thought to account for higher variation in numbers of bottlenose dolphins.
- Snubfin dolphins were the least observed species in the Darwin Harbour region with highly irregular numbers observed between surveys. Only one snubfin dolphin was detected in the vicinity of Darwin Harbour East Arm during the surveys.
- While significant changes in detection rates in East Arm were evident through this study, these differences occurred prior to any construction activity associated with the Ichthys project. Significant changes were also observed at Bynoe Harbour, a site distant from any potential construction impact.

The EPBC protected matters database also lists the following as “species or species habitat [that] may occur within area”, though the species are not known to occur within Darwin Harbour:

- Blue whale (*Balaenoptera musculus*).
- Bryde's Whale (*Balaenoptera edeni)*.
- Humpback Whale (*Megaptera novaeangliae*).
- Killer Whale (*Orcinus orca*).

4.3.2.2 Dugongs

Dugongs are known to occur in Darwin Harbour waters, although in relatively low numbers. Dugongs have been recorded in higher densities at Gunn Point and the Vernon Islands, some 30–50 km to the north-east of the mouth of the harbour. Dugongs have also been observed in relatively high numbers at Bare Sand Island and Dundee Beach in Fog Bay, 60 km south-west of Darwin Harbour, and are known to travel long distances (Whiting 2008).

Cardno (2014) compared the results of baseline surveys with four surveys undertaken throughout the dredging phases of the Turtle and Dugong Monitoring Program associated with the INPEX Ichthys project. This study revealed that dugongs were observed in varying numbers between surveys however no trends (including seasonal trends) were evident. There was a higher number of dugong observed in shallower waters (6 – 10 m), generally in foraging areas where seagrass was present. It was concluded that variation in dugong numbers observed at each site between surveys was most likely to be a result of short term movement to visit optimum foraging areas of seagrass.

During baseline surveys (June to October 2012) most sightings in Darwin Harbour were around Weed Reef, West Arm and near Bladin Point, as well as in the shallow regions of Shoal Bay. During later baseline surveys, most dugong sightings were around outer Darwin Harbour, with aggregations around mapped seagrass near Casuarina Beach.

During the first of the Dredging Phase surveys (May 2013), dugongs were predominantly sighted in outer Darwin Harbour, with only one dugong sighted near Weed Reef and another in the shallow areas in West Arm. During the Dredging Phase surveys in July/August and October 2013, no dugongs were sighted in the inner Darwin Harbour, while during the end of dredging survey (May 2014) three dugongs were sighted near Weed Reef.

During the two surveys undertaken in October 2013, sightings were concentrated around Casuarina Beach and were associated with areas of seagrass (*Halodule* sp.). Lower numbers were observed in this area in Wet Season surveys and it was considered that the reduced seagrass coverage in this season was likely to have been a contributing factor (Cardno 2014).

In general, it is considered that dugongs could occur anywhere in the harbour that could support seagrasses or algae. The closest benthic community to East Arm Wharf and the MSB that has been found to support a notable amount of macroalgae is the mixed sand and rocky reef habitat around Old Man Rock (Geo Oceans 2012a,b), some 2 km to the east of the dredging and spoil disposal locations. The nearest known area of substantial macroalgal communities to Fort Hill Wharf are those on the intertidal platform extending to the north-west from Wickham Point (Geo Oceans 2012a); these are some 2 km from the dredging and spoil disposal locations. Substantially greater areas of potential foraging habitat for dugong exist elsewhere in the harbour (INPEX 2011).

4.3.2.3 Turtles

Six species of marine turtles are known to occur in NT waters. Of these, four (green [*Chelonia mydas*], hawksbill [*Eretmochelys imbricata*], olive Ridley [*Lepidochelys olivacea*] and flatback [*Natator depressus*]) are considered to occur in the Darwin region, though olive Ridleys are thought to occur only occasionally within the harbour (Cardno 2014). Loggerhead (*Caretta caretta*) and leatherback (*Dermochelys coriacea*) turtles are considered unlikely to occur in Darwin Harbour (Whiting 2003).

Turtles recorded during surveys associated with the Ichthys Turtle and Dugong Monitoring Program (Cardno 2014) showed a general trend of decreasing numbers with depth (62% observed in water 0–5 m deep) with the majority of turtles observed in the Darwin Harbour region over sand, gravel or reef habitats. There were only a few turtles sighted in association with mangroves and mud habitats (0.5% and 3%, respectively).

The shoreline throughout Darwin Harbour, and particularly in East Arm, consists largely of mangrove forests and mudflats and does not provide suitable nesting habitat for any species of turtle. The nearest nesting beach (used by the flatback turtle) is located in the Casuarina Coastal Reserve near Lee Point on the north-eastern shore of the harbour. Turtles visiting the harbour are more likely to be foraging for food. Flatback and hawksbill turtles forage on the filter-feeder communities which are extensive in the harbour. The hawksbill turtle also forages on seagrass and macroalgal communities in addition to filter-feeders. Green turtles forage amongst seagrass and macroalgal communities (INPEX 2011).

4.3.2.4 Sawfish

The EPBC protected matters database indicates that four species of sawfish may potentially occur within the search area:

- Three threatened species, all designated as vulnerable - dwarf sawfish (*Pristis clavata*), green sawfish (*Pristis zijsron*) and largetooth sawfish (*Pristis pristis*).
- One migratory species - narrow sawfish (*Anoxypristis cuspidata)*.

Although the database indicates that the “species or species habitat [is] known occur within [the] area”, the Atlas of Living Australia (biocache.ala.org.au) indicates that:

- The only two records of dwarf sawfish in the Darwin Harbour region are:
  - Buffalo Creek, which discharges into Shoal Bay, outside of the main harbour (Museums and Art Galleries of the Northern Territory record).
  - An Australian Museum record with an imprecise location, possibly from Rapid Creek which is more than 10 km from the dredging and spoil disposal locations.
- Two green sawfish have been recorded from Buffalo Creek.
- There are no records of largetooth sawfish within the harbour.

- The only record of narrow sawfish in the Darwin region is also from Buffalo Creek.

Buffalo and Rapid creeks are tidal creeks; quite a different environmental setting from the dredging and spoil disposal locations.

4.3.3 Other EPBC-listed marine species

The EPBC protected matters database indicates that the following threatened "species or species habitat may occur within [the] area", though there are no records (in the Atlas of Living Australia) of these species occurring within Darwin Harbour:

- Great White Shark (*Carcharodon carcharias*)
- Northern River Shark (*Glyphis garricki*)
- Whale Shark (*Rhincodon typus*).

The database also indicates that the following migratory marine "species or species habitat may occur within [the] area":

- Estuarine Crocodile (*Crocodylus porosus*) – this is known to occur within Darwin Harbour but is likely to typically avoid areas of high vessel activity, such as the dredging and spoil disposal locations.
- Coastal Manta Ray (*Manta alfredi*) and Oceanic Manta Ray (*Manta birostris*) – manta rays are known (from anecdotal accounts) to occur in the harbour, though there are no records (in the Atlas of Living Australia) from which to determine which particular species have been present.

5.0 Sediment Transport Modelling and Impact Assessment

5.1 Synthesis of assessment approach

Darwin Port commissioned AIMS to undertake sediment transport modelling to assess the potential impacts of the proposed maintenance dredging operations on local water quality, and potential sedimentation impacts in the local area. The assessment of potential environmental impacts from the dredging works was informed by:

- A two-dimensional hydrodynamic model that incorporated water levels, currents and waves.
- A sediment transport model that determined suspended sediment dispersion and sediment accumulation.
- GIS analyses to quantify and depict potential impacts on habitats on the basis of tolerance limits.
- Preliminary sediment geochemical analysis undertaken on sediment samples collected to inform the modelling process.

5.2 Hydrodynamic model

The hydrodynamic model used by Williams (2017) was the 'Darwin Harbour hydrodynamic model', which has been used for previous dredging assessments for Darwin Port in the vicinity of East Arm and Fort Hill wharves. This model was developed for the original East Arm Wharf development and, over a period of 16 years, has been applied to many of the dredging campaigns within Darwin Harbour.

Over the past five years the model has been refined by AIMS to assist in understanding the general movement of cohesive and non-cohesive sediments and nutrients in the harbour. It has been enhanced with data from Multibeam Echo Sounder (MBES) surveys conducted in 2011 and 2015-16 and from Acoustic Doppler Current Profiler (ADCP) measurements in 2015 (Williams 2016).

The model was also refined around the wharf infrastructure and friction in the model elements was increased to emulate the effect of the wharf piles and braces at Fort Hill Wharf and the berthing fenders at East Arm Wharf (Williams 2017).

Boundary conditions for the model were taken from observations recorded at Buoy 5 at the entrance to Darwin Harbour. Buoy 5 is a Darwin Port channel marker that is equipped with instrumentation to measure wind speed and direction; tidal depth, current and direction; and waves. This model was applied to the dredging and spoil disposal management method proposed for the dredging works.

5.3 Sediment transport model

Williams (2017) modelled the sequential dredging of Fort Hill Wharf, East Arm berth 1, East Arm berth 2, East Arm berth 3 and the MSB berth, in that order, with a two-day break in between sites. Parameters adopted for the model were:

- Dredge rate of 2,000 m^3/hr (as indicated in Section 2.4 this rate may be as low as 1,400 m^3/hr, in which case the quantity of sediment released into suspension at the dredge head, and the rate of deposition at the harbour disposal locations, would be lower than those modelled)
- 9:1 water to sediment ratio (as indicated in Section 2.4 this may be as high as 19:1, in which case the sediment concentrations released at the harbour disposal locations would be only 50% of those modelled)
- 1% of total flow disturbance factor at dredge head (as indicated in Section 2.4 this is also conservative as the dredge will operate in suction-only mode for the majority of dredging works)
- Critical shear stress for erosion - 0.06 N/m^2
- Critical shear stress for deposition - 0.08 N/m^2
- Sediment fall velocity - 0.0006 m/s

- Sediment bulk density (assuming ~50% moisture) - 1400 kg/m^3.

Sediment characteristics were determined from samples collected in 2016 and 2017 (Streten, Tsang & Harries 2017).

The model was run to represent the dredging and spoil disposal operations carried out using a small CSD for:

- Alternative spoil disposal locations 200 m and 500 m from Fort Hill Wharf and East Arm Wharf. As the 500 m locations showed improved dilution of turbid plumes from spoil disposal, these are the locations that have been carried forward for the purposes of impact assessment in this LTDMP.
- 12-hour and 24-hour dredging operations (the latter modelled assuming 20 hours of productive dredging per day, allowing four hours per day for dredge repositioning and maintenance). 24-hour dredging and spoil disposal operations have been carried forward in this LTDMP to provide for a conservatively high assessment of the risk of impact from the works.

5.4 Modelling results

Model outputs (from Williams 2017) presented here are:

- 90th percentile plot of modelled SSC (Figure 9)
- 95th percentile plot of modelled SSC (Figure 10)
- Time series chart of SSC at South Shell Island, the closest location with substantial areas of communities that could potentially be affected by plumes, during dredging (Figure 11) and after completion of dredging (Figure 12).

It is important to note that these figures show total SSCs; i.e. a 5 mg/L Dry Season background SSC plus dredging-related SSC. Hence the 5 mg/L contours in Figure 9 and Figure 10 show the lateral extent of SSC elevation due to dredging and spoil disposal activities.

No sediment deposition in excess of 2.5 mm was predicted within the harbour at the end of dredging, or two weeks after completion of dredging. Peak sediment deposition at South Shell Island was predicted to be approximately 0.55 mm (Williams 2017).

Figure 9 90th percentile SSC

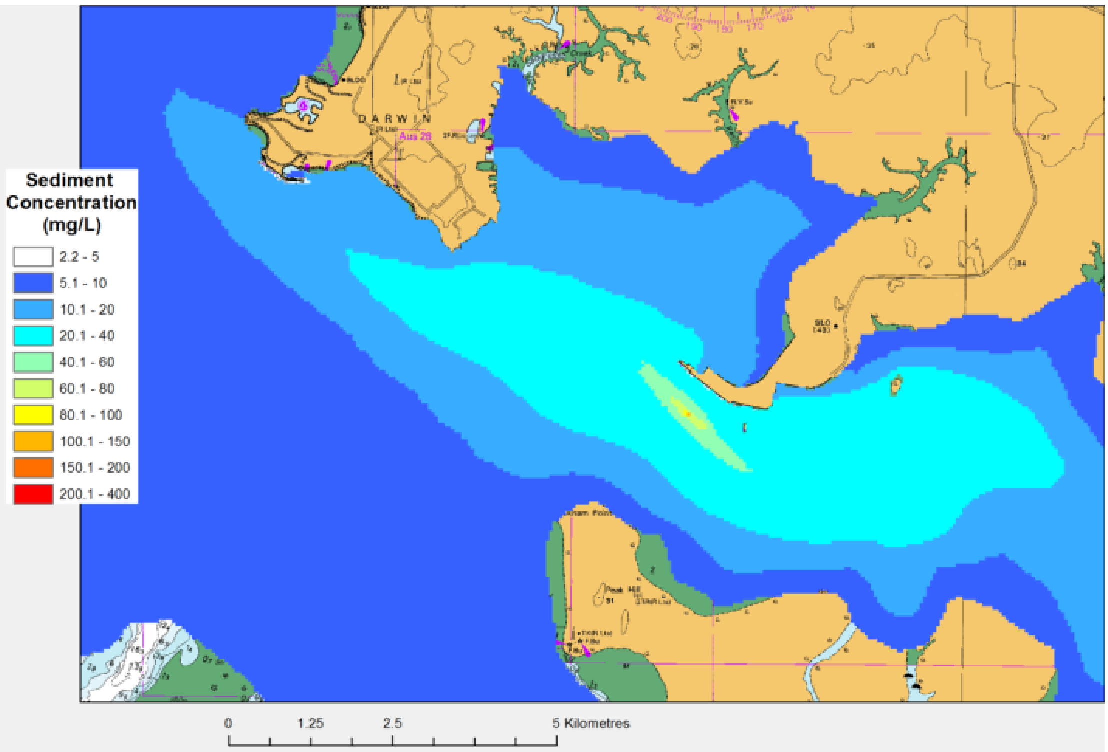


Figure 10 95th percentile SSC

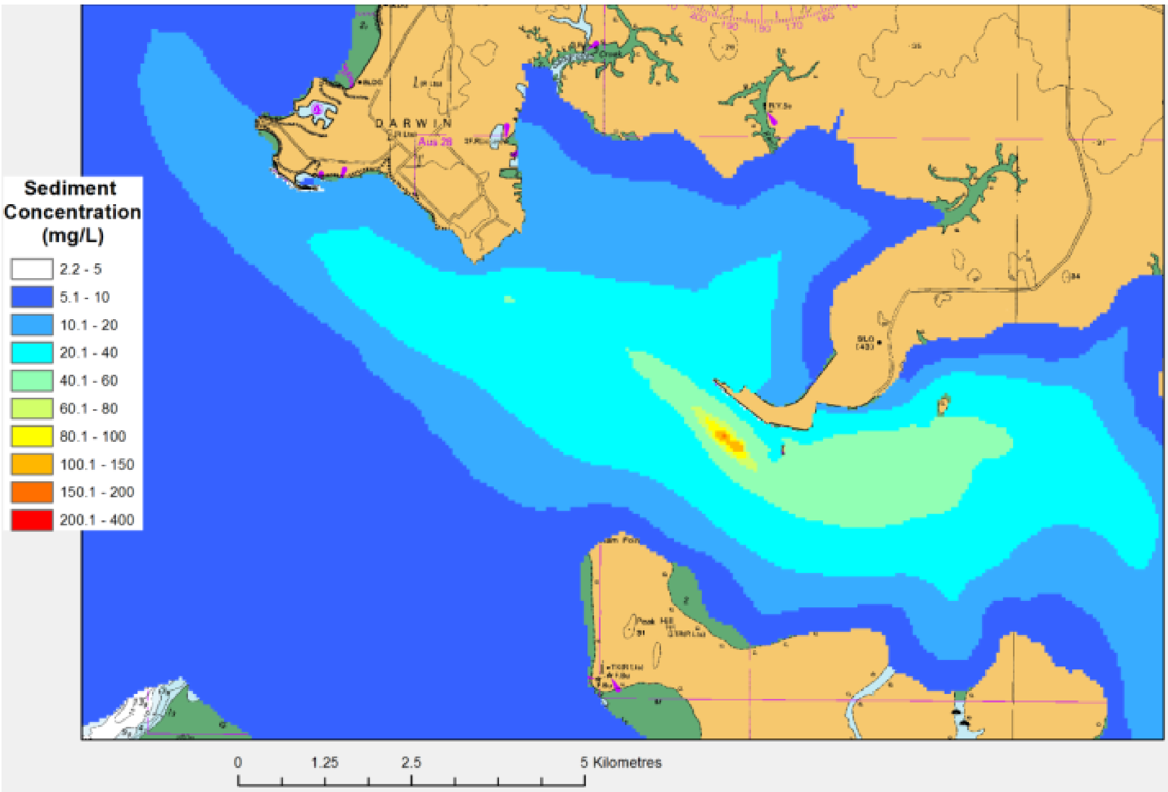


Figure 11 SSC at South Shell Island during dredging

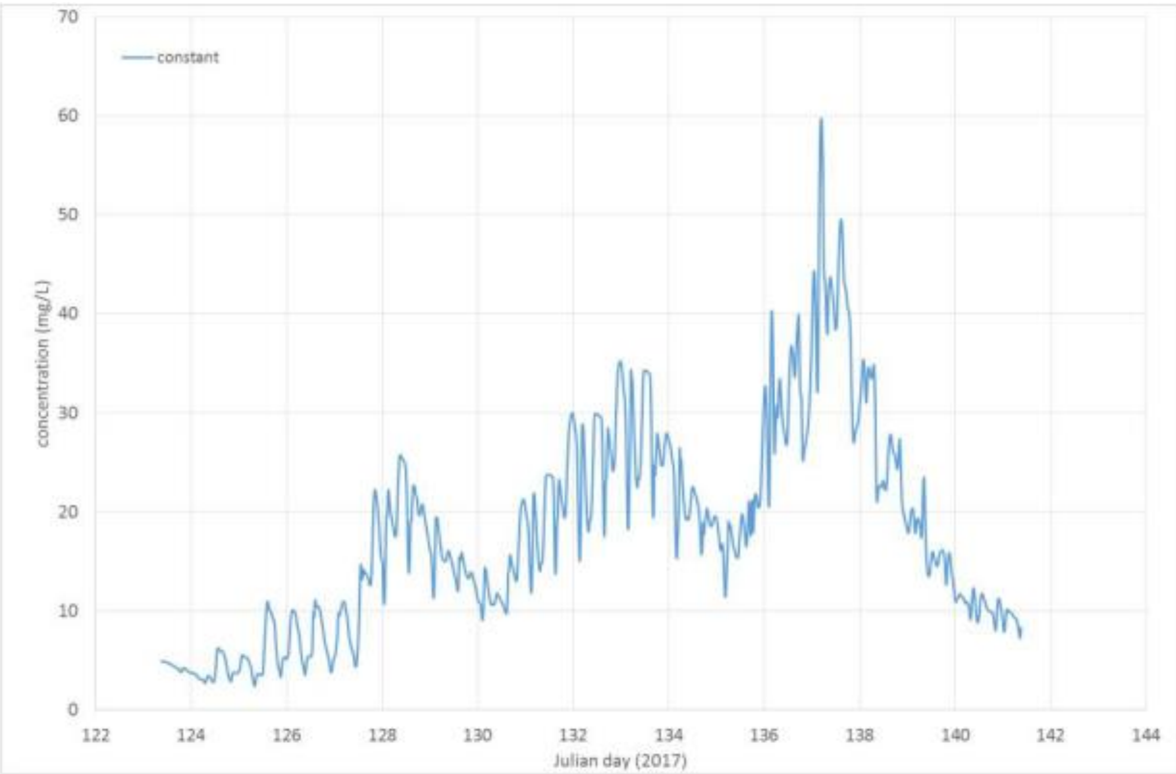
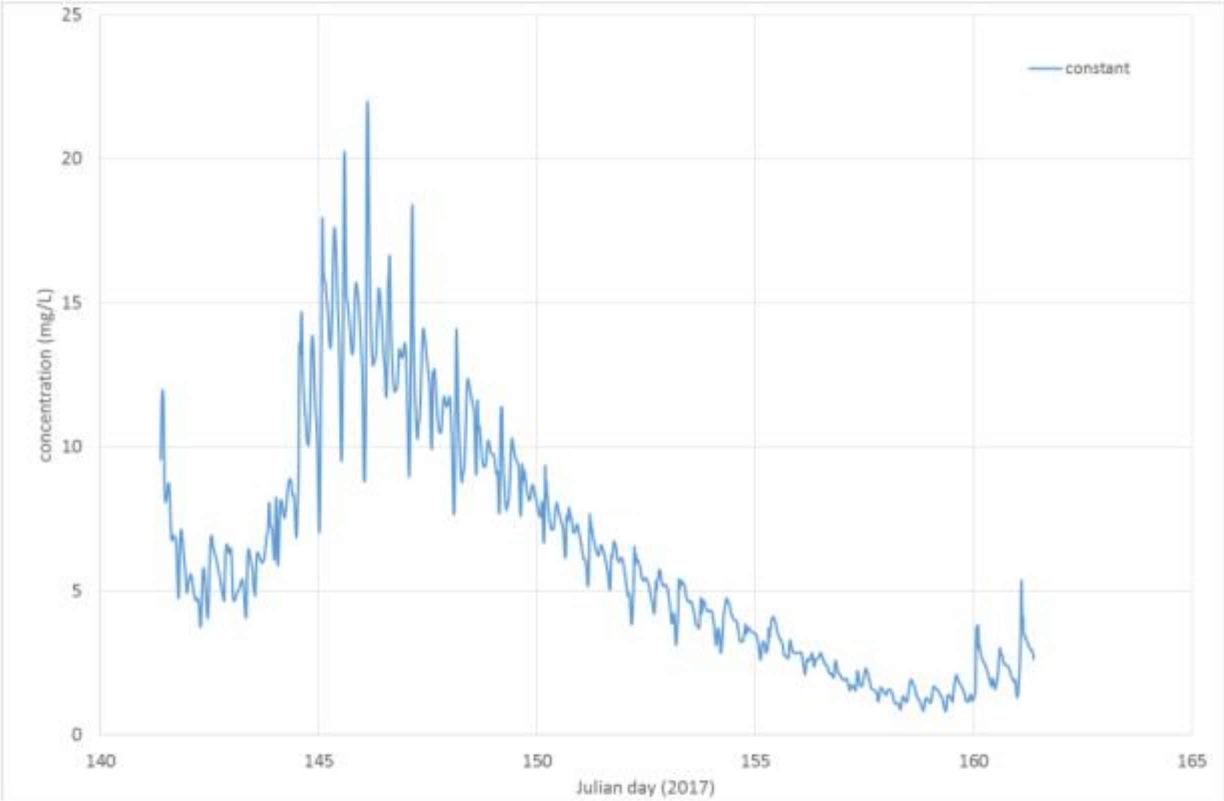


Figure 12 SSC at South Shell Island after dredging



5.5 Tolerance limits for biological communities

Tolerance limits used for the previous dredging around East Arm Wharf will be adopted for future maintenance dredging. These are considered to be appropriate as the only sensitive receptors likely to be impacted upon are in this region and it would be expected that they would have developed a tolerance to the naturally higher background SSC concentrations in the upper estuary in East Arm.

Given that the schedule for future maintenance dredging will be variable (depending on factors such as siltation rates and dredge availability) the tolerance limits applicable to the dredging will be dependent on whether dredging takes place in the Dry or Wet Season.

Tolerance limits were calculated from the appropriate (Dry or Wet Season) subset of a one-year baseline dataset of water quality (URS 2011), on the presumption that biological communities in East Arm are adapted to local conditions but will be stressed if exposed to conditions that regularly exceed the 95th percentile of normally prevailing background concentrations (calculated from URS 2011).

As the sediment transport model calculates excess (above background) SSC caused by the dredging and spoil disposal, the median of the background concentrations was subtracted from the 95th percentile of the background concentrations to provide a comparable tolerance limit. This yielded a tolerance limit for Dry Season dredging of 10 mg/L SSC and a Wet Season SSC tolerance limit of 25 mg/L.

Tolerance limits for sediment deposition on mangroves were derived by INPEX (2010, 2011) from a review of the outcomes of habitat-specific dose-response experiments and field observations reported in the scientific literature. These tolerance limits will be applied to the maintenance dredging campaigns – i.e. 50 mm accretion may lead to reduced health or mortality; at above 100 mm accretion, mortality of trees is considered “likely”.

For corals and filter-feeder communities, INPEX (2011) contended that a meaningful sedimentation threshold could not be derived from the literature due to factors such as wide variations in tolerances between species, and between morphologies within species. Subsequent laboratory research has been undertaken into sedimentation effects on corals and filter-feeders (e.g. Duckworth, Giofre & Jones 2017, Pineda et al 2017). Whilst these provide data that are indicative of sedimentation tolerance limits under laboratory conditions, they are of limited applicability in field conditions, especially conditions as dynamic as those within Darwin Harbour where strong tidal currents enhance the removal of sediments that settle on benthic biota.

5.6 Zones of Impact and Influence

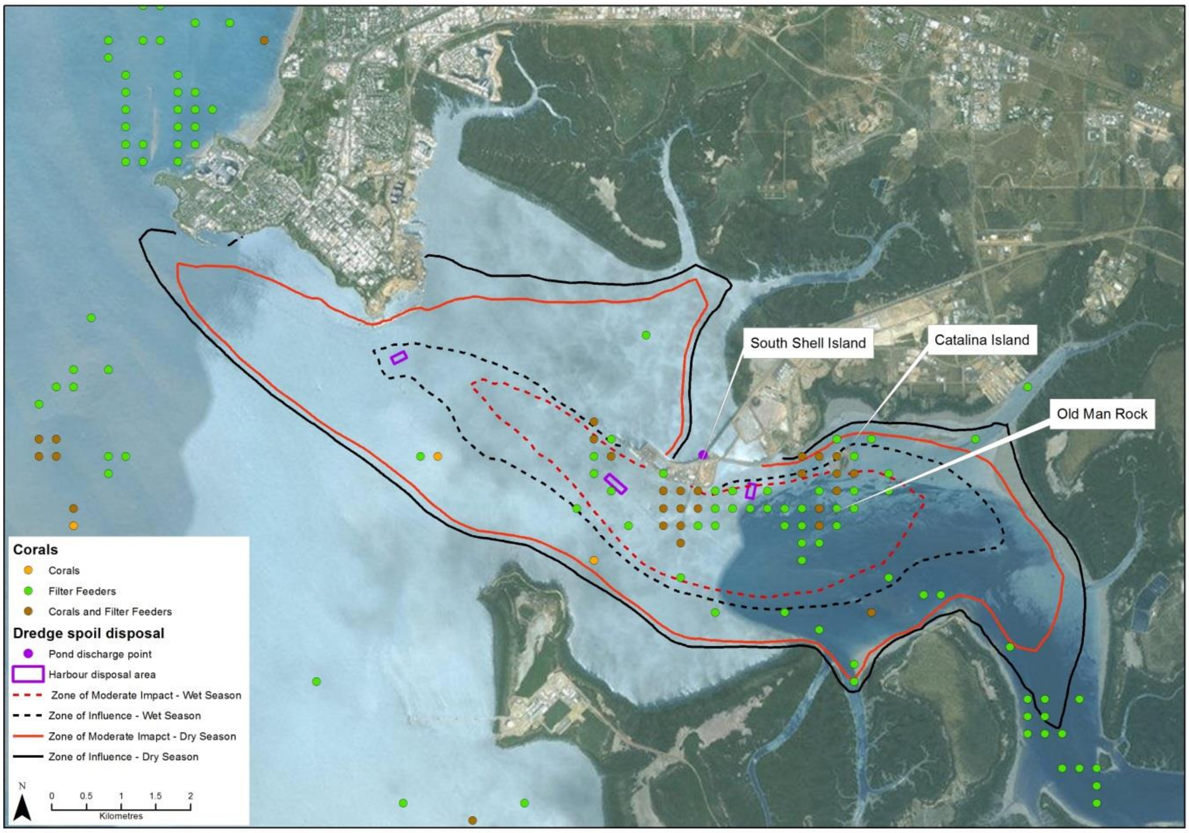
For the assessment of potential dredging-related impacts upon benthic communities due to suspended sediment, definitions of Zones of Impact and Influence have been adopted in line with WA EPA Technical Guidance (WA EPA 2016), which is consistent with the NT EPA Guidelines (NT EPA 2013):

- **Zone of High Impact**: this zone constitutes the direct footprint of the dredged area and a 20 m wide annulus around the footprints to account for smothering from coarse sediments liberated from the cutter head during dredging. Impacts in these areas are predicted to be severe and often irreversible.
- **Zone of Moderate Impact**: within this zone, damage to benthic habitats and mortality of benthic biota may occur, primarily as a result of the indirect impacts from increased turbidity that may occur at times over areas within the zone. Impacts within this zone are predicted to occur, but the disturbed areas may recover (after completion of the dredging and disposal operations). It is expected that there will be no long-term modification of the benthic habitats in this zone. The outer edge of the Zone of Moderate Impact is delineated by the 90th percentile contour plot for SSC, as defined by dredge plume modelling. This delineates the areas where, for 90% of the time, the predicted SSC is below the calculated tolerance for benthic communities (dredging-related SSC of 10 mg/L for East Arm communities during the Dry Season, 25 mg/L during the Wet Season, refer Section 5.5). The 10% of time during which the SSC threshold is predicted to be met or exceeded is likely to represent periods of mid-flow tidal states (particularly during spring tides) and any one exceedance event is not likely to exceed two hours.
- **Zone of Influence**: this zone includes the areas in which, at some time during the dredging works, benthic communities may experience (detectable) changes in sediment-related environmental quality outside the natural ranges that are normally expected. However, the intensity, duration and frequency of these changes is such that any damage to benthic habitats is likely to be reversible, and no mortality of benthic biota is expected to occur. The outer boundary of this zone is delineated by the 95th percentile contour plot for SSC, as defined by dredge plume modelling. This reflects the area where, for 95% of the time, excess SSC from the dredging will be below the calculated tolerance for benthic communities (10 mg/L in the Dry Season, 25 mg/L in the Wet Season, refer Section 5.5).

The predicted Zone of Moderate Impact and Zone of Influence for Dry Season and Wet Season dredging operations (at all three sites) are shown in Figure 13. These are based upon SSC, not upon sedimentation, as the predicted sedimentation rates are insufficiently high for equivalent zones to be determined (Section 5.4). The locations of recorded hard coral and filter-feeder communities are also shown.

The predicted impact zones have been determined on the basis of the MSB berth material being deposited onshore. For a scenario in which this material is deposited at the harbour disposal site (Section 2.6.1), the Zones of Moderate Impact and Influence are predicted to generally be encompassed within the corresponding zones shown in Figure 13. The only exception is the Wet Season Zone of Moderate Impact, which extends 35 m further to the north than the boundary shown in Figure 13.

Figure 13 Zone of Moderate Impact and Zone of Influence for Dry Season and Wet Season dredging operations



5.7 Conclusions

5.7.1 Suspended sediments

From Figure 13 it is evident that the hard coral and filter-feeder communities around South Shell Island are predicted to lie within the Zone of Moderate Impact during dredging operations in either the Dry Season or the Wet Season. Following the definition within WA EPA (2016), this would indicate that mortality of benthic biota could occur, but that the disturbed areas may recover and there would be no long-term modification of the benthic habitats. However, in considering the SSC time series at South Shell Island presented in Figure 11 and Figure 12 it is evident that:

- During the Dry Season, the 10 mg/L SSC tolerance limit for benthic communities is predicted to be exceeded on eight days during dredging and two days following dredging (the latter due to continued resuspension and dispersion of sediments deposited during the dredging campaign). It is emphasised that the 10 mg/L tolerance limit is for dredging-related SSC, whereas Figure 11 and Figure 12 show total SSC (background of 5 mg/L plus dredging-related SSC).
- During the Wet Season, the 25 mg/L SSC tolerance limit for benthic communities is predicted to only be exceeded on three days during dredging.

This indicates that, provided the SSCs generated during dredging and spoil disposal are not significantly greater than those upon which the modelling of Williams (2017) was based, then:

- In the Dry Season, it is considered highly unlikely that such short-term elevations in SSC would result in mortality within the hard coral and filter-feeder communities of South Shell Island. It is reasonable to conclude that elevations of SSCs over longer time periods would be necessary for detectable impacts to occur.
- The risk of turbidity impacts during the Wet Season can be considered negligible. It could be expected that similar SSCs would regularly occur in the waters around South Shell Island on each spring tide cycle during the Wet Season.

Hence, it can be concluded that the implementation of robust monitoring of SSCs at South Shell Island and around the dredging and spoil disposal locations (as presented in Section 7.2.3) will be key to the protection of the benthic communities around South Shell Island.

5.7.2 Sedimentation

The sediment dispersion modelling predicts that the accumulation of dredging-derived sediment is not predicted to approach the 50 mm tolerance limit in any of the mangrove communities that are potentially reached by the turbid plumes generated by the dredging and spoil disposal. Hence sediment accumulation is not expected to impact on mangrove communities in areas such as Bleesers Creek and Charles Darwin National Park. It would be reasonably expected that Wet Season wave activity under normal conditions would have a greater impact in these areas than sedimentation associated with the dredging and spoil disposal.

The sediment dispersion modelling also predicts that there will be no net sedimentation of >2.5 mm within the hard coral and filter-feeder communities in East Arm. Hence it is concluded that the dredging and spoil disposal activities will pose a negligible risk of significant sedimentation impacts upon these communities.

It is concluded that potential sedimentation effects need not be given further detailed consideration in this Plan and that monitoring and management of suspended sediment levels within the pond system, and around the spoil disposal locations, will provide an appropriate level of mitigation against the risk of sedimentation impacts upon the receiving environment.

6.0 Environmental Risk Assessment

6.1 Purpose

A systematic environmental risk assessment process has been applied to address the potential risks associated with maintenance dredging by Darwin Port. It takes into account guidance within the draft *Guideline for the Preparation of an Environmental Management Plan* (NT EPA 2015b) and is aligned with the standard *AS/NZS ISO 31000: 2009 Risk Management* and with Environment Institute of Australia and New Zealand guidelines (EIANZ 2015).

The purpose of the risk assessment process was to identify the activities, and the environmental aspects associated with those activities, that have the potential to result in environmental impacts; and to guide the development of management measures and controls to avoid or reduce those potential impacts. The assessment of environmental risk is an essential component of Darwin Port's approach to the environmental impact assessment process. It forms that basis for ongoing management and review of significant environmental risks that may arise over the course of maintenance dredging activities. Management controls identified through the risk assessment process are included in the Environmental Management Frameworks (EMFs) presented in Section 7.0 of this Plan.

6.2 Methodology

The risk assessment methodology ensured that a systematic approach was applied to the assessment and management of environmental risk; it comprised two main steps – risk scoping and risk assessment.

6.2.1 Risk scoping

The risk scoping step comprised the identification of:

- Environmental aspects - features or characteristics of a project activity that have the potential to affect the environment.
- Potential environmental impacts - any potential change to the environment, whether adverse or beneficial, wholly or partly resulting from a project's environmental aspects.

Each environmental aspect was considered in turn against each sensitive receptor in the surrounding environment for a potential pathway or interaction. Where pathways existed, each potential environmental impact was considered.

6.2.2 Risk assessment

The risk assessment process considered two factors:

- The magnitude of direct or indirect impacts on environmental receptors from project activities (Table 4).
- The sensitivity of these receptors to direct or indirect impacts (Table 5).

Following the matrix in Figure 14 the predicted magnitude of impact, and receptor sensitivity, were used to produce a risk ranking (Table 6) for each impact. The outcomes of the risk assessment process are presented in Table 7.

It should be noted that the risk assessment encompasses activities that are directly related to operation of the dredge and to disposal of spoil. General vessel-related environmental aspects (e.g. unplanned hydrocarbon releases, waste disposal, marine pest introduction) are managed under other auspices (e.g. Oil Spill Response Plan, Port Environmental Management Plan, biosecurity regulations).

Table 4 Criteria for assessment of magnitude of impacts

Rank	Water Quality	Ecology
Negligible	Change from baseline conditions is immeasurable, undetectable or within the range of normal variation.	Negligible effect on known population or range of species.
Small	Minor detectable change from baseline conditions over a limited distance (hundreds of metres) from source. Baseline conditions return within one month of cessation of activity.	Affects a specific group of localised individuals within a population over a short time period (one generation or less), but does not affect other trophic levels or the population itself.
Medium	Readily discernible change in quality beyond 1 km from source. Baseline conditions return within weeks of cessation of activity.	Affects a portion of a population and may bring about a change in abundance and/or distribution over more than one generation, but does not threaten the integrity of that population or any population dependent on it.
Large	Readily discernible change in quality over a large area (>10 km^2) that persists over several months, with likely secondary impacts on marine ecology.	Affects a high portion of a population and may bring about a change in abundance and/or distribution over two or more generations, potentially threatening the integrity of that population or a population dependent on it.
Severe	Major alteration to baseline conditions over a large area (>10 km^2) that persists for more than 12 months, with probable secondary impacts on marine ecology.	Affects an entire population or species in sufficient magnitude to cause a decline in abundance and/or change in distribution beyond which natural recruitment (reproduction, immigration from unaffected areas) would not return that population or species, or any population or species dependent upon it, to its former level within several generations.

Table 5 Criteria for assessment of receptor sensitivity

Rank	Water Quality	Ecology
Low	Existing water quality is good and the ecological resources that it supports are not sensitive to a change in water quality.	The ecological features are abundant, common or widely distributed and are generally adaptable to changing environments. Species are not endangered or protected.
Moderate	Existing water quality already shows some signs of stress and/or supports ecological resources that could be sensitive to change in water quality.	Some ecological features have low abundance, restricted ranges, are currently under pressure or are slow to adapt to changing environments. Species are valued locally/regionally and may be endemic, endangered or protected.
High	Existing water quality is already under stress and/or the ecological resources it supports are very sensitive to change (secondary ecological impacts are likely).	Some ecological features in the area are rare or endemic, under significant pressure and / or highly sensitive to changing environments. Species are valued nationally /globally and are listed as endangered or protected.

Figure 14 Risk matrix

		Sensitivity		
		Low	Moderate	High
Magnitude	Negligible	Minor	Minor	Minor
	Small	Minor	Minor	Moderate
	Medium	Minor	Moderate	Major
	Large	Moderate	Major	Major
	Severe	Major	Major	Major

Table 6 Risk categories

Risk	Description
Minor	Negligible risk of persistent changes to receptors. No management measures beyond those routinely applied to operations are required for the risk to be considered as low as reasonably practicable (ALARP).
Moderate	Reversible changes to receptors may occur. Corrective actions (i.e. management measures that are additional to those routinely applied to operations) are likely to be required to reduce risk to ALARP.
Major	Unacceptable risks to receptors. Project modifications or additional management measures are required to reduce risk to ALARP.

Table 7 Risk assessment outcomes

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
Fort Hill Wharf						
Seabed disturbance	Dredging of unconsolidated material from berths	Mortality of biota entrained within dredged sediments.	Medium	Low	Minor	Biota will be those that have colonised the sediments subsequent to the previous dredging campaign. Hence they are likely to be pioneer species that will recolonise the dredged seabed once the activities are complete. They are unlikely to represent a significant component of the harbour food web as similar habitats are widespread within the harbour.
	Spoil disposal in harbour	Smothering of biota in, and on, the seabed at disposal location, potentially leading to mortality.	Medium	Low	Minor	Colonisation of the deposited dredge spoil is likely to occur in the short term, most likely by species present in unconsolidated sediment habitats nearby. Biota at the disposal location are unlikely to represent a significant component of the harbour food web as similar habitats are widespread within the harbour.
Sediment plumes	Dredging and spoil disposal	Increased SSC in water column.	Small	Low	Minor	SSC increases will be orders of magnitude greater at the spoil disposal location than at the dredging site. However, it is predicted from modelling (Section 5.4) that tidal currents will rapidly disperse the suspended sediments.
		Increased toxicant concentrations in water column.	TBC	Moderate	TBC	Magnitude of potential impact and risk rank are to be confirmed (TBC) on the basis of sediment characterisation undertaken prior to each dredging campaign. A recent preliminary sediment geochemistry investigation did not detect elevated toxicants or nutrients in samples from the East Arm Wharf berths.
		Increased nutrient concentrations in water column.	TBC	Low	TBC	
		Reduction in incident light levels to benthic biota, potentially leading to	Small	Low	Minor	Benthic biota within the area over which reduced light levels may occur are well represented within

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
		reduced growth or to mortality.				the harbour. No benthic communities of conservation significance are known to occur in the vicinity of the dredging and spoil disposal activities.
		Clogging of fauna feeding or respiratory structures, potentially leading to reduced growth or to mortality.	Small	Low	Minor	The habitats for biota which may come into contact with suspended sediments from the dredging and spoil disposal activities are well represented within the harbour.
		Reduction in food availability or foraging habitat for protected marine species, potentially leading to displacement.	Small	Moderate	Minor	No benthic communities of critical importance to protected marine species are known to occur in the vicinity of the dredging and spoil disposal activities. Some individuals may temporarily forage in alternative harbour areas for the duration of the activities.
Indirect sedimentation	Dredging and spoil disposal	Smothering of biota distant from activity, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	It is predicted from modelling that net sedimentation in mangroves, and on benthic biota, in the vicinity of Fort Hill Wharf will be imperceptible from that which occurs in the absence of dredging (Section 5.7).
Underwater noise and vibration	Dredging	Displacement of protected marine species.	Small	Moderate	Minor	Some individuals of protected marine species may temporarily relocate to alternative locations in the harbour for the duration of the dredging activities. There are no known areas within the vicinity of Fort Hill Wharf that are of critical importance to feeding or breeding for protected marine species. The area in which dredging will take place is currently subjected to underwater noise and vibration from vessel activity.
Vessel movements	Dredging	Vessel collision with protected marine species.	Small	Moderate	Minor	The area in which dredging will take place is currently subjected to substantial vessel activity, including small, fast-moving craft that pose a greater risk of impact to marine fauna than slow-moving work vessels associated with dredging operations. The dredge itself will be essentially stationary whilst operational.

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
						A marine fauna observer (MFO) will be on board the dredge and operators of project vessels will have been notified of marine fauna risks during project inductions.
East Arm Wharf						
Seabed disturbance	Dredging of unconsolidated material from berths	Mortality of biota entrained within dredged sediments.	Medium	Low	Minor	Biota will be those that have colonised the sediments subsequent to the previous dredging campaign. Hence they are likely to be pioneer species that will recolonise the dredged seabed once the activities are complete. They are unlikely to represent a significant component of the harbour food web as similar habitats are widespread within the harbour.
	Spoil disposal in harbour	Smothering of biota in, and on, the seabed at disposal location, potentially leading to mortality.	Medium	Low	Minor	Colonisation of the deposited dredge spoil is likely to occur in the short term, most likely by species present in unconsolidated sediment habitats nearby. Biota at the disposal location are unlikely to represent a significant component of the harbour food web as similar habitats are widespread within the harbour.
Sediment plumes	Dredging and spoil disposal	Increased SSC in water column.	Small	Low	Minor	SSC increases will be orders of magnitude greater at the spoil disposal location than at the dredging site. However, it is predicted from modelling (Section 5.4) that tidal currents will rapidly disperse the suspended sediments.
		Increased toxicant concentrations in water column.	TBC	Moderate	TBC	Magnitude of potential impact and risk rank are to be confirmed (TBC) on the basis of sediment characterisation undertaken prior to each dredging campaign. A recent preliminary sediment geochemistry investigation did not detect elevated toxicants or nutrients in samples from the East Arm Wharf berths.
		Increased nutrient concentrations in water column.	TBC	Low	TBC	

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
		Reduction in incident light levels to benthic biota, potentially leading to reduced growth or to mortality.	Small	Low	Minor	Benthic biota within the area over which reduced light levels may occur are well represented within the harbour. In the past, a degree of research importance has been ascribed to the filter-feeder communities around South Shell Island. However, it is predicted from modelling (Section 5.4) that the duration of elevations in SSC (above predicted tolerance limits [Section 5.5]) over these communities will be in the order of days. It is considered likely that the communities will not be adversely affected by such temporary SSC elevations as they are exposed to similar elevations during each spring tide phase.
		Clogging of fauna feeding or respiratory structures, potentially leading to reduced growth or to mortality.	Small	Low	Minor	The habitats for biota which may come into contact with suspended sediments from the dredging and spoil disposal activities are well represented within the harbour.
		Reduction in food availability or foraging habitat for protected marine species, potentially leading to displacement.	Small	Moderate	Minor	No benthic communities of critical importance to protected marine species are known to occur in the vicinity of the dredging and spoil disposal activities. Some individuals may temporarily forage in alternative harbour areas for the duration of the activities.
Indirect sedimentation	Dredging and spoil disposal	Smothering of benthic biota distant from activity, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	It is predicted from modelling that net sedimentation in mangroves, and on benthic biota, in the vicinity of East Arm will be imperceptible from that which occurs in the absence of dredging (Section 5.7).
Underwater noise and vibration	Dredging	Displacement of protected marine species.	Small	Moderate	Minor	Some individuals of protected marine species may temporarily relocate to alternative locations in the harbour for the duration of the dredging activities. There are no known areas within the vicinity of East Arm Wharf that are of critical importance to feeding or breeding for protected marine species. The area in which dredging will take place is currently

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
						subjected to underwater noise and vibration from vessel activity.
Vessel movements	Dredging	Vessel collision with protected marine species.	Small	Moderate	Minor	The area in which dredging will take place is currently subjected to substantial vessel activity, including small, fast-moving craft that pose a greater risk of impact to marine fauna than slow-moving work vessels associated with dredging operations. The dredge itself will be essentially stationary whilst operational. An MFO will be on board the dredge and operators of project vessels will have been notified of marine fauna risks during project inductions.
MSB						
Seabed disturbance	Dredging of unconsolidated material from berths	Mortality of biota entrained within dredged sediments.	Medium	Low	Minor	Biota will be those that have colonised the sediments subsequent to the previous dredging campaign. Hence they are likely to be pioneer species that will recolonise the dredged seabed once the activities are complete. They are unlikely to represent a significant component of the harbour food web as similar habitats are widespread within the harbour.
Sediment plumes	Dredging	Increased SSC in water column.	Small	Low	Minor	It is predicted from modelling (Section 5.4) that increases in SSC due to the liberation of suspended sediments at the dredge cutter head will be imperceptible from those due to disposal of spoil from the East Arm Wharf dredging.
		Increased toxicant concentrations in water column.	TBC	Moderate	TBC	Magnitude of potential impact and risk rank are to be confirmed (TBC) on the basis of sediment characterisation undertaken prior to each dredging campaign. A recent preliminary sediment geochemistry investigation did not detect elevated toxicants or nutrients in samples from the MSB berths.
		Increased nutrient concentrations in water column.	TBC	Moderate	TBC	

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
		Reduction in incident light levels to benthic biota, potentially leading to reduced growth or to mortality.	Small	Low	Minor	Benthic biota within the area over which reduced light levels may occur are well represented within the harbour. In the past, a degree of research importance has been ascribed to the filter-feeder communities around South Shell Island. However, it is predicted from modelling (Section 5.4) that there will be no increases in SSC above the benthic community tolerance limits during dredging at the MSB.
		Clogging of fauna feeding or respiratory structures, potentially leading to reduced growth or to mortality.	Small	Low	Minor	The habitats for biota which may come into contact with suspended sediments from the dredging and spoil disposal activities are well represented within the harbour.
		Reduction in food availability or foraging habitat for protected marine species, potentially leading to displacement.	Small	Moderate	Minor	No benthic communities of critical importance to protected marine species are known to occur in the vicinity of the dredging and spoil disposal activities. Some individuals may temporarily forage in alternative harbour areas for the duration of the activities.
Indirect sedimentation	Dredging	Smothering of biota, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	It is predicted from modelling that net sedimentation in mangroves, and on benthic biota, in the vicinity of East Arm will be imperceptible from that which occurs in the absence of dredging (Section 5.7).
Underwater noise and vibration	Dredging	Displacement of protected marine species.	Small	Moderate	Minor	Some individuals of protected marine species may temporarily relocate to alternative locations in the harbour for the duration of the dredging activities. There are no known areas within the vicinity of the MSB that are of critical importance to feeding or breeding for protected marine species. The area in which dredging will take place is currently subjected to underwater noise and vibration from vessel activity.

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
Vessel movements	Dredging	Vessel collision with protected marine species.	Small	Moderate	Minor	The area in which dredging will take place is currently subjected to vessel activity. The dredge itself will be essentially stationary whilst operational. An MFO will be on board the dredge and operators of project vessels will have been notified of marine fauna risks during project inductions.
Tailwater release	Spoil disposal into decant ponds	Increased SSC in receiving waters.	Negligible	Low	Minor	During previous dredging campaigns, in which far greater volumes of dredge spoil were disposed within the decant ponds, tailwater clarity has typically been higher (i.e. SSC has been lower) than in the receiving waters of Frances Bay.
		Increased acidity or alkalinity in receiving waters.	Negligible	Low	Minor	Prior to its release, tailwater will be tested to ensure the pH is within a range over which adverse impacts to biota are unlikely.
		Increased toxicant concentrations in receiving waters.	Negligible	Low	Minor	Prior to its release, tailwater will be tested to ensure toxicant concentrations are below levels at which adverse impacts to biota may occur
		Increased nutrient concentrations in receiving waters.	Negligible	Low	Minor	Any nutrients within the tailwater will be rapidly dispersed once they enter the Frances Bay environment and are likely to be imperceptible from background concentrations within a short distance from the bund wall.
		Reduction in incident light levels to benthic biota, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	During previous dredging campaigns, tailwater clarity has typically been higher than in the receiving waters of Frances Bay; hence incident light levels may increase, rather than decrease.
		Clogging of fauna feeding or respiratory structures, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	During previous dredging campaigns, tailwater clarity has typically been higher than in the receiving waters of Frances Bay; hence there is reduced risk of clogging of fauna feeding and

Aspect	Activity	Impact	Magnitude	Sensitivity	Risk	Comments
		Smothering of biota, potentially leading to reduced growth or to mortality.	Negligible	Low	Minor	respiratory structures, and a reduced risk of smothering.
		Reduction in food availability or foraging habitat for protected marine species, potentially leading to displacement.	Negligible	Moderate	Minor	The tailwater will not have any characteristics that may cause a reduction in food availability for protected marine species.
Tailwater flow	Spoil disposal into decant ponds	Disturbance to migratory birds at roost sites in Pond K and Pond D.	Negligible	Moderate	Minor	Pond D is a protected habitat used by shorebirds at East Arm Wharf. This pond will not be used for direct placement of dredge spoil or tailwater storage and the dredge contractor will ensure that there is no direct disturbance to the pond. Adding further dredge spoil to Pond K is not expected to create any significant disturbance to migratory shorebirds roosting on Pond D. Birds have continued to roost in the vicinity during similar activities undertaken previously and there is a long history of vehicular movements in the general vicinity of Pond and Pond D. (Dr Stephen Garnett, pers. comm., 20 November 2017)

7.0 Environmental Monitoring and Management

7.1 Introduction

This section describes the EMFs, and associated monitoring programs, that have been developed for the key risks associated with the dredging works. The EMFs are instrumental to effectively manage and mitigate environmental risks to sensitive receptors identified in Section 4.0.

EMFs have been developed for the following aspects:

- Darwin Harbour - water quality
- Dredge spoil decant ponds - water quality
- Protected marine species – physical interaction
- Protected marine species – underwater noise

Each EMF states the relevant project commitments made and objectives to be met, and contains specific, measurable targets to achieve the objectives. It also summarises the management actions required to meet these targets, the relevant KPIs and the monitoring activities to be employed to measure success in meeting the requirements and identify the need for corrective actions.

It should be noted that:

- Management actions are routine tasks that will be undertaken to meet the objectives of each EMF.
- Corrective actions are those tasks that are possible to be undertaken if monitoring indicates that trigger values have been exceeded.

Where trigger values are proposed, it should be noted that these are triggers for further investigation and are set well below levels at which significant adverse ecological effects could be anticipated, thus protecting the declared beneficial uses of Darwin Harbour (Section 1.6). Each EMF also indicates the relevant reporting requirements (detailed further in Section 8.0) and the responsibilities of project personnel.

7.2 Darwin Harbour - water quality

7.2.1 Potential impacts

The cutter head of the dredge and the discharge of dredge spoil will generate plumes of turbid water containing elevated levels of suspended sediments. The magnitude of the impacts due to dredge related suspended sediment plumes will be proportionate to the duration of dredging and the volume of sediment to be dredged, both of which are relatively minor for the maintenance dredging proposed. The tailwater discharge from the dredge spoil decant ponds will also contribute suspended sediments to the receiving environment in vicinity of the permeable railway bund wall at East Arm Port, though on occasions (e.g. during spring tides) the concentrations of suspended sediments in the tailwater may be less than those in the receiving environment.

Plumes of suspended sediments may impact upon marine organisms through clogging of feeding or respiratory structures or through a reduction in light penetration through the water column.

7.2.2 Trigger values

Reactive turbidity trigger values have been set for the monitoring sites at South Shell Island and at sites 200 m down-current from the dredging and spoil disposal sites (Section 7.2.3.2); these are based on turbidity data collected by URS (2011) in a long-term water quality study conducted in Darwin Harbour. The URS data were collected every 15 minutes at two sites in East Arm (South Shell Island and North-east Wickham Point) over a year-long program. Data were grouped and averaged based on tidal cycle and seasonal variation, allowing seasonal means, medians, and percentiles to be calculated. This gives a robust body of data to compare background levels of turbidity with potential increases associated with various natural and artificial turbidity-generating events in the harbour.

Different trigger values will apply between the Wet Season and the Dry Season due to differences in background SSC concentrations:

- If dredging is undertaken during the Wet Season (November to April), then dredging-related SSC at the monitoring sites will need to be maintained below 25 mg/L (the predicted Wet Season tolerance limit of benthic communities to excess SSC [refer Section 5.5]). As SSC cannot be directly monitored in the field, a dredging-related turbidity trigger value of 21.2 NTU will be applied; calculated as per the URS (2011) relationship between NTU and SSC for East Arm; NTU = (SSC- 7.0477)/0.848.
- If dredging is undertaken during the Dry Season (May to October), then dredging-related SSC at the monitoring sites will need to be maintained below 10 mg/L (the predicted Dry Season tolerance limit of benthic communities to excess SSC [refer Section 5.5]) and a dredging-related turbidity trigger value of 3.5 NTU will be applied (as per URS [2011]). Depending upon background levels, this may maintain turbidity outside of the ‘mixing zone’ to below the neap tide, Dry Season benchmark level of 4 NTU for Darwin Harbour (Cassilles-Southgate 2016, Fortune 2016).

7.2.3 Darwin harbour water quality monitoring program

7.2.3.1 Objective

The objective of this monitoring program is to ascertain turbidity levels over the duration of dredging and spoil disposal activities. This will enable assessments to be made of the potential for impacts on marine communities to occur from these activities. The approach is aligned with guidance provided in publications such as those of the Central Dredging Association (CEDA 2015) and the International Association of Dredging Companies (IADC 2016).

The program will:

- Utilise existing water quality data as a pre-dredging baseline (refer Section 7.2.2).
- Monitor turbidity levels in the water at South Shell Island, and near the dredging footprints and spoil disposal locations, during dredging.
- Trigger the implementation of dredge management measures (refer Section 7.2.5) if water quality data indicate that turbidity levels from dredging and spoil disposal are greater than those predicted from modelling (refer Section 5.4).

7.2.3.2 Monitoring locations

Turbidity monitoring within Darwin Harbour will be undertaken at the following locations (

Figure 15):

- South Shell Island locations. These are putative impact sites due to their proximity to the dredging and spoil disposal locations, the model outcomes (Section 5.4) and the known presence of benthic communities that may be adversely affected by increased turbidity levels from dredging at East Arm Wharf and the MSB. Hard coral communities are present at the location of site SSI-West, while site SSI-E is located within filter-feeder communities. Site SSI-West is the closer of the two to the dredging activities at East Arm Wharf and, due to the passage of ebb tide currents to the north of South Shell Island, there may also be a greater potential for turbid plumes from the MSB dredging to impinge upon this site than upon site SSI-East. For this reason, site SSI-West is treated as the ‘primary’ potential impact site, with data from site SI-East used to inform the attributability assessment that would be conducted in the event of a trigger value exceedance at site SSI-West (see Section 7.2.4).
- Locations 200 m up-current and down-current from the dredging and spoil disposal locations for the Fort Hill Wharf dredging operations. While modelling indicates that these operations are sufficiently distant from benthic communities that may be sensitive to increased turbidity levels, this monitoring will be used to verify the veracity of the turbidity levels predicted by the modelling.
- Locations 200 m up-current and down-current from the dredging and spoil disposal locations for the East Arm Wharf dredging operations. Monitoring will be undertaken on flood tides, as these

are the times when the chance of plumes from the dredging operation reaching the benthic communities around South Shell Island is highest.

- Locations 200 m up-current and down-current from the dredging activity at the MSB. Monitoring will be undertaken on ebb tides, as these are the times when the chance of plumes from the dredging operation reaching the benthic communities around South Shell Island is highest.
- A reference location distant from the dredging and spoil disposal operations. Data from a reference location are required in the event that it is necessary to assess whether changes in water quality at the South Shell Island sites are due to the dredging and spoil disposal activities, or to the influence of harbour-wide changes in water quality (e.g. due to a period of high rainfall or elevated wave action).

Figure 15 Turbidity monitoring locations

*Monitoring locations:
- Are shown for ebb tides; on flood tides the upstream (U) and downstream (D) sites will be in reverse positions.
- Are shown relative to the dredge and spoil disposal locations depicted; actual monitoring locations will vary in accordance with the positions of the dredge and spoil disposal at the time of monitoring.
- MSB-Sp will only be monitored during harbour disposal of MSB spoil.

It should be noted that the '200 m up-current and down-current' sites shown in Figure 15are relative to the dredging and spoil disposal locations depicted in the figure; these monitoring sites will vary slightly according to the actual locations of dredging and spoil disposal at the time of monitoring. They are also depicted for an ebb tide scenario; on flood tides the up-current and down-current sites will be in the reverse positions.

The 200 m radius 'mixing zones' extending from the dredging and spoil disposal locations are considered appropriate as the model outputs represent probability plots for plume distribution; they do not represent 'snapshots' of plume distribution. Hence maintaining SSCs below the tolerance limits for turbidity-sensitive benthic communities at distances of 200 m or less from the turbidity-generating activities will provide assurance that the tolerance limits will not be exceeded at the nearest sensitive receptors (for East Arm Wharf and the MSB these are the coral and filter-feeder communities around South Shell Island).

7.2.3.3 Methodology

Monitoring will be undertaken daily for the duration of dredging and spoil disposal (into the harbour). The timing of the monitoring will be:

- Fort Hill Wharf – on flood tides, to ascertain the turbidity levels entering Frances Bay.
- East Arm Wharf - on flood tides, to ascertain the turbidity levels approaching the benthic communities on the western side of South Shell Island.
- MSB - on ebb tides, to ascertain the turbidity levels approaching the benthic communities of South Shell Island.

Turbidity will be measured, using a calibrated turbidity sensor, through the entire water column at each site and the mean (i.e. depth-averaged) turbidity calculated.

7.2.3.4 Data analysis

Turbidity data from the South Shell Island monitoring sites will be compared against the appropriate seasonal trigger value (21.2 NTU in the Wet Season or 3.5 NTU in the Dry Season).

For each monitoring location that is down-current from a dredging or spoil disposal location, the mean turbidity (in NTU) measured will be ‘corrected’ to account for non-dredging-related turbidity by subtracting the mean turbidity measured at the corresponding up-current site. The resultant mean turbidity value will then be compared against the appropriate seasonal trigger value.

7.2.3.5 Outcomes

The data outputs from the monitoring will enable ongoing assessments to be made of the need to implement management measures within the dredging and spoil disposal operations to maintain turbidity levels at the South Shell Island monitoring sites to below the predicted tolerance thresholds for the coral and filter-feeder communities around the island. Figure 16, Figure 17 and Figure 18 summarise the approaches for assessing the need to implement management measures for each of the three dredging and spoil disposal locations.

Figure 16 Turbidity monitoring flowchart – Fort Hill Wharf

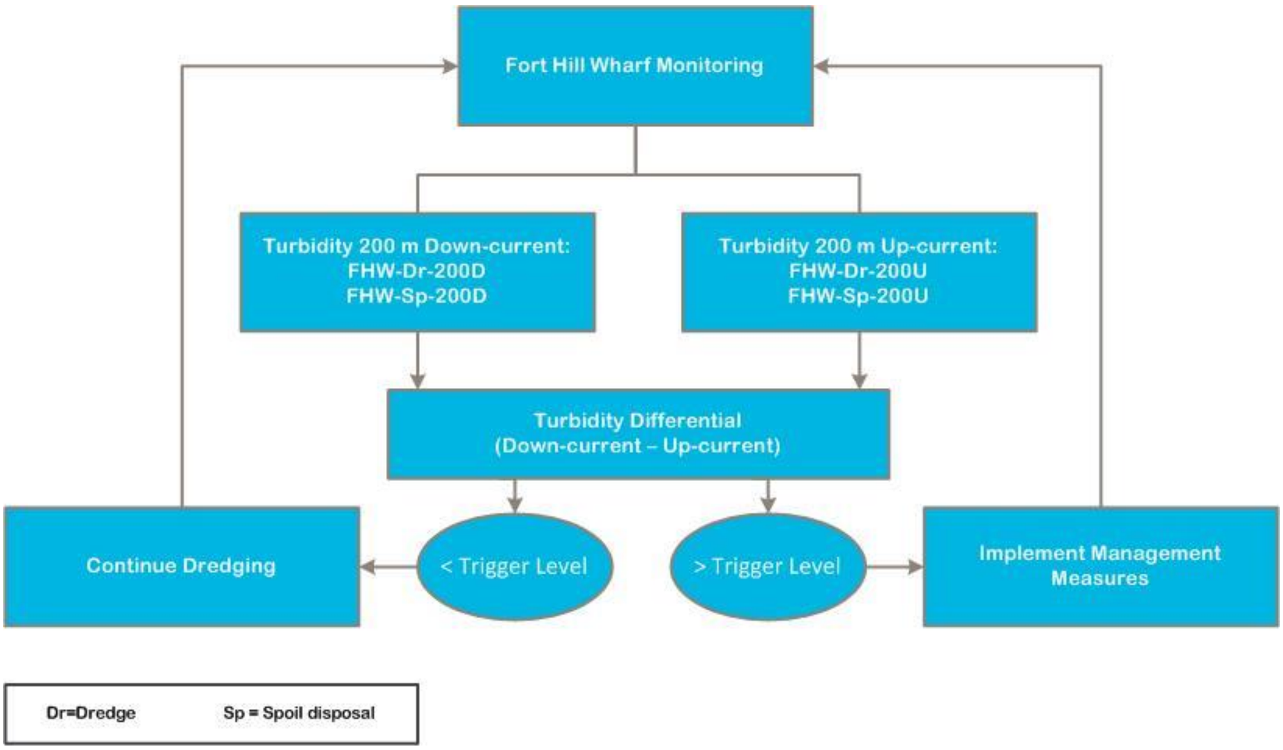


Figure 17 Turbidity monitoring flowchart – East Arm Wharf

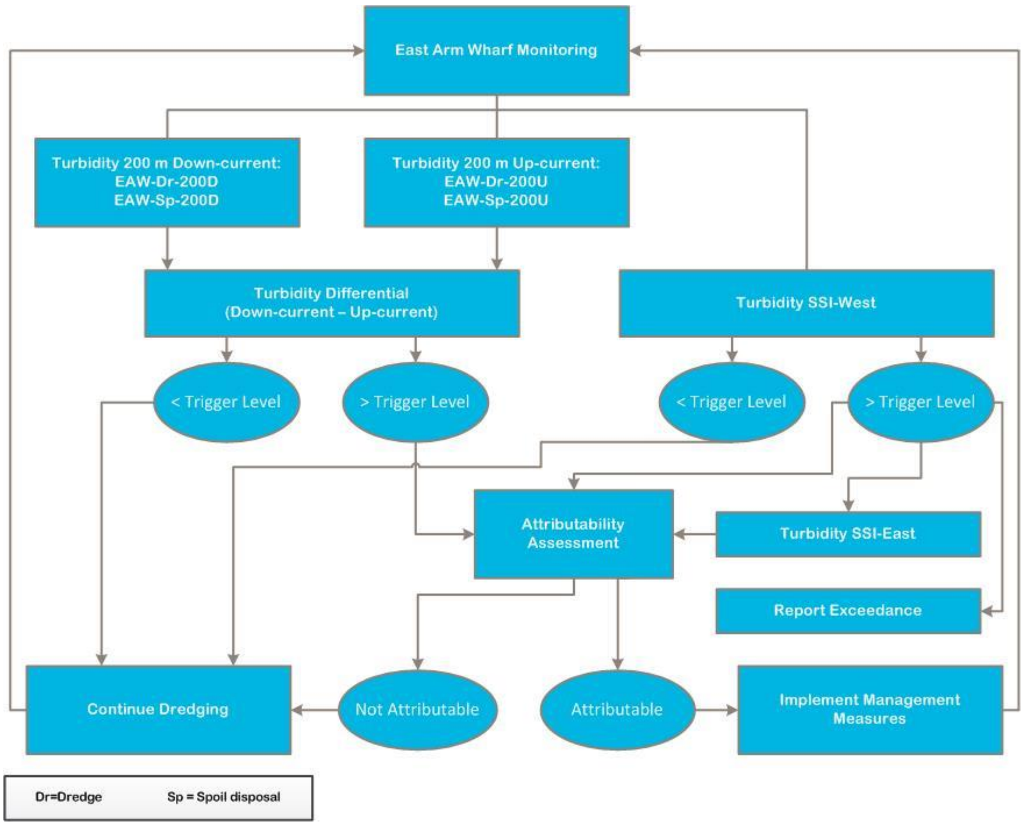
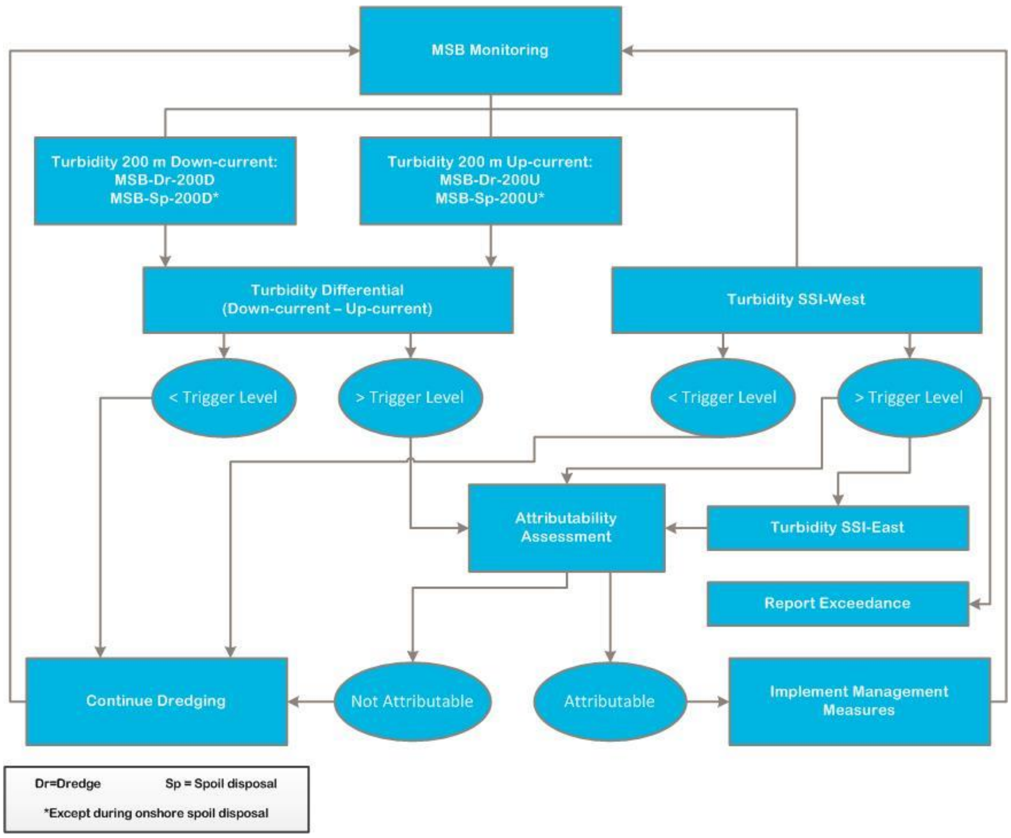


Figure 18 Turbidity monitoring flowchart – MSB



7.2.4 Response to trigger exceedance

Trigger exceedances will only apply to data from the SSI-West monitoring site. The data from the monitoring locations that are down-current from the dredging and spoil disposal locations (refer Section 7.2.3.2) will be used as 'early warning' indicators that corrective actions may need to be applied to the dredging operations to minimise the potential for trigger exceedances to occur at the SSI-West site.

If a seasonal turbidity trigger value (21.2 NTU in the Wet Season or 3.5 NTU in the Dry Season) is exceeded at the SSI-West monitoring site, then this will be reported by the Contractor to Darwin Port within 24 hours of the exceedance occurring. Also within 24 hours, additional monitoring and corrective actions (see Section 7.2.5, Table 8 and Table 9) will be implemented in a manner aimed at determining which have the greatest potential to reduce the dispersion of plumes from the dredging and spoil disposal operations towards South Shell Island.

Concurrently, an attributability assessment will be initiated by the Contractor and submitted to Darwin Port to determine whether or not the exceedance was likely to have been caused by dredging or spoil disposal activities. This assessment will be completed within three business days of the exceedance occurring and will include consideration of information such as:

- Changes in water quality at the reference location (which would indicate whether there were regional increases in turbidity due to natural factors such as storm activity) and at site SSI-East.
- Observations of turbid plumes emanating from other sources within East Arm.
- Wind, wave, current direction and tidal data.

If it is deemed that the exceedance is potentially due to the maintenance dredging or spoil disposal operations, then those corrective actions (Table 8) that are most effective in adequately reducing turbidity emanating from these activities will continue to be implemented until such time as the turbidity levels fall to below the trigger value.

7.2.5 Management measures

The following inherent characteristics of the dredging operation are anticipated to minimise the generation of turbid plumes:

- The maintenance dredging operations are situated close to shore, at locations which are afforded some protection from the effects of tidal currents.
- The dredge operations will involve a single, static CSD with the suction pipe directly behind the cutter head. This maximises feed to the suction pipe and minimise the release of sediment into the water column surrounding the dredge.
- Cutter speed will be as low as possible, and the cutter will be disengaged for much of the time given the unconsolidated nature of the sediment to be dredged and its close proximity to infrastructure, while dredge pumps will operate at the maximum speed possible.

Consideration of trends in the water quality data collected during the monitoring program (Section 7.2.3) will be used to adaptively manage the maintenance dredging and spoil disposal operations to minimise the potential for water quality trigger values to be exceeded. The monitoring will provide advanced warning of any impending trigger value exceedance, allowing precautionary corrective actions (refer Table 8; these take account of contemporary guidance, such as that in Mills & Kemps [2016]) to be implemented before the trigger value is exceeded. For example, observations during monitoring will indicate the times within the tidal cycle when the migration of dredge and spoil disposal plumes towards South Shell Island is highest; maintenance or relocation of the dredge can then be scheduled to coincide with those times. The trigger and response procedures for monitoring at South Shell Island are summarised in Table 9.

Table 8 Water quality EMF – Darwin Harbour

Darwin Harbour Water Quality Management Framework	
Element	Maintenance of water quality within Darwin Harbour.
Commitments	Waste Discharge Licence conditions.
Objective	To minimise impacts upon the hard coral and filter-feeder communities at South Shell Island from turbid plumes emanating from dredging and spoil disposal operations.
Target	No instances of exceedance of turbidity trigger values at the South Shell Island monitoring sites.
Key Performance Indicator(s)	• Number of instances of exceedance of turbidity trigger value at South Shell Island monitoring site SSI-West that require corrective actions to be implemented to return turbidity to an acceptable level. • Number of hours before turbidity at site SSI-West reduces to below the trigger value.
Management	Dredge cutter head and pump speeds managed to minimise dispersion of fine sediments from the cutter head.
Monitoring	• Reactive water quality monitoring at sites around South Shell Island, the dredging and spoil disposal locations, and a reference site. • Visual observation of plume dispersion from spoil disposal locations.
Reporting	• Daily reporting of data by Contractor to Darwin Port. • Monitoring report to NT EPA at conclusion of dredging. • Trigger value exceedances at South Shell Island monitoring site SSI-West will be reported by Contractor to Darwin Port within 24 hours of the exceedance occurring. • A report on corrective actions implemented to address the cause of the exceedance will be submitted by Contractor to Darwin Port within two business days of the notification. • Contractor will notify Darwin Port of the outcome of their investigation into attributability of the exceedance to dredging within three business days of the notification
Corrective Action(s)	• Slowing the cutter head or slew speed on the dredge to reduce sediment loss into the water column. • Increasing the water content of the discharged spoil (i.e. increasing the water-to-sediment ratio). • Reducing or temporarily suspending dredging and spoil disposal activity during tidal periods when the migration of dredge plumes towards South Shell Island is greatest.
Term	For the duration of dredging and spoil disposal operations.
Responsibility	• Contractor to ensure documents are compliant with the LTDMP. • Contractor project manager to ensure monitoring program and water quality management measures are implemented. • Contractor is required to take direction from the Darwin Port project manager.

Table 9 South Shell Island monitoring – triggers and responses

Components	Water Quality Trigger
Trigger value	Depth-averaged mean NTU at South Shell Island monitoring site SSI-West exceeds: • Wet Season – 21.2 NTU • Dry Season – 3.5 NTU
Trigger Description	An exceedance will be deemed to have occurred if the appropriate seasonal trigger listed above is exceeded. Trigger value exceedances will be reported to Darwin Port within 24 hours of the exceedance occurring.

Components	Water Quality Trigger
Attributability Assessment	If a trigger value is exceeded, then an assessment will be undertaken to determine whether or not the exceedance is attributable to dredging. This assessment will be completed within three business days of the exceedance occurring. The assessment will include consideration of information such as: • Changes in water quality at the reference site and at site SSI-East. • Observations of turbid plumes emanating from other sources within East Arm. • Climatic and tidal conditions.
Monitoring Response	Hourly monitoring of turbidity at site SSI-West until such time as the turbidity levels fall to below the trigger value.
Management Response	Within 24 hours of exceedance of the water quality trigger, implement corrective action(s) (Table 8) to reduce turbidity attributable to dredging and spoil disposal that impinges upon the South Shell Island benthic communities.
Reporting	Reports detailing the monitoring data collected and corrective action(s) implemented will be submitted to Darwin Port within two business days of exceedance.

7.3 Dredge spoil decant ponds - water quality

7.3.1 Potential impacts

There are two primary sources of impact upon the receiving environment in Frances Bay from tailwater discharge from the decant ponds:

- Elevated concentrations of suspended sediments; these are addressed in Section 7.2.1.
- Increased acidity (i.e. reduced pH) and/or elevated toxicant concentrations. These could result in acute or chronic adverse impacts upon biota in the vicinity of the permeable section of the railway bund wall.

7.3.2 Water quality criteria for disposal of tailwater

The key water quality guidelines that are relevant to the management of the dredging and spoil disposal works are the ANZECC Guidelines (ANZECC & ARMCANZ 2000) and the Darwin Harbour Region WQOs (Fortune 2016). The Darwin Harbour Region Report Cards (e.g. Fortune 2016) are also relevant as they contain data from ongoing NTG water quality monitoring in Darwin Harbour.

The National Water Quality Management Strategy recommends that “the guidelines for each indicator should be based on locally derived data to reflect local (ambient) conditions. Where derivation of guidelines based on local monitoring is not possible, it is recommended that the national ANZECC Guidelines are used instead (for tropical Australia)”. Therefore, the most applicable guidelines for this project are Darwin Harbour Region WQOs, and in the absence of guidelines for certain parameters, reference will be made to the national ANZECC Guidelines.

The most stringent water quality criterion for Darwin Harbour was considered by NRETAS (2010) to be the environmental beneficial use category. This was because the intent of the environmental beneficial use was to maintain the health of aquatic ecosystems, and a water body that meets an environmental beneficial use will in almost all circumstances also meet the requirements for all other beneficial uses.

NRETAS (2010) adopted the ANZECC Guidelines approach for physico-chemical indicators for ‘slightly to moderately disturbed’ systems. The ANZECC guidelines have defined acceptable effect sizes for each level of protection for different indicator types (Table 10).

Table 10 ANZECC Guidelines default effect size for varying levels of protection

Indicator Class	Effect Size or Departure from Reference		
	High Conservation Value Systems	Slightly to Moderately Disturbed Systems	Highly Disturbed Systems
Toxicants in water	No change to natural values	95% of species protected	80-90% spp. protected
Toxicants in sediments	No change to natural values	>90% individuals protected	
Physico-chemical*	No change to natural values	Median lies within $20^{th}/80^{th}$ percentile of reference range*	Locally determined ($10^{th}/90^{th}$ percentile of range)
Biological	No change to natural values	Median lies within $20^{th}/80^{th}$ percentile of reference range	Locally determined ($10^{th}/90^{th}$ percentile of range)

*Applicable to the approach taken with WQOs for the Darwin Harbour Region

NRETAS (2010) states that the Darwin Harbour Region WQOs can be used as a tool for monitoring water quality and supporting decision making on the management of activities affecting coastal marine waters in the Darwin Harbour catchment. They apply to ambient waters (i.e. the receiving waters) and should not be regarded as individual discharge criteria. The values include protection of aquatic ecosystems and recreational activities associated with the use of marine waters such as swimming, boating and fishing. Where the values are not being met, planning and management of these areas should move towards achieving the objectives over time.

The Darwin Harbour Region WQOs and the ANZECC Guidelines can be used to provide guidance to those undertaking water quality monitoring programs by providing key water quality indicators that can be monitored over time. Measured water quality can be compared with the criteria to determine whether management goals are being achieved or where management action is required.

The Darwin Harbour Region WQOs and ANZECC Guidelines apply to the receiving environment, rather than to the tailwater within the decant ponds. However, if the tailwater meets the following criteria then it will be considered suitable for continued disposal:

- The daily mean pH of the three water samples tested during monitoring at the discharge point from Pond E (South) (see Section 7.3.3.2) is >6.0 and <8.5. This will meet the WQO for an Upper Estuary setting (Fortune 2016).
- For toxicants the Darwin Harbour Region WQOs defer to the ANZECC Guidelines. Hence concentrations of toxicants will be compared against the ANZECC Guidelines for ‘slightly to moderately disturbed’ ecosystems (i.e. for 95% species protection) (ANZECC & ARMCANZ 2000). For some toxicants the ANZECC Guidelines have no criteria levels for marine waters as there are considered to be insufficient data to derive reliable trigger values. In these instances, it is proposed to adopt the criteria levels for fresh water. The list of metallic toxicants to be tested (Table 11) is based on the potential presence and toxicity of these metals in Darwin Harbour.
- The target SSC for the tailwater will be 100 mg/L (140 NTU). As SSC cannot be monitored directly in the environment, turbidity (in NTU) is used as a surrogate measure. A mathematical relationship between NTU and SSC was derived from water samples collected within the pond system and analysed for both SSC and turbidity as part of the MSB capital dredging monitoring program (DoI 2014). This relationship (100 mg/L = 140 NTU) will be applied during interpretation of water quality monitoring undertaken during the maintenance dredging campaigns. As the relationship was based upon the finer sediment fraction of the capital material that had migrated through the pond system, it is considered equally applicable to the finer sediment fraction of maintenance dredge material.

Table 11 Toxicant trigger levels

Toxicant	Trigger Level
Arsenic (AsIII)	24 µg/l (freshwater)
Arsenic (AsV)	13 µg/l (freshwater)
Cadmium	5.5 µg/l
Chromium (CrIII)	27.4 µg/l
Chromium (CrVI)	4.4 µg/l
Copper	1.3 µg/l
Lead	4.4 µg/l
Mercury (inorganic)	0.4 µg/l
Nickel	70 µg/l
Selenium (total)	5 µg/l (freshwater)
Zinc	15 µg/l

7.3.3 Decant ponds water quality monitoring program

7.3.3.1 Objective

The objective of monitoring water quality within the decant ponds is to confirm the physico-chemical properties (SSC, pH and toxicant concentrations) of the tailwater are suitable for release from the ponds to the harbour waters. That is, the quality of water discharging through the permeable section of the railway bund wall is within the criteria discussed in Section 7.3.2.

7.3.3.2 Monitoring locations

The water quality monitoring sites are shown in Figure 19. The pH and toxicant concentrations of the tailwater within Pond K (i.e. at Site 1) will be ascertained before discharge into Pond E (North) is permitted to commence. When tailwater is flowing through the pond system, turbidity will be monitored at the reclamation boxes (Sites 1 and 2) and within Pond E (South), close to the permeable section of the railway bund wall (Site 3). Pond E (South) is effectively considered to be the ‘receiving environment’, with the railway bund wall providing an additional buffer against impacts upon the environment of Frances Bay.

7.3.3.3 Methodology

During disposal of dredged material into Pond K, the weir to Pond E (North) will be closed such that all tailwater is retained within Pond K. At the completion of spoil disposal into Pond K, three water samples will be collected from the tailwater in the immediate proximity of the reclamation box leading to Pond E (North); i.e. at Site 1 in Figure 19. The samples will be sent to a National Association of Testing Authorities (NATA) accredited laboratory for analysis of toxicant concentrations. Prior to analysis, the samples will be filtered to remove particles >45 µm in diameter; this will reduce the potential for sediment-bound toxicants to be included in the analyses and will provide a measure of the bioavailable concentrations of any toxicants that are present. Based on potential toxicity and presence within Darwin Harbour sediments, the toxicants to be monitored through collection of water samples are shown in Table 11. Speciated toxicants (arsenic and chromium) will be analysed for total values, and if any total exceeds the trigger level of one of the species, then the samples will be reanalysed for the individual species.

The pH of the tailwater at Site 1 will also be tested, using a hand-held pH meter, to ascertain whether there are any causes for concern with respect to pH (i.e. pH <6.0 or >8.5) that may need to be addressed whilst the samples are being analysed for toxicants.

If the laboratory analytical results indicate that the mean concentrations of all toxicants are below ANZECC Guideline criteria levels (Table 11), the pH levels in three samples of tailwater from Site 1 will be ascertained. If the mean pH is within the range 6.0-8.5, then tailwater release into Pond E (North) will commence.

Commencing at the time of first tailwater flow through the reclamation box between Pond K and Pond E (North), and continuing until tailwater ceases to flow through the reclamation box between Pond E (North) and Pond E (South), tailwater turbidity will be monitored (using a hand-held probe) at Sites 1, 2 and 3 (Figure 19) three times daily. The turbidity level at Site 3 will be compared against the turbidity trigger value (140 NTU) to ascertain whether or not contingency measures (as per Table 12) need to be implemented. The turbidity levels at Sites 1 and 2 will assist in determining whether any elevations in turbidity at Site 3 are due to tailwater from the spoil disposal operation or from other factors (such as stormwater inputs or the resuspension of settled sediments within Pond E [South] due to meteorological or tidal effects).

Over the duration of tailwater flow through the reclamation box between Pond E (North) and Pond E (South), daily visual inspections of the water outside of the permeable section of the railway bund wall will be conducted to confirm that the tailwater discharge is not giving rise to any of the adverse impacts listed in Table 12.

Figure 19 Water quality monitoring locations

7.3.4 Outcomes

The data outputs from the monitoring will enable assessments to be made of the need to implement corrective actions to:

- Render the tailwater suitable for release from Pond K (on the basis of pH level and toxicant concentrations).
- Maintain turbidity levels within Pond E (South) below the trigger level in order to render the water suitable for continued disposal.

7.3.5 Response to trigger exceedance

Prior to the release of tailwater from Pond K, if the laboratory analytical results indicate that the mean concentrations of any (dissolved) toxicants exceed ANZECC Guideline criteria levels, or if the pH lies outside of the range 6.0-8.5, then further investigations and contingency measures (e.g. dilution of tailwater with seawater, refer Table 12) will be instigated and tailwater will be retained within Pond K.

During tailwater discharge, if the mean turbidity level in Pond E (South) exceeds the trigger level (140 NTU) then (subject to the need to keep the weir open under high stormwater flow conditions), the reclamation box between Pond E (North) and Pond E (South) will be closed until turbidity levels have fallen to below 140 NTU.

7.3.6 Management measures

7.3.6.1 Tailwater

Tailwater release into Pond E (North) will not commence until such time as the quality of the tailwater (pH level and toxicant concentrations) at Site 1 is deemed acceptable (as per criteria listed in Table 12). Once the mean concentrations of all toxicants are below the trigger levels listed in Table 11, and the pH is confirmed to be within the acceptable range (6.0-8.5), the upper weir boards will be progressively removed such that the clearest surface layers of tailwater begin to flow into Pond E (North), thence into Pond E (South) and eventually through the permeable section of the bund wall and into Frances Bay.

In the event that the reclamation box between Pond E (North) and Pond E (South) is closed during tailwater discharge (due to exceedance of the turbidity trigger level), then corrective actions (Table 12) will be implemented and confirmed as successful by monitoring before recommencing discharge.

7.3.6.2 Potential Acid Sulfate Soil

Should PASS be detected in the pre-dredging geochemical assessment of the material to be dredged from the MSB (in volumes likely to have a noticeable impact on water quality), then dredge spoil will be disposed of at the harbour location to the east of the MSB (Section 2.6.1), provided all toxicant concentrations are below ANZECC Guideline criteria levels. This will remove the risk of spoil coming into contact with the atmosphere and the potential acidification of the sediments.

Table 12 Water quality EMF - dredge spoil decant ponds

Water Quality Management Framework - dredge spoil decant ponds	
Element	Maintenance of water quality within dredge spoil decant ponds.
Commitments	Waste Discharge Licence conditions.
Objectives	To protect receiving waters from dredging-related impacts.
Target	1. No increase in tailwater acidity within Pond K to the extent that it is unacceptable for discharge due to low pH (<6.0). 2. No increase in tailwater alkalinity within Pond K to the extent that it is unacceptable for discharge due to high pH (>8.5). 3. No exceedances of ANZECC Guideline criteria for toxicants (refer Table 11) in tailwater within Pond K prior to the commencement of transfer into Pond E (North). 4. 100% of tailwater discharging from Pond E (South) has SSC less than 100 mg/L (measured as turbidity [140 NTU], refer Section 7.3.2). 5. No occasions when tailwater discharging from Pond E (South): a. Contains floating oil or grease or petroleum hydrocarbon sheen or scum, or litter or

Water Quality Management Framework - dredge spoil decant ponds	
	other objectionable matter. b. Causes or generates odours which would adversely affect the use of surrounding waters. c. Causes algal blooms. d. Causes adverse impacts on plants.
Key Performance Indicator(s)	• Number of instances when SSC in Pond E (South) is >100 mg/L (measured as turbidity, refer Section 7.3.2). • Number of instances when target criteria 5 (a)-(d) are not met.
Management	• Dredge spoil will be directly deposited only into Pond K or, if required for PASS management, to the harbour disposal site to the east of the MSB. • The reclamation box between Pond K and Pond E (North) will remain closed during deposition of spoil into Pond K. • Once deposition of spoil has been completed, tailwater will be tested to ascertain the pH and the concentrations of all toxicants. • Once it is confirmed that pH is in the range 6.0-8.5 and the mean concentrations of all toxicants are below the ANZECC Guideline criteria (refer Table 11), the upper weir boards will be progressively removed such that the clearest surface layers of tailwater begin to flow into Pond E (North).
Monitoring	• Water quality monitoring within ponds – turbidity, pH and toxicants. • Visual monitoring of target criteria 5 (a)-(d) outside the permeable section of railway bund. • Water level monitoring to ensure no overflow from ponds and to control residence times.
Reporting	• Weekly reporting of data by Contractor to Darwin Port. • Trigger level exceedances at any monitoring location will be reported by Contractor to Darwin Port within 24 hours of the exceedance being detected. • A report on corrective actions implemented to address the cause of the exceedance will be provided by Contractor to Darwin Port within one business day of the notification. • Monitoring report to NT EPA at conclusion of dredging.
Corrective Action(s)	• If deemed by the Contractor to be potentially effective in increasing the pH of the water in Pond K to >6.0 (but not above 8.5), high carbonate-content soil may be used to cover pond sediments that are exposed to air if it is apparent they are a source of acidification of the water. • Harbour water may be pumped into Pond K to return the pH of the tailwater to between 6.0 and 8.5. The mean recorded pH of seawater in the vicinity of South Shell Island is 8.0 (Table 3). • If pH is >8.5 in Pond K, then the water will not be discharged into Pond E (North) until such time as the pH decreases to below 8.5 (but not below 6.0). • If toxicant concentrations exceed ANZECC Guideline levels (Table 11) in Pond K and the bioavailable component is deemed to pose a risk, then tailwater will not be released into Pond E (North) until such time as they fall below the trigger levels (e.g. through dilution with harbour water). • If SSC exceeds 100 mg/L in Pond E (South) at the railway bund wall then (subject to the need to keep the weir open under high stormwater flow conditions) tailwater flows out of Pond E (North) will be blocked at the reclamation box until SSC levels at the transfer point between Pond E (North) and Pond E (South) have fallen to below 100 mg/L.
Term	From the completion of spoil disposal into the ponds, until tailwater ceases flowing from Pond E (North) into Pond E (South).
Responsibility	• Contractor to ensure documents are compliant with the LTDMP. • Contractor project manager to ensure monitoring program and water quality management measures are implemented. • Contractor is required to take direction from the Darwin Port project manager.

7.4 Protected marine species – physical interaction

7.4.1 Potential impacts

The main risk of physical interaction with protected marine species will be in relation to the movement of dredge support vessels (e.g. crew transfer vessel, tender vessel). The risk of direct impact to protected marine species from the operating dredge is considered to be very low; the dredge will be stationary during most of the works and the cutter head will not often be engaged (due to the nature of the sediment to be dredged and its proximity to infrastructure).

When moving between or within the dredging footprint, the dredge will transit at low speeds (<5 kn) and only over small distances (tens of metres). In these circumstances, the dredge and support vessels will be replacing regular vessel traffic in what is usually an operational environment, meaning the risk of vessel strike is not greater than that posed during usual port operations.

It should be noted that physical interactions between dredging vessels and marine species are a higher risk when mobile dredges such as trailer suction hopper dredges are used and when dredged material is disposed offshore by barges. Neither of these scenarios is applicable to the maintenance dredging works.

7.4.2 Protected marine species monitoring program

7.4.2.1 Objective

The objective of the monitoring program is to minimise the risk of injury to, or mortality of, protected marine species.

7.4.2.2 Methodology

At all times that the dredge is operational, the crew will include at least one member that is trained (by a recognised training provider) as an MFO. The MFO will be responsible for undertaking visual assessments (for protected marine species) of the 150 m radius Observation Zone around the dredge (Figure 20) for a period of 10 minutes prior to the commencement of each period of dredging (i.e. on each occasion that the dredge has been non-operational for a period exceeding 30 minutes). The assessment of the Observation Zone will be made from an elevated position on the dredge, where a clear line of sight is achievable to the edge of the zone. The MFO will not be engaged in any other activities during the dedicated assessment periods.

During dredging, at 30 minute intervals the designated MFO will check, over a period of five minutes, the Exclusion Zone (Figure 20) for the presence of protected marine species.

7.4.3 Response to sightings

Sightings of protected marine species will be recorded (including details of the time and results of observation) if they are present within the:

- 150 m radius Observation Zone prior to the commencement of a period of dredging.
- Exclusion Zone during dredging.

If warranted, the corrective actions described in Table 13 will be implemented.

7.4.4 Management measures

The Contractor will provide awareness training to selected crew members to inform them about the protected marine species which may occur within Darwin Harbour; to provide a description of the record form to be used for recording protected marine species sightings; and to explain how to apply appropriate avoidance mitigation measures to minimise potential impacts or collisions with marine fauna. The purpose of the training is to raise awareness; to encourage recording and reporting of protected marine species sightings, and to emphasise the requirement to report stranded, injured or dead marine species regardless of what caused the injuries or deaths.

The Contractor will undertake observations for protected marine species and will report all positive sightings by the MFO to their Project Manager, who will ensure that sightings are logged and information is provided to Darwin Port. All sightings of protected marine species are recorded by the MFO on marine fauna observation forms similar to that presented in Figure 22; these will be available on all Project vessels. These records will then be logged into the Project marine fauna sighting register and will be used to identify potential fauna interaction areas which will be incorporated by the Contractor into pre-starts, toolboxes, marine fauna awareness training, and other general awareness sessions. The Contractor will report any incidents of injury or mortality to a listed threatened or migratory species (that may be attributable to the dredging activity) to Darwin Port within 24 hours.

Table 13 Protected marine species EMF - physical interaction

Protected Marine Species Management Framework – physical interaction	
Element	Vessel interaction with protected marine species.
Objectives	• Minimise the risk of injury to, or mortality of, protected marine species. • Develop and maintain awareness of the need to protect marine species.
Target	• No incidents of vessel interaction with protected marine species. • All dredging personnel to complete an HSE induction, including protected marine species awareness and management requirements. • All vessel masters competent in protected marine species interaction procedures. • At all times that the dredge is operational, at least one crew member is a trained MFO.
Key Performance Indicator(s)	• Number of incident reports. • Number of reported sightings of live, injured or dead marine fauna. • Number of personnel completing an HSE site induction. • Availability of MFO trained dredge operator
Management	• Training of Vessel Masters in interaction procedures and specified crew as MFOs. • A trained MFO must be on duty, above deck with good visibility, during all dredging operations. • On each occasion that the dredge has been non-operational for a period exceeding 30 minutes, a visual assessment shall be undertaken of the 150 m radius Observation Zone by the MFO for a period of 10 minutes. Dredging will not recommence until no protected marine species have been sighted within the 150 m radius Observation Zone for a period of 10 minutes. • The assessment of the Observation Zone will be made from an elevated position on the dredge, where a clear line of sight is achievable to the edge of the zone. • The MFO will not be engaged in any other activities during the 10 minute assessment period. • Every 30 minutes whilst the dredge is operating, the MFO will dedicate a period of five minutes for scanning (from an elevated position) for protected marine fauna within the Exclusion Zone. • If protected marine species are sighted within the Observation or Exclusion Zone, then a response in accordance with vessel interaction procedures (Figure 20) will be implemented. Dredging will be temporarily suspended if turtles, dugongs or dolphins enter within 50 m of the cutter head, or dolphins with calves enter within 150 m of the cutter head (i.e. the Exclusion Zone). • Dredging that commences prior to sunset, or prior to a period of low visibility, will continue unless, within the preceding 12 hours, there have been three or more suspensions of dredging due to protected species encroaching within the Exclusion Zone • On the few occasions when the dredge cutter head is used, it will only start when it is positioned near the seafloor, and rotation will be stopped before the cutter is raised through the water column. • Guidelines on approach distances for protected marine species (Figure 21) will be followed. • Support vessels will adhere to Darwin Port speed restrictions. • Support vessels will not approach, circle or wait in front of wildlife for the purposes of casual viewing. • Watch will be maintained for stranded, injured or dead protected marine fauna; if observed, the NT Government Marine Wildwatch line (1800-453-941) will be contacted for retrieval, treatment or post-mortem of the fauna.

Protected Marine Species Management Framework – physical interaction	
Monitoring	• Regular monitoring for the presence of stranded, injured or dead marine fauna • Marine fauna observations (refer to management section)
Reporting	• Daily submission to Darwin Port of marine fauna observations sheets (Figure 22). • Weekly summary reporting to Darwin Port of number of sightings, incidents and corrective actions. • Monitoring report to NT EPA at conclusion of dredging. • Any vessel interaction incidents and protected species injury or mortality will be reported to Darwin Port, and to NT EPA, within 24 hours of the incident occurring.
Corrective Action(s)	• In the event that an incident or near miss occurs between vessels and protected marine species, the incident will be investigated in order to identify opportunities to further improve awareness, and/or to develop procedures to reduce risk of collision. • For mobile vessels, a 5 kn vessel speed limit will be applied in areas where frequent sightings (an average of >1 per day in any one week) are made of protected marine species. • If protected marine species approach within the Caution Zone (Figure 21), vessels that are under way will proceed at a “no wash” speed.
Term	For the duration of dredging activities.
Responsibility	• Contractor to ensure their documents are compliant with the LTDMP. • Contractor to ensure protected marine species management and monitoring program is implemented. • Contractor project manager to liaise with NTG (via Marine Wildwatch [1800-453-941]) on response to stranded, injured or dead marine fauna and potential recovery, treatment or post-mortem.

Figure 20 Vessel interaction management flowchart

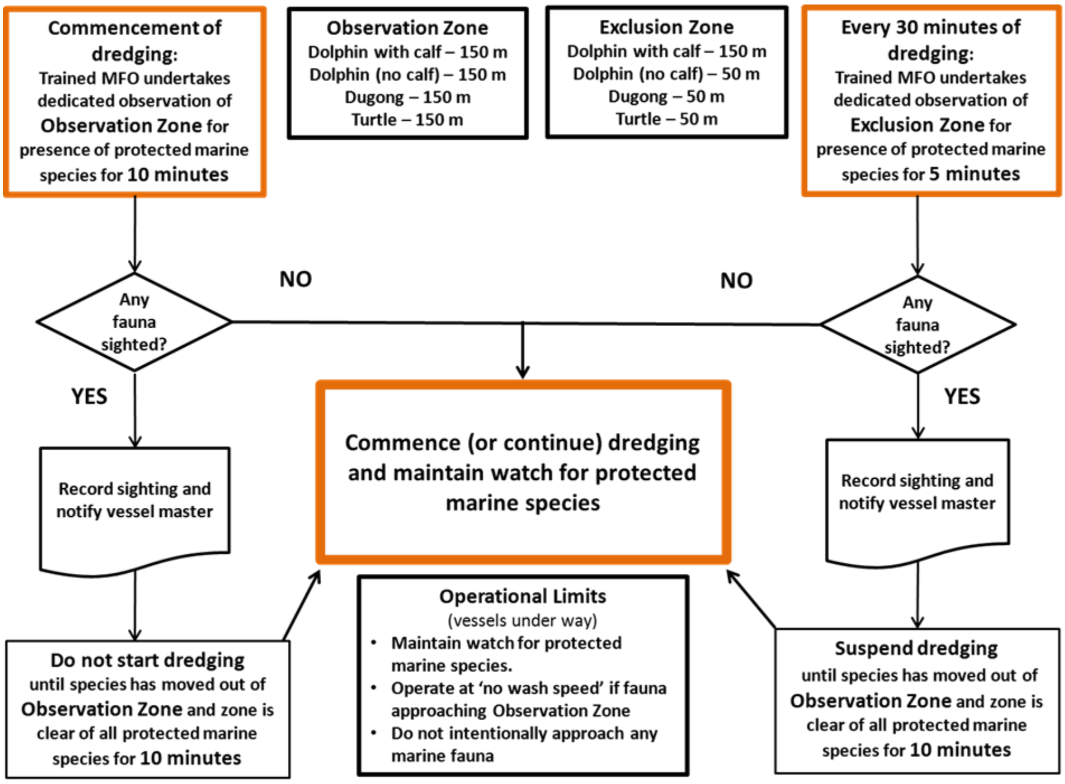
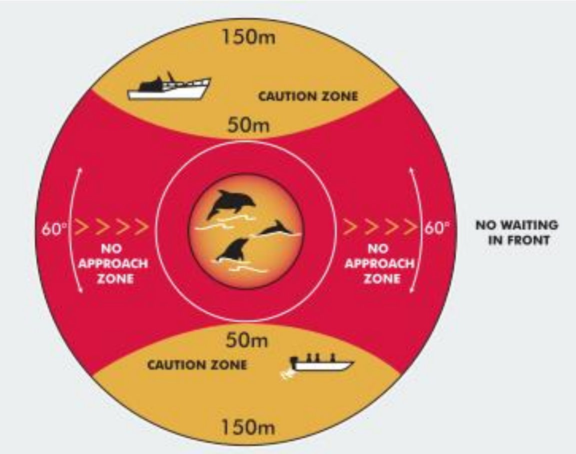


Figure 21 Guidelines on approach distances for dolphins



Source: Natural Resource Management Ministerial Council (2005)

Figure 22 Marine fauna observations form

Name : **Date** :

Employer : **Day or Night Shift** :

Time	Reported Observations & Actions							Initial
	Species[1]	No.	Calves (Y/N)	Distance (m)	Mitigation response[2]	Beaufort state	Comment	

[1] Record the species as accurately as you can. If unsure, use the general terms "dolphin", "turtle", "sawfish", etc.
[2] If no mitigation response is required, you should still record this.
Take photos if possible.

7.5 Protected marine species – underwater noise

Maintenance dredging will temporarily create additional underwater noise in various forms and intensity above current ambient levels in Darwin Harbour. However, noise levels at the dredging locations may be lower during dredging than during wharf operations due to the exclusion of shipping operations from these locations. Given the short duration of each maintenance dredging campaign, it is considered there is negligible risk of significant impacts upon protected marine species from underwater noise.

Coastal dolphins use sound for navigation, feeding and avoiding predators (through echolocation) and also for communication (through narrow band frequency modulated sound). The ability of dolphins to communicate, navigate and echolocate can be compromised by sound generated by human activity. While the ocean is naturally noisy, marine mammals are well adapted to natural levels of ambient noise. However, anthropogenic noise can cause masking (i.e. the blocking of the perception stimulus due to the presence of another stimulus in the same range) to occur (Jensen et al. 2009). Dolphins may be temporarily displaced from the vicinity of the dredging sites by the noise levels. Alternatively, the dolphins may adapt (dolphins are known to frequent busy harbours such as Singapore) or may tolerate the increased noise to feed on fish attracted to the operating dredge in search of food.

Turtle auditory morphology is adapted for hearing in water. They hear largely in the low frequency range (<1000 Hz), though the bandwidth and peak sensitivity varies between species. The use of sound by turtles is little understood. Experimentally, turtles have initially shown avoidance behaviour, then eventually habituating to the noise (Moein Bartol & Musick 2003). Observation of dredge activities around Australia is that turtles largely avoid coming in close proximity to the dredge. In part this is attributed to the sound of the dredge.

Little information is available on the auditory systems of dugongs and little research has been undertaken to investigate the sensitivity of dugongs to noise. There are only anecdotal reports of dugongs avoiding areas with high boat traffic.

Monitoring of protected marine species is described in Section 7.4.2. Management measures implemented to reduce the risk of disturbance of protected marine species by underwater noise generated by the dredging works are listed in Table 14.

Table 14 Protected marine species EMF - underwater noise

Protected Marine Species Management Framework – underwater noise	
Element	Impact of underwater noise on protected marine species.
Objectives	• Minimise the risk of disturbance to protected marine species from underwater noise. • Establish and maintain awareness of the importance of protecting marine species.
Target	• No avoidable disturbance to protected marine species as a result of noise generated during dredging activities. • All dredging personnel to complete an HSE induction. • At all times that dredge is operational, at least one crew member is trained MFO.
Key Performance Indicator(s)	• Number of audits and incident reports. • Number of reported sightings of live, injured or dead protected marine species. • Number of personnel completing an HSE site induction. • Availability of MFO trained crew member.
Management	• Ensure that all equipment is maintained in good operating condition (balancing, greasing, etc.) and have proper noise control systems in place. • Ensure all noise minimisation measures such as mufflers, special enclosures and sound-insulation mounts are fitted and working. • Ensure revolving equipment such as propellers and drive shafts are balanced to reduce vibration. • Minimise the noise generation of equipment (thrusters and auxiliary plant) by switching them off when not used (i.e. avoid running on standby mode).
Monitoring	• Marine fauna observations. • Regular monitoring for stranded, injured or dead marine fauna.
Reporting	• Daily submission of marine fauna observations sheets (Figure 22). • Weekly summary reporting to Darwin Port of number of sightings of protected marine species. • Monitoring report to NT EPA at the conclusion of dredging. • Any suspected noise related incidents will be reported by Contractor to Darwin Port within 24 hours of the incident occurring. Incidents will also be reported by Contractor direct to NT EPA within 24 hours of the incident occurring. • Any corrective actions implemented in response to suspected noise-related incidents will be detailed in the weekly report to Darwin Port. This report will also be provided to NT EPA.

Protected Marine Species Management Framework – underwater noise	
Corrective Action(s)	In the event that noise-related impact is suspected, the cause of any excessive noise will be investigated to identify the most appropriate action(s) to reduce the noise.
Term	For the duration of dredging activities.
Responsibility	• Contractor to ensure their documents are compliant with the LTDMP. • Contractor to implement noise management measures aboard vessels.

7.6 Summary of monitoring programs

Key aspects of each of the monitoring programs are summarised in Table 15 (commencing on the following page).

Table 15 Summary of monitoring program

Locations	Parameter	Methods	Frequency	Triggers	EMF
DREDGE AND SPOIL DISPOSAL PLUMES (refer Figure 15)					
Section 7.2.3.2 Water column at locations 200 m up-current and down-current from Fort Hill Wharf, East Arm Wharf and MSB dredge and spoil disposal locations.	Turbidity	Visual Hand-held probe	Daily on ebb tide for MSB dredging and flood tide for Fort Hill Wharf and East Arm Wharf dredging.	Differential in depth-averaged turbidity (NTU, measured through the water column) between the relevant pairs of up-current and down-current sites: Wet Season: 21.2 NTU Dry Season: 3.5 NTU Continue to monitor. Modify dredging and spoil disposal operations (Table 8) to reduce turbidity levels below the trigger value at a distance of 200 m from the dredge or spoil disposal location.	Water Quality Management - Darwin Harbour
Section 7.2.3.2 Water column at South Shell Island monitoring site SSI-West and a reference location.			Daily on ebb tide for MSB dredging and flood tide for East Arm Wharf dredging.	Average turbidity (NTU, measured through the water column) at site SSI-West: Wet Season: 21.2 NTU Dry Season: 3.5 NTU Increase frequency of monitoring at site SSI-West (Table 9), monitor site SSI-East and implement corrective actions (Table 8) to reduce turbidity levels to below trigger value.	
DREDGE SPOIL PLACEMENT PONDS (Corresponding relevant monitoring locations from Figure 19 are shown as ⊗ in the text)					
Section 7.3.3.2 At all pond outlets where tailwater is flowing and in Pond E (South) prior to discharge through the bund wall.	pH	Hand-held probe	Pond K, near the weir box leading to Pond E (North): • Once when water samples for toxicant analysis are collected. • Once prior to release of tailwater into Pond E (North).	pH<6.0 or pH>8.5 Refer to Table 12 for corrective actions to be considered by the Contractor in the event of a trigger exceedance. Relevant monitoring location: ①	Water Quality Management - Dredge Spoil Placement Ponds
	Toxicants	Laboratory	Pond K, near the weir box leading to Pond E (North): Prior to release of	Exceedance of any ANZECC Guidelines 95% level of protection levels	

Locations	Parameter	Methods	Frequency	Triggers	EMF
			tailwater to Pond E (North) being permitted to commence. Three samples collected on one occasion for laboratory analysis.	(Section 7.3.2; trigger levels detailed in Table 11). Refer to Table 12 for corrective actions to be considered by the Contractor in the event of a trigger exceedance. Relevant monitoring location: ①	
	Turbidity (NTU)	Hand-held probe	Three times daily from the commencement of tailwater flow from Pond K into Pond E (North) until the cessation of tailwater flow from Pond E (North) into Pond E (South).	Trigger level: 100 mg/L SSC = 140 NTU Continue to monitor and consider pre-emptive management actions to prevent exceedance in Pond E (North) at the weir into Pond E (South) or in Pond E (South) if trigger exceeded. Relevant monitoring locations: ① ② ③	
DREDGING AREA					
Section 7.4.2 Observation Zone and Exclusion Zone around dredge	Protected Marine Species - presence	Observation by trained observers (MFOs)	On each occasion that the dredge has been non-operational for a period exceeding 30 minutes, a visual assessment will be undertaken of the 150 m radius Observation Zone by the MFO, for a period of 10 minutes prior to the recommencement of dredging.	Trigger – presence of protected marine species within the 150 m Observation Zone. Dredging shall not commence until no protected marine species have been sighted within the Observation Zone for a period of 10 minutes.	Protected Marine Species Management – physical interaction and underwater noise
			Every 30 minutes, the Exclusion Zone will be assessed by the MFO for a period of five minutes.	Trigger – entry of protected marine species into the Exclusion Zone: • 150 m for dolphin with calf • 50 m for all other protected marine species, including dolphin without calf. Dredging will be temporarily suspended until such time as there has been no protected marine species sighted within the 150 m Observation Zone for a period of 10 minutes.	

8.0 Reporting

8.1 Routine reporting

8.1.1 Daily reporting

Brief daily reports will be provided by the Contractor to Darwin Port and will include:

- a summary of the dredging completed on that day and status of dredging operations
- turbidity (NTU) data from monitoring at sites up-current and down-current from the active dredge and spoil disposal locations and (during East Arm Wharf and MSB dredging) at South Shell Island monitoring site SSI-West and the reference site (Section 7.2.3)
- turbidity (NTU) data within Pond E (South), over the duration of tailwater flow from Pond K to Pond E (South) (Section 7.3.3.3)
- information relating to any exceedances detected through monitoring
- proposed schedule for dealing with exceedances reported and next steps to be followed
- records of sightings of protected marine species (Section 7.4.2)
- daily dredge logs showing work area and availability.

8.1.2 Weekly monitoring report

Each week during the dredging and tailwater discharge activities, a weekly summary report of monitoring data will be submitted by the Contractor to Darwin Port. The report will include:

- pH data for Pond K water at the time of collection of samples for toxicant analysis, and prior to tailwater release into Pond E (North) (Section 7.3.3)
- toxicant data for Pond K water, once available from the laboratory (Section 7.3.3.3)
- summary of daily data reports (Section 8.1.1)
- discussion of any trigger level exceedances (Section 8.2)
- corrective actions taken to address exceedances (Section 7.0)
- details of any injuries to, or mortalities of, turtles, dugongs or dolphins as a result of dredging activities (Section 8.3)
- a summary of environmentally significant equipment failures or events and an outline of corrective actions taken, or proposed, to reduce environmental harm arising therefrom (Section 8.3).

8.1.3 Dredge operation records and reporting

The Contractor will maintain daily records of areas dredged, the volumes of material removed and dredge availability. These records will be provided to Darwin Port weekly, and the findings from hydrographic surveys confirming dredge volumes and locations will be included in the Contractor report to the Darwin Port on completion of the dredging (see Section 8.1.4). Copies of the daily environmental inspection checklists and other relevant environmental records will be provided by the Contractor to Darwin Port. All records will be provided in a format that allows auditing by environmental regulators if required.

8.1.4 End of dredge phase reporting

Within one month of the conclusion of dredging, the Contractor will submit a monitoring report to Darwin Port which includes the outcomes of all monitoring activities, exceedances, management actions and any relevant trend analysis and interpretation of analytical data collected in accordance with environmental conditions.

8.1.5 Compliance reporting

Darwin Port will hold Waste Discharge Licences for the spoil disposal activities. As the licensee, Darwin Port will submit to NT EPA any reports, data and information in accordance with any timeframes required under the licenses. During dredging, the licensee will notify NT EPA of any non-compliance with the Waste Discharge Licences, as required by those licences.

8.2 Exceedance notification and reporting

The following notifications of exceedances will be made to Darwin Port within 24 hours of the exceedances occurring:

- The depth-averaged mean NTU at South Shell Island monitoring site SSI-West exceeding the relevant seasonal turbidity trigger value (Section 7.2.2).
- Exceedance of SSC (measured as NTU) trigger level within Pond E (South) during tailwater disposal from the MSB maintenance dredging (as per Section 7.3.2).

For any of these exceedances, the Contractor will provide Darwin Port with a report on the corrective actions implemented to address the cause of the exceedance and an assessment of attributability of the exceedance. These reports will be submitted in accordance with the timeframe stipulated in Table 8 and Table 12.

8.3 Environmental incident notification and reporting

In the event of the following environmental incidents, the Contractor will notify Darwin Port within 24 hours of the incident occurring:

- vessel interaction with protected marine species, including details of injury to, or mortality of, individuals (Section 7.4)
- suspected disturbance of protected marine species related to noise generated by dredging activities (Section 7.5).

Other environmental incidents (spills, etc.) will also be recorded and reported in environment monitoring reports to Darwin Port. If the incident is a notifiable incident under the *Waste Management and Pollution Control Act*, then Darwin Port will notify the NT EPA within 24 hours.

All incidents will be investigated and recorded on a Contractor ‘Incident Report Form’, ‘Environmental Incident Details Form’ or similar in accordance with Contractor’s accident investigation and reporting procedures. Preventative and corrective actions will be established and these will be recorded on the Contractor’s ‘Non-conformance and Corrective Action Register’, and the progress tracked for completion.

8.4 Complaints reporting

In the event of a complaint received as a result of dredging or spoil disposal activities, they will be entered and tracked using the Contractor’s incident management system. Details to be recorded include:

- date, time and method of complaints
- description of complaint
- complainant details
- cause, action and proposed action, including allocation of a person to action the complaint and an action date
- follow-up and close-out.

Corrective action in response to valid complaints is to occur within 48 hours following receipt of the complaint. Records will be made available to the Darwin Port and authorities upon request, taking into account any privacy issues of the complainant as appropriate.

8.5 Reporting and notification summary

The reporting and notification requirements for the Project are summarised in Table 16.

Table 16 Reporting and notification summary

Reporting Type	Time	Reporting to	Content/Comments
Routine Reporting			
Daily reporting (Section 8.1.1)	Dredging contractor to report daily during dredging and tailwater discharge activities.	Darwin Port	Brief work summary including the items identified in Section 8.1.1.
Weekly monitoring report (Section 8.1.2)	Weekly during dredging and tailwater discharge activities.	Darwin Port	Weekly summary report of monitoring data including the items identified in Section 8.1.2.
Dredge operations reporting (Section 8.1.3)	Dredging contractor to record daily, report weekly.	Darwin Port	Records of areas dredged, the volumes of material removed and dredge availability. Daily environmental inspection checklists and other relevant environmental records as outlined in Section 8.1.3.
End of dredging phase reporting (Section 8.1.4)	Dredging contractor to report within one month of conclusion of dredging.	Darwin Port	Outcomes of all monitoring activities, exceedances, management actions and any relevant interpretation of analytical data collected in accordance with environmental conditions.
Compliance reporting (Section 8.1.5)	Darwin Port to report as specified in the relevant Waste Discharge Licences.	NT EPA	Any reports, data and information will be submitted in accordance with any timeframes required under the licenses. During dredging, the licensee will notify NT EPA of any non-compliance with the Waste Discharge Licences, as required by those licences
Exceedance notification and reporting			
Water quality exceedance (Section 8.2)	Contractor to report any exceedance within 24 hours of occurrence.	Darwin Port	Location and value of exceedance.
Water quality corrective actions report (Section 8.2)	Contractor to report within two business days of exceedance.	Darwin Port	Corrective actions implemented to address the cause of the exceedance.
Water Quality attributability notification (Section 8.2)	Contractor to notify within three business days of exceedance.		Outcome of contractor's investigation into attributability of the exceedance to dredging including any data analysis undertaken.
Environmental incident notifications and reporting			
Injury to, mortality of, or disturbance of, a protected species (Section 8.3)	Contractor to report within 24 hours.	Darwin Port	Time, location and photos.

Reporting Type	Time	Reporting to	Content/Comments
Other environmental incidents (Section 8.3)	Contractor to report within 24 hours.	Darwin Port	Report generated from Contractor incident management system
Complaints reporting			
Complaints (Section 8.4)	Contractor to report within 48 hours following receipt of the complaint.	Darwin Port	Date, time and method of complaints, description of complaint, complainant details, cause, action and proposed action, including allocation of a person to action the complaint and an action date.

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Appendix A

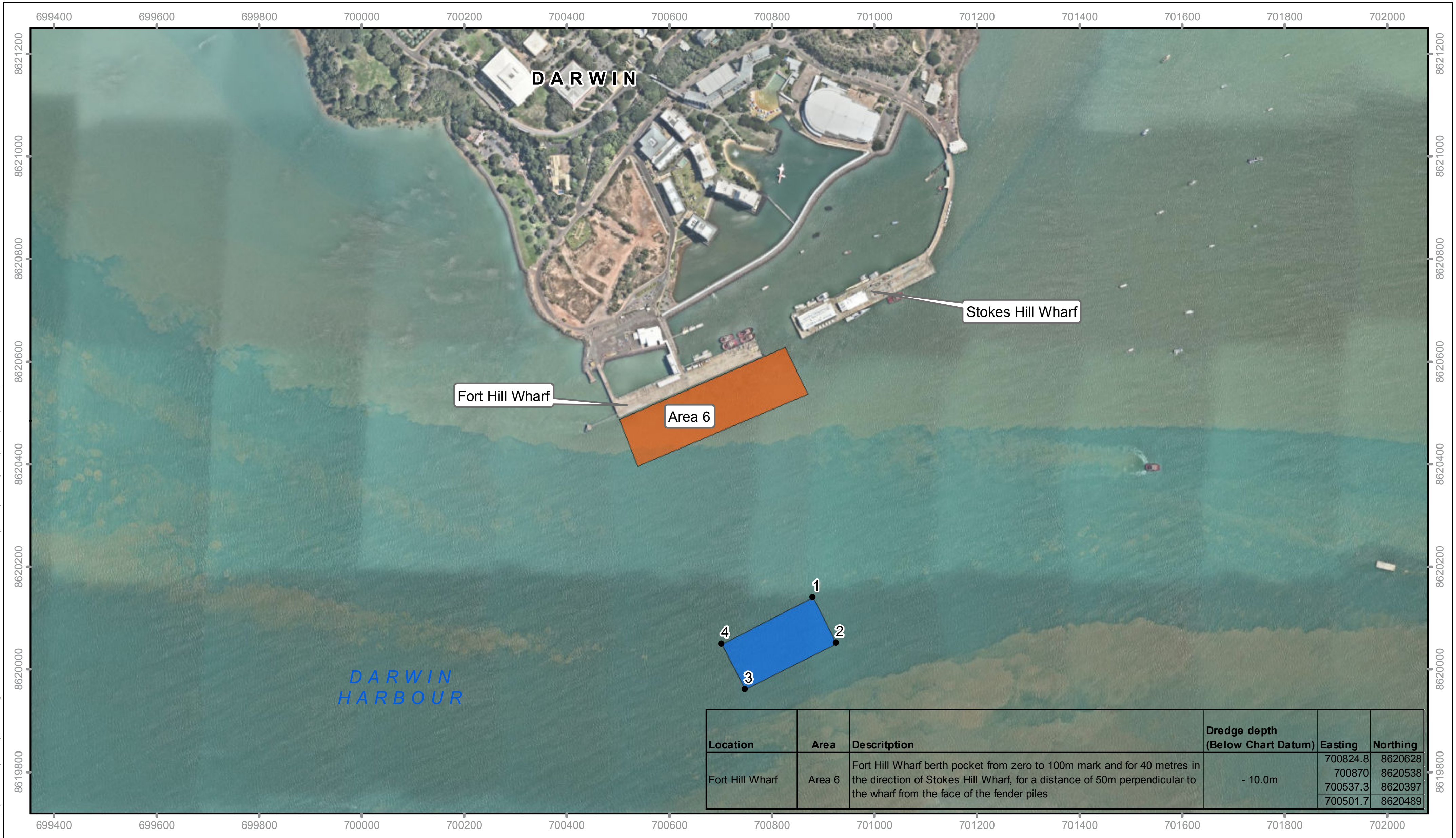
Dredging and Dredge Spoil (Harbour) Disposal Locations

Appendix A Dredging and Dredge Spoil (Harbour) Disposal Locations

Table 17 Boundary coordinates for areas where future potential dredging may occur.

Area	Longitude	Latitude
East Arm Wharf		
East Arm Berth 1	130.88392	-12.49252
East Arm Berth 1	130.88368	-12.49284
East Arm Berth 1	130.88255	-12.49204
East Arm Berth 1	130.88281	-12.49168
East Arm Berth 2	130.88283	-12.49168
East Arm Berth 2	130.88256	-12.49204
East Arm Berth 2	130.88033	-12.49044
East Arm Berth 2	130.88063	-12.49003
East Arm Bulk Port	130.88061	-12.49003
East Arm Bulk Port	130.88032	-12.49044
East Arm Bulk Port	130.87781	-12.48865
East Arm Bulk Port	130.87811	-12.48822
Fort Hill Wharf		
Fort Hill Wharf	130.84779	-12.47132
Fort Hill Wharf	130.84822	-12.47214
Fort Hill Wharf	130.84516	-12.47343
Fort Hill Wharf	130.84483	-12.47260
Marine Supply Base		
Marine Supply Base Berth 1	130.88973	-12.49181
Marine Supply Base Berth 1	130.89002	-12.49187
Marine Supply Base Berth 1	130.88980	-12.49298
Marine Supply Base Berth 1	130.88953	-12.49293
Marine Supply Base Berth 2	130.88973	-12.49180
Marine Supply Base Berth 2	130.89000	-12.49053
Marine Supply Base Berth 2	130.89030	-12.49059
Marine Supply Base Berth 2	130.89003	-12.49187
Marine Supply Base Swing Basin	130.89029	-12.49058
Marine Supply Base Swing Basin	130.89040	-12.49063
Marine Supply Base Swing Basin	130.89146	-12.49300
Marine Supply Base Swing Basin	130.89137	-12.49345
Marine Supply Base Swing Basin	130.88949	-12.49311
Marine Supply Base Swing Basin	130.88951	-12.49293

Area	Longitude	Latitude
Marine Supply Base Swing Basin	130.88981	-12.49298
Marine Supply Base Channel	130.89020	-12.49673
Marine Supply Base Channel	130.88766	-12.49859
Marine Supply Base Channel	130.88682	-12.49784
Marine Supply Base Channel	130.88906	-12.49638
Marine Supply Base Channel	130.88976	-12.49410
Marine Supply Base Channel	130.88945	-12.49309
Marine Supply Base Channel	130.89136	-12.49345
Marine Supply Base Channel	130.89067	-12.49435
Marine Supply Base Sandbar	130.88650	-12.49944
Marine Supply Base Sandbar	130.88563	-12.49863
Marine Supply Base Sandbar	130.88684	-12.49785
Marine Supply Base Sandbar	130.88767	-12.49858



Location	Area	Descritption	Dredge depth (Below Chart Datum)	Easting	Northing
Fort Hill Wharf	Area 6	Fort Hill Wharf berth pocket from zero to 100m mark and for 40 metres in the direction of Stokes Hill Wharf, for a distance of 50m perpendicular to the wharf from the face of the fender piles	- 10.0m	700824.8	8620628
				700870	8620538
				700537.3	8620397
				700501.7	8620489

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DATUM GDA 1994, PROJECTION MGA ZONE 52

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LEGEND

- Dredge Disposal Boundary Point
- Sediment Area Boundaries
- LTDMP Disposal Location

Disposal Location Corner Coordinates

Point	Easting	Northing
1	700879.28	8620141.04
2	700924.80	8620052.00
3	700746.72	8619960.96
4	700701.20	8620050.00

Data sources:

Base Data: (c) 20XX (data source) (additional data)

DARWIN PORT LONG TERM DREDGING MANAGEMENT PLAN

Fort Hill Wharf

PROJECT ID 60553579
CREATED BY peter.young
LAST MODIFIED 08-Dec-2017
VERSION 1

Figure 23

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Location	Area	Descritption	Dredge depth (Below Chart Datum)	Easting	Northing
East Arm Wharf	Area 3	berth pocket 1 (zero to 150m mark) at East Arm Wharf for a distance of 50m perpendicular to the wharf from the face of the fender piles	- 12.0m	704735.1	8618255
				704709.1	8618220
				704587	8618309
				704615.8	8618349
	Area 4	berth pocket 2 (150m to 500m marks) at East Arm Wharf for a distance of 50m perpendicular to the wharf from the face of the fender piles.	- 13.0m	704618.3	8618349
				704587.9	8618309
				704346.6	8618488
				704379.5	8618533
	Area 5	Bulk Liquids berth (500m to 900m marks) at East Arm Wharf for a distance of 50m perpendicular to the wharf from the face of the fender piles	- 12.0m	704377.8	8618533
				704345.8	8618488
				704074.4	8618688
				704107.8	8618736

Location	Area	Descritption	Dredge depth (Below Chart Datum)	Easting	Northing
Marine Supply Base	Area 1	Berth Pockets 2 and 3 (from the 120m mark to 265m mark along the quay line) at the Marine Supply Base for a distance of 50m perpendicular to the wharf from the face of the fender piles	- 7.7m	705367.3	8618330
				705397.8	8618470
				705430.2	8618464
				705400.4	8618322
	Area 2	Berth pocket 1 (from zero to 120m mark along the quay line) at the Marine Supply Base for a distance of 50m perpendicular to the wharf from the face of the fender piles	- 8.7m	705367.3	8618330
				705399.7	8618323
				705375	8618200
				705345.1	8618206
Marine Supply Base channel sand bar intrusion	Area 7	Marine Supply Base channel sand bar intrusion. The area of sand bar intrusion into the south eastern edge of the channel entrance, as confirmed by pre dredging hydrographic survey	- 7.7m	705011	8617488
				704917	8617578
				705048.4	8617663
				705139	8617582

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DATUM GDA 1994, PROJECTION MGA ZONE 52

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LEGEND

- Dredge Disposal Boundary Point
- Dredging Area Boundaries
- LTDMP Disposal Location

Service Layer Credits: Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Disposal Location Corner Coordinates

Point	Easting	Northing
5	703850.36	8618370.36
6	704091.36	8618158.36
7	704020.64	8618087.64
8	703779.64	8618299.64
9	705857.00	8618234.98
10	705954.98	8618214.98

Point	Easting	Northing
11	705915.00	8618019.02
12	705817.02	8618039.02
13	705301.71	8617599.74
14	705234.00	8617599.74
15	705234.00	8617415.29
16	705301.71	8617415.29

DARWIN PORT LONG TERM DREDGING MANAGEMENT PLAN

East Arm Wharf

PROJECT ID 60553579
CREATED BY peter.young
LAST MODIFIED 29-Jan-2018
VERSION 1

Figure 24

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