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MAINTENANCE DREDGING AND SPOIL DISPOSAL MANAGEMENT PLAN

Plan

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Terms, abbreviations and acronyms

Term, abbreviation or acronym	Meaning
2D	two-dimensional
3D	three-dimensional
ABWM Requirements	Australian Ballast Water Management Requirements. Version 7. (DAWR 2017)
AFS Convention	International Convention on the Control of Harmful Anti-fouling Systems on Ships
ALARP	as low as reasonably practicable
AAPA	Aboriginal Areas Protection Authority (Northern Territory)
BTEX	benzene, toluene, ethylbenzene and xylene
BWM Convention	International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004
CA	Cosmos Archaeology Pty Ltd.
CPF	central processing facility
CR	INPEX client representative
CMT	crisis management team
Cwlth	Commonwealth
Darwin Port	Darwin Port Operations Pty Ltd.
DEE	Department of the Environment and Energy (Commonwealth)
DELWAQ	DELFT-3D Water Quality Module
DGPS	Differential Global Positioning System
DIPL	Department of Infrastructure, Planning and Logistics (Northern Territory)
DENR	Department of Environment and Natural Resources (Northern Territory)
Draft EIS	draft environmental impact statement
DSDA	dredge spoil disposal area
DSDMP	dredging and spoil disposal management plan
EMF	environmental management framework
EO	explosive ordinance
EPBC Act	*Environment Protection and Biodiversity Conservation Act 1999*
ERT	emergency response team

Term, abbreviation or acronym	Meaning
Final EIS	The Draft EIS and the EIS Supplement together made up the “Final EIS”
FPSO	floating production, storage and offloading facility
GEP	gas export pipeline
GIS	geographic information systems
Heritage Branch	Department of Tourism and Culture—Heritage Branch (Northern Territory)
HSE	health, safety and environment
HSEQ	health, safety, environment and quality
HSEQ-MS	Health, Safety, Environment and Quality Management System
IMT	incident management team
INPEX	INPEX Operations Australia Pty Ltd
LAT	lowest astronomical tide
LNG	liquefied natural gas
London Convention	Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, and the 1996 Protocol Thereto
LOR	limits of reporting
LPG	liquefied petroleum gas
Maintenance DSDMP	This Maintenance Dredging and Spoil Disposal Management Plan (INPEX Doc. No. L060-AH-PLN-60010)
Management triggers	Refers to specified criteria that, if exceeded during dredging and found to be Project attributable, would trigger a management response. They can refer to either abiotic (e.g. turbidity) or biotic variables (e.g. early-warning indicators of the health status of a sensitive receptor). Again, these variables are usually expressed as levels, rates or concentrations, or are calculated as specific percentiles, durations or frequencies over a certain period. Management triggers are generally established for use in the management of dredging works for the prevention of impacts. This is often implemented in the form of a ‘tiered management framework’. While management triggers are based on an understanding of the tolerance thresholds of sensitive receptors, they are usually set at precautionary levels below these thresholds (early warning) to enable timely management of dredging activities to avoid impacts before they occur.
MARPOL 73/78	International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 Thereto
MHWN	mean high water neaps
MHWS	mean high water springs
MLWN	mean low water neaps
MMO	marine megafauna observer

Term, abbreviation or acronym	Meaning
MODIS	Moderate Resolution Imaging Spectroradiometer
MP	management practices
MSDS	material safety data sheet
MSL	mean sea level
NAGD	National Assessment Guidelines for Dredging (Commonwealth of Australia 2009)
NEMP	nearshore environmental monitoring program
Non-Aboriginal	In context of this Maintenance DSDMP this term refers to heritage objects or sites, which are not defined as "sacred sites" under the *Northern Territory Aboriginal Sacred Sites Act* (NT) or considered Aboriginal or Macassan archaeological places or objects as defined under the *Heritage Act 2011* (NT).
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
NTU	nephelometric turbidity unit
OCP	organochlorine pesticide
PAH	polycyclic aromatic hydrocarbon
PAR	photosynthetic active radiation
PCB	polychlorinated biphenyl
PDCA	plan, do, check, act
PIANC 100 Report	Port Infrastructure and Navigation Congress 100 Report Dredging Management Practices for the Environment 2009 (Netzband et al. 2009)
PSD	particle size distribution
PSU	practical salinity unit
QA	quality assurance
QC	quality control
Qualified person	A person included on the register established and maintained pursuant to section 68 of the WMPC Act, with suitable experience in the matter being assessed.
Qualified professional	A person who has professional qualifications, training and skills and experience relevant to the nominated subject matters and can give authoritative assessment, advice and analysis about performance relevant to the subject matters using relevant protocols, standards, methods, literature.
Qualified sampler	A person who has been suitably trained and has suitable experience obtaining quality controlled environmental samples from the relevant environmental medium.

Term, abbreviation or acronym	Meaning
SD	standard deviation
SN	spring-neap
SOPEP	Shipboard Oil Pollution Emergency Plan
SSC	suspended sediment concentration
TBT	tributyltin
the Project	the Ichthys LNG Project
Tolerance Limits	Refers to descriptive characteristics of environmental variables (usually expressed as levels, rates or concentrations or calculated as specific percentiles, durations or frequencies over a certain period), that are considered to represent the upper or lower limits that a particular sensitive receptor is able to tolerate, beyond which undesirable consequences (e.g. lethal effects) are likely to occur. They are typically derived from scientific literature or datasets on local environmental baseline conditions. Tolerance limits are generally established for use in the prediction of potential impacts from the effects of dredging and disposal activities (e.g. by interrogation of plume modelling results). For the Maintenance DSDMP, they are habitat specific values for excess suspended sediment concentration and sedimentation, used in habitat impact assessment to determine the simulated area of impact and influence to sensitive receptor habitat, based on modelling outputs
TPH	total petroleum hydrocarbon
TPWC Act	*Territory Parks and Wildlife Conservation Act* (Northern Territory)
TSHD	trailing suction hopper dredge
TV	Tek Ventures Pty Ltd.
UXO	unexploded ordnance
WAMSI	Western Australia Marine Science Institution
WMPC Act	*Waste Management and Pollution Control Act* (Northern Territory)
WS	dredge work supervisor
ZoHI	zone of high impact
ZoI	zone of influence
ZoMI	zone of moderate impact

1 Introduction

The Ichthys LNG Project (herein referred to as the Project) is a joint venture between INPEX group companies, major partner Total, and the Australian subsidiaries of CPC Corporation Taiwan, Tokyo Gas, Osaka Gas, Kansai Electric Power, JERA and Toho Gas. Drawing on the hydrocarbon resources of the Ichthys gas and condensate field in the Browse Basin at the western edge of the Timor Sea offshore Western Australia, the Project is expected to produce 8.9 Mt of liquefied natural gas (LNG) and 1.6 Mt of liquefied petroleum gases (LPGs) per annum, along with approximately 100 000 barrels of condensate per day at peak.

The extraction of natural gas and condensate will be carried out via a floating semi-submersible central processing facility (CPF) at the Ichthys Field. This will remove water and most of the condensate from the reservoir fluids and the separated condensate will be transferred to a floating production, storage and offloading facility (FPSO) moored approximately 3.5 km from the CPF. After further processing on the FPSO, the condensate will be exported directly from the field at an average rate of up to 85 000 barrels per day (at the start of LNG production).

The dehydrated gas and the remainder of the condensate will be compressed and exported through an approximately 890 km long gas export pipeline (GEP) to the Project’s onshore processing plant at Bladin Point in Darwin Harbour in the Northern Territory.

To support the nearshore infrastructure at Bladin Point, capital dredging works were carried out within Darwin Harbour’s East Arm. Approximately 16.1 Mm^3 of material, consisting of fine clays, silts, sands and hard rock was dredged between 2012 and 2014.

Removal of this material required a fleet of dredges including backhoe dredges, a cutter suction dredge and trailing suction hopper dredges. Split hopper barges and trailing suction hopper dredges were used to transport and dispose of the dredged material at a designated dredge spoil disposal area (DSDA) within the Beagle Gulf, approximately 45 km north from East Arm and around 12 km north-west of Lee Point.

Over the life of the Project it is expected that sediment will accumulate within some areas of the existing dredged footprint (herein referred to as the dredge area), having the potential to impact on the operability of Ichthys LNG Plant, in terms of tidally restricting product carriers. Consequently, periodic maintenance dredging within the dredge area is required.

1.1 Purpose

The purpose of this Maintenance Dredging and Spoil Disposal Management Plan (Maintenance DSDMP) is to:

- demonstrate that all reasonable and practicable measures have been taken to manage the risks associated with, and the potential environmental impacts arising from proposed maintenance dredging and spoil disposal activities
- demonstrate how the requirements of Condition 10 (Appendix A.1) of the Project *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) approval decision (EPBC 2008/4208), the waste discharge licence (WDL240; Appendix A.2) and the development permit (DP17/0336; Appendix 0), have been met.

This Maintenance DSDMP describes:

- the maintenance dredging and spoil disposal method and rationale
- the existing environment within which the maintenance dredging and spoil disposal activities will occur

- the environmental risk assessment process including a conceptual site model and demonstration of risk to as low as reasonably practicable (ALARP)
- an overview of the sediment plume modelling and impact assessment
- the environmental management frameworks to be implemented, including an adaptive management strategy
- the proposed environmental monitoring
- the proposed stakeholder engagement and communication
- the implementation strategy including reporting, auditing and review requirements.

1.2 Scope

This Maintenance DSDMP has been prepared to allow for a maximum volume of 1.5 Mm^3 to be dredged within an approved five-year period, with no single campaign exceeding 0.75 Mm^3.

The total volume of 1.5 Mm^3 consists of a planned maintenance dredging campaign and up to four contingency campaigns, as required following major sediment accretion events (e.g. following a cyclone/significant wet season). These campaigns may be undertaken at any time within the approved five-year period.

The activities covered by this Maintenance DSDMP include maintenance dredging within the dredge area and disposal of dredged sediment at the existing DSDA. A detailed description of the maintenance dredging and spoil disposal activities, inclusive of work locations and methods, is provided in Section 3.

Under the *Project Development Agreement Ichthys LNG Project* entered into between INPEX and the Northern Territory Government, INPEX's maintenance dredging obligations extend only to the turning basin adjacent to INPEX's facilities and do not include maintenance of the common-use shipping channel, which remains the responsibility of third parties. Maintenance dredging activities may occur anywhere within the area defined in Section 3.2.1 and Figure 3-1. However, this does not constitute acceptance by INPEX that it is obliged to maintain areas beyond the turning basin or to release others from their responsibility to obtain their own regulatory approvals to maintain the shipping channel.

Maintenance dredging works will be executed in accordance with obtained regulatory approvals (Section 2.2) and the endorsed/approved Maintenance DSDMP (this Plan).

1.3 Proponent

INPEX Operations Australia Pty Ltd (INPEX), a wholly owned subsidiary of INPEX CORPORATION, is the proponent and Operator for the Ichthys LNG Project on behalf of its joint venture partners.

The addresses of the INPEX's offices in Australia are as follows:

Perth	Darwin
INPEX Operations Australia Pty Ltd	INPEX Operations Australia Pty Ltd
Level 22, ENEX 100	Level 8, Mitchell Centre
100 St Georges Terrace	59 Mitchell Street
PERTH WA 6000	DARWIN NT 0800

1.4 Independent expert review

In accordance with Condition 10 (k) of the approval decision EPBC 2008/4208 and the Northern Territory Environment Protection Authority (NT EPA) *Guidelines for the Environmental Assessment of Marine Dredging in the Northern Territory* (NT EPA 2013), independent experts have been consulted in the development of the Maintenance DSDMP and monitoring program required to detect and manage impacts.

Details of the independent experts consulted in the development of this plan are provided in Table 1-1.

Table 1-1: Independent experts consulted in the development of this Maintenance DSDMP

Name	Experience
Dr Paul Erftemeijer (Benthic ecology specialist)	Dr Erftemeijer has 25 years of international experience as a specialist consultant and applied scientist focusing on human impacts, management, recovery and restoration of critical marine and coastal ecosystems around the world. He has extensive working experience in a consulting role with governments, industry and other clients as technical advisor to address environmental concerns related to coastal and marine development projects, including dredging operations. He frequently provides expert advice in relation to the restoration of seagrasses, mangroves, coral reefs and coastal wetlands. Dr Erftemeijer has served on two World Association for Waterborne Transport Infrastructure (PIANC) expert working groups developing best practice guidelines for dredging and port construction near coral reefs and coastal plant habitats. Recently, he was invited to participate in an Expert Panel to draft a synthesis of the effects of dredging and dredged spoil on the Great Barrier Reef. He holds an adjunct position as Research Professor at the UWA Oceans Institute, University of Western Australia.
Dr Andrew Heyward (Coral specialist)	Dr Heyward has 30 years of experience in coral research, starting on the Great Barrier Reef and extending to Japan, Micronesia, Hawaii, and the Pacific and Indian oceans. He and his international collaborators have studied the population dynamics of reef building corals, including renewal, seasonal reproduction and recruitment. Dr Heyward was the senior scientist responsible for establishing the Australian Institute of Marine Science's permanent base in north western Australia and he has facilitated and participated in multidisciplinary marine research conducted by the Institute in all areas of tropical Western Australia. Dr Heyward served as key member (coral specialist) of the Ichthys Project Dredging Expert Panel (IPDEP), which was established to provide advice to regulatory bodies, and feedback and advice to INPEX and the Dredging Contractor, on the environmental management and monitoring of INPEX's capital dredging program.
Mr Johan Pronk (Dredging specialist)	Mr Pronk is the Director of Pro Dredging and Marine Consultants Pty Ltd in Brisbane. Previously he was Managing Director of Van Oord Australia Pty Ltd and Director Operations for Ballast Nedam Dredging. Further, he served as key member (dredging specialist) of the IPDEP during INPEX's capital dredging program. Mr Pronk's 35 years of international experience in the dredging industry has taken him through all operational positions within a dredging company. The greater part of his work experience has been gained in Australia, New Zealand and South East Asia. His long association with the Australasian region has given him knowledge of most dredging and reclamation projects in the region. His experience and understanding of the dredging industry is extensive.

1.5 Interface other INPEX and Dredging Contractor documents

Figure 1-1 illustrates the relationships between this Maintenance DSDMP and other supporting INPEX and Dredging Contractor documents.

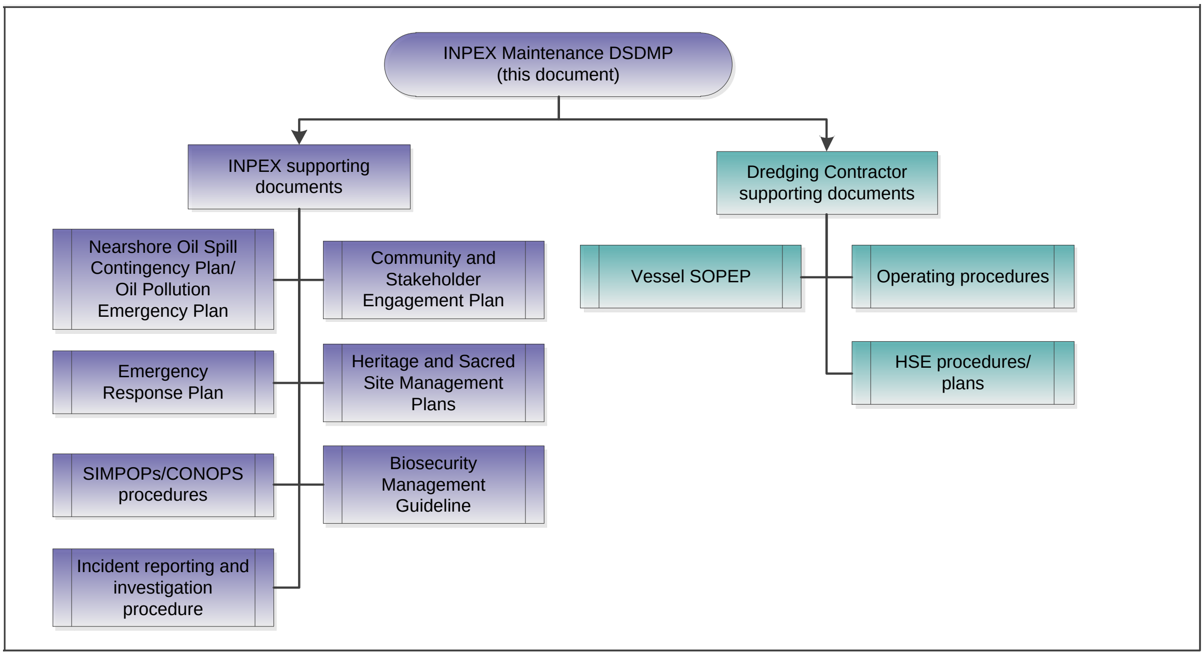


Figure 1-1: Interface documents

1.6 Review and revision of this Plan

This Maintenance DSDMP will be reviewed by INPEX prior to the commencement of any maintenance dredging campaign to ensure its continuing suitability and consistency with current regulatory requirements.

A revision of this Maintenance DSDMP will be undertaken in circumstances where there has been a significant deviation from the activities and management controls described within this Plan. Any proposed changes will be assessed to determine their potential to result in new or increased environment harm in accordance with management of change process described in Section 10.10.

If the assessment indicates that the proposed activity will, or may, cause or increase the potential for environmental harm, then that activity will not commence until the revised Maintenance DSDMP (or an Addendum to the Maintenance DSDMP) has been submitted to the NT EPA (for consideration) and DEE (for approval). The revised Maintenance DSDMP (or an Addendum to the Maintenance DSDMP) will be reviewed and endorsed by a Qualified Professional.

Where a revision does not result in new or increased environmental harm or impact, then the revised Maintenance DSDMP will be provided to the NT EPA and DEE for information only.

2 Legislative framework

The following sections describe the legislative framework governing the maintenance dredging and spoil disposal activities.

2.1 Ichthys Project environmental approval

In May 2008, INPEX initiated the formal environmental assessment process for the Project. This required the preparation of a comprehensive Draft Environmental Impact Statement (Draft EIS) for assessment by the Australian Commonwealth Government under the EPBC Act and by the Northern Territory Government under the *Environmental Assessment Act*. The Draft EIS described the Project's potential environmental, social and economic impacts and the approaches that INPEX plans to take to manage these impacts.

The Draft EIS was published in 2010 for government and public review and comment. The public submissions and subsequent Project responses were published as a supplement to the Draft EIS in April 2011. The Draft EIS and the EIS Supplement together made up the "Final EIS" which was assessed by the Northern Territory Government and the Commonwealth Government. The Northern Territory Government assessment report with recommendations (Assessment Report 65; NRETAS 2011) was received in May 2011 and the Commonwealth Government approval (EPBC 2008/4208) with conditions was received in June 2011.

The requirement for maintenance dredging was described within the Final EIS (INPEX 2010, 2011) with foreseen impacts predicted to be less than that of the East Arm capital dredging program (herein referred to as the capital dredging program; INPEX 2013).

No formal recommendations were made in Assessment Report 65 (NRETAS 2011) with respect to maintenance dredging; however, it was noted that any maintenance dredging would require a new notification under the Northern Territory *Environmental Assessment Act* (e.g. through a notice of intent or equivalent).

In contrast, maintenance dredging was considered within the Commonwealth Ministers Statement of Reasons supporting EPBC 2008/4208 and therefore Condition 10 of EPBC 2008/4208 applies (Section 2.2).

2.2 Maintenance dredging approvals

This Maintenance DSDMP has been developed to comply with the requirements of the following approvals and certificates:

- Commonwealth approval decision EPBC 2008/4208 (Condition 10)
- NT EPA Waste Discharge Licence (WDL240)
- Department of Infrastructure, Planning and Logistics (DIPL) Development Permit (DP17/0336)
- Aboriginal Areas Protection Authority (AAPA) Authority Certificate (C2014/007)
- AAPA Authority Certificate (C2012/138)
- AAPA Authority Certificate (C2011/166).

Conditions of approvals, and demonstration of how these requirements have been met are presented in Appendix A.

The development permit, waste discharge licence and Maintenance DSDMP will be made available on the Project's website one week prior to the commencement of a

maintenance dredging campaign. Further a hard copy of WDL240 (as amended) will be maintained on the bridge of the dredge vessel and at INPEX's Darwin office.

As AAPA Authority Certificates contain confidential and sensitive information and these will only be provided to relevant contractors and consultants as appropriate to their scopes of work.

2.3 Relevant conventions, legislation, standards and guidelines

The following sections describe the conventions, legislation, standards and guidelines applicable to maintenance dredging and spoil disposal activities.

2.3.1 International conventions, agreements and guidelines

International conventions, agreements and guidelines relevant to maintenance dredging and spoil disposal activities are presented in Table 2-2.

Table 2-1: International conventions, agreements and guidelines

Name	Description
Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter, 1972, and the 1996 Protocol Thereto (London Convention)	The Convention applies to the deliberate disposal at sea of wastes or other matter from vessels, aircraft, platforms and other man-made structures at sea. It requires signatories of the Convention to issue a permit for the dumping of wastes and other matter at sea and generally prohibits the dumping of certain hazardous materials.
International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78)	The Convention applies to prevention of pollution to the marine environment by ships from operational or accidental causes. It includes regulations on the prevention of pollution by oil, chemicals and harmful substances in packaged form, sewage and garbage.
Guidelines for the Control and Management of Ships' Biofouling to Minimize the transfer of Invasive Aquatic Species (IMO 2012)	The Guidelines provide a globally consistent approach to the management of biofouling on vessels. The Guidelines include practical guidance on measures to minimise the risk of transferring invasive aquatic species from vessels' biofouling.
International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (BWM Convention; IMO 2009)	The Convention requires all vessels on international journeys to manage their ballast water and sediments to a certain standard, according to a vessel-specific ballast water management plan. All vessels also have to carry a ballast water record book and an international ballast water management certificate.
International Convention on the Control of Harmful Anti-fouling Systems on Ships (AFS Convention)	The Convention prohibits the use of harmful organotins in anti-fouling paints used on ships and establishes a mechanism to prevent the potential future use of other harmful substances in anti-fouling systems.
Port Infrastructure and Navigation Congress 100 Report Dredging Management Practices for the Environment 2009 (PIANC 100 Report; Netzband et al. 2009)	The PIANC 100 Report provides guidance to proponents on the selection of appropriate environmental management practices best suited to specific dredging project conditions and requirements.

2.3.2 Commonwealth and Northern Territory legislation, standards and guidelines

Commonwealth and Northern Territory legislation, standards, and guidelines relevant to maintenance dredging and spoil disposal activities are presented in Table 2-2 and Table 2-3.

Table 2-2: Commonwealth legislation, standards and guidelines

Name	Description
Aboriginal and Torres Strait Islander Heritage Protection Act 1984	The Act provides for the preservation and protection from injury or desecration of areas and objects in Australia and in Australian waters, being areas and objects that are of particular significance to Aboriginal and Torres Strait Islander people in accordance with their traditions.
Biosecurity Act 2015	The Act and subordinate legislation are the primary legislative means for managing risk of pests and diseases entering Australian territory and causing harm to animal, plant and human health, the environment and/or the economy. It gives effect to a number of international conventions including the BWM Convention and AFS Convention.
Environment Protection and Biodiversity Conservation Act 1999	The Act provides a provides a legal framework to protect and manage nationally and internationally important flora, fauna, ecological communities and heritage places defined as matters of national environmental significance.
Historic Shipwrecks Act 1976	The Act provides for the protection of historic shipwrecks, associated relics, and objects deposited on the seabed which are more than 75 years old and lie within Australian waters.
Protection of the Sea (Harmful Anti-fouling Systems) Act 2006	The Act provides a legal framework to control the application or use of harmful anti-fouling compounds on ships used for commercial purposes and implements provisions of the AFS Convention.
Protection of the Sea (Prevention of Pollution from Ships) Act 1983	The Act is the primary legislation giving effect to MARPOL 73/78 as it relates the prevention of accidental and operational marine environmental pollution from shipping.
Australian and New Zealand guidelines for fresh and marine water quality (ANZECC/ARMCANZ 2000a)	The Guidelines provide a framework for recognising and protecting water quality for the full range of existing environmental values. They serve as a guide for setting water quality objectives required to sustain current or likely future environmental values for natural and semi-natural water resources in Australia and New Zealand.
Australian Ballast Water Management Requirements. Version 7. (ABWM Requirements; DAWR 2017)	The ABWM Requirements provide guidance on how vessel operators should manage ballast water when operating within Australian seas in order to comply with the *Biosecurity Act 2015*.
National Assessment Guidelines for Dredging (NAGD; Commonwealth of Australia 2009)	The Guidelines set out the framework for the environmental impact assessment and permitting of the ocean disposal of dredged material.
National Biofouling Management Guidance for Non-trading Vessels (NSPMMPI 2009)	The Guidelines provide guidance to vessels operators on how to minimise the amount of biofouling accumulating on their vessels, infrastructure and submersible equipment and thereby minimising the risk of spreading introduced marine pests.
National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ 2000b)	The Guidelines set out the framework for the monitoring and reporting of fresh and marine waters and groundwater. This includes the design, application, analysis and reporting on monitoring programs.
Revision of the ANZECC/ARMCANZ Sediment Quality Guidelines (SQG; Simpson et al. 2013)	The Guidelines provide an update to the sediment component of the Australian and New Zealand Guidelines for Fresh and Marine Water Quality released in 2000 (ANZECC/ARMCANZ 2000a). The Guideline revision builds on the original document with the tiered, decision-tree approach adopted for the interim sediment quality guideline values maintained, and guidance is provided for use of a weight-of-evidence framework to improve the assessment of the potential impacts of

Name	Description
	contaminated sediments for more complex risk assessments.

Table 2-3: Northern Territory legislation, standards, plans and guidelines

Name	Description
Environmental Assessment Act	The Act and subordinate legislation establish the framework for the assessment of potential or anticipated environmental impacts of development. The object of the Act is to ensure that matters affecting the environment to a significant extent are fully examined and taken into account in decisions made by the Northern Territory Government.
Dangerous goods Act	The Act and its associated regulations provide for the safe storage, handling and transport of certain dangerous goods.
Fisheries Act	The Act and its associated regulations provide for the regulation, conservation and management of fisheries and fishery resources so as to maintain their sustainable utilisation. Under the Act a permit is required for activities which directly or indirectly introduce or displace substances in or into waters of the Northern Territory that may impact on fish or aquatic life or their habitats.
Heritage Act 2011	The Act provides a framework for identification, assessment, recording, conservation, and protection of places and objects of, among other things, historic, social or aesthetic value.
Marine Act	The Act and its associated regulations regulate shipping within the Northern Territory and provide for the application of the uniform shipping laws code and for related matters.
Marine Pollution Act	The Act and its associated regulations provide for protection of the marine and coastal environment by minimising intentional and negligent discharges of pollutants (such as oil, garbage, etc.) from ships into coastal waters and for related purposes.
Northern Territory Aboriginal Sacred Sites Act	The Act and its associated regulations provides for the protection of Aboriginal sacred sites within the Northern Territory and confers specific functions on the Aboriginal Areas Protection Authority that include the registration of sacred sites, enforcement and approvals for access or proposed works.
Planning Act	The Act establishes the rules for land use planning and development in the Northern Territory. The Development Assessment Services is responsible for the development assessment and control processes within the provisions of the Act.
Ports Management Act 2015	The Act provides for the control, management and operation of Northern Territory ports.
Territory Parks and Wildlife Conservation Act (TPWC Act)	The Act provides for the classification and management of wildlife, classification and control of pest animals, permits for taking wildlife and entering land, designation and management of protected areas.
Waste Management and Pollution Control Act (WMPC Act)	The Act provides for the protection of the environment through encouragement of effective waste management and pollution prevention and control practices.
Water Act	The Act provides for the investigation, use, control, protection, management and administration of water resources in the Northern Territory. Under the Act a waste discharge licence is the regulatory instrument used to regulate the quality and quantity of waste

Name	Description
	discharged to water in the Northern Territory.
Work Health and Safety (National Uniform Legislation) Act	The Act provides a framework to protect the health, safety and welfare of all workers at work and of other people who might be affected by the work. The subordinate regulations specify the way in which some duties under the Act must be met and prescribe procedural or administrative requirements to support the Act.
Guidelines for Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA 2013)	The Guidelines describe the obligations and requirements of proponents proposing to undertake dredging projects in the Northern Territory.
Guideline for Reporting on Environmental Monitoring (NT EPA 2016)	The Guideline outlines the Northern Territory Environment Protection Authority's (NT EPA) requirements for environmental monitoring reports including how to report the information collected to the NT EPA.
Guideline for the Preparation of an Environmental Management Plan (NT EPA 2015)	The Guideline outlines when and environmental management plan may be required by the NT EPA; and what is required in preparing an environmental management plan for assessment by the NT EPA.
Declaration of Beneficial Uses and Objectives, Darwin Harbour Region, Northern Territory Government Gazette No. G27, 7 July 2010.	The declared beneficial uses and objectives for the Darwin Harbour Region under the Northern Territory *Water Act*.
Water Quality Objectives for the Darwin Harbour Region - Background document (NRETAS 2010)	The document describes the methodology undertaken when developing the locally derived water quality guidelines and objectives for waterways of the Darwin Harbour Region.
Darwin Harbour Water Quality Protection Plan (DLRM 2014)	The Plan identifies management actions being undertaken by government, industry and community stakeholders that are focused on monitoring, assessing and/or managing nutrient and sediment inputs to Darwin Harbour waterways. The aim of the Plan is to ensure that water quality objectives (local guidelines) are maintained and that community's values for waterways (beneficial uses) are protected.
Darwin Port Environnemental Management Plan (Darwin Port 2016)	The Plan sets out the high-level framework, objectives and targets for sound and responsible environmental management within Darwin Port areas of responsibility as defined under the *Ports Management Act 2015*.

3 Maintenance dredging and spoil disposal activity

The following sections provide an overview of the proposed maintenance dredging and spoil disposal activity, including the work locations, methods and rationale.

3.1 Maintenance dredging campaigns

As described in Section 1.2, this Maintenance DSDMP has been prepared to allow for a maximum of 1.5 Mm^3 of material to be dredged during the life of the approval (i.e. nominally five years), with no single campaign to exceed 0.75 Mm^3. The total volume of 1.5 Mm^3 is considered worst-case and includes a planned maintenance dredging campaign and up to four contingency campaigns. These campaigns may be undertaken at any time within the five-year period. The proposed maximum single campaign volume (0.75 Mm^3) is within the same order of magnitude of other maintenance dredging campaigns around Australia[1].

Contingency has been included to provide flexibility, as the sediment infill rate associated with major natural events has yet to be established given the two preceding wet seasons (2014/2015; 2015/2016) since completion of the capital program, have been benign with below average rainfall. Natural events such as cyclones, tropical storms and major flooding periods, which are common in subtropical and tropical regions, have the potential to deposit large amounts of sediment within the dredge area. If severe enough, such events could effectively reduce or shut down operations for a period until a hydrographic survey has been completed and the required maintenance dredging (if any) has been carried out.

During a maintenance dredging campaign, the Dredging Contractor will undertake dredging and spoil disposal activities 24 hours per day, 7 days per week, subject to stand-downs resulting from operational limitations and requirements (e.g. bunkering, concurrent operations within the dredge area, etc.).

With regard to timing of the first maintenance dredging campaign, no decision has been made. However hydrographic surveys, which monitor accretion and erosion of sediment within the dredge area, will be undertaken to inform the decision making process in addition to other aspects including, but not limited to, the availability of dredge vessels of opportunity, planned shutdown periods for maintenance and the operational schedule of the Ichthys LNG Plant.

A summary of the rate and location of sediment accretion and erosion within the dredge area since the completion of the capital dredging program is provided in Appendix B.1.

3.2 Work locations

3.2.1 Dredge area

The dredge area lies within East Arm, Darwin Harbour (Figure 3-1). Maintenance dredging may be undertaken anywhere within the dredge area as defined in Figure 3-1 provided that the total dredging volume remains within that approved. Maintenance

[1] Regular maintenance dredging volumes in Australian ports over the past decade ranged from <10,000 m^3 to as much as 1.3 Mm^3. For example, the Port of Brisbane requires annual maintenance dredging with volumes ranging from 450,000 to 1.3 Mm^3 per year (HaskoningDHV, 2016). Port Hedland requires the removal of 114,000 m^3 to 730,000 m^3 every 3 to 4 years (Ports Australia 2014). The Port of Townsville required removal of ~814,000 m^3 in 2011 following the passage of Tropical Cyclone Yasi, which silted up channels and berths. This was significantly higher than its usual annual maintenance dredging requirement, which ranged from ~115,000 m^3 to ~500,000 m^3 over the last decade (State of Queensland (Department of Transport and Main Roads) 2016).

dredging will not extend beyond the boundary (depth and width) of the area[2] achieved during the capital dredging program.

Under the *Project Development Agreement Ichthys LNG Project* entered into between INPEX and the Northern Territory Government, INPEX's maintenance dredging obligations extend only to the turning basin adjacent to INPEX's facilities and do not include maintenance of the common-use shipping channel, which remains the responsibility of third parties. Maintenance dredging activities may occur anywhere within the area defined in Figure 3-1. However, this does not constitute acceptance by INPEX that it is obliged to maintain areas beyond the turning basin or to release others from their responsibility to obtain their own regulatory approvals to maintain the shipping channel.

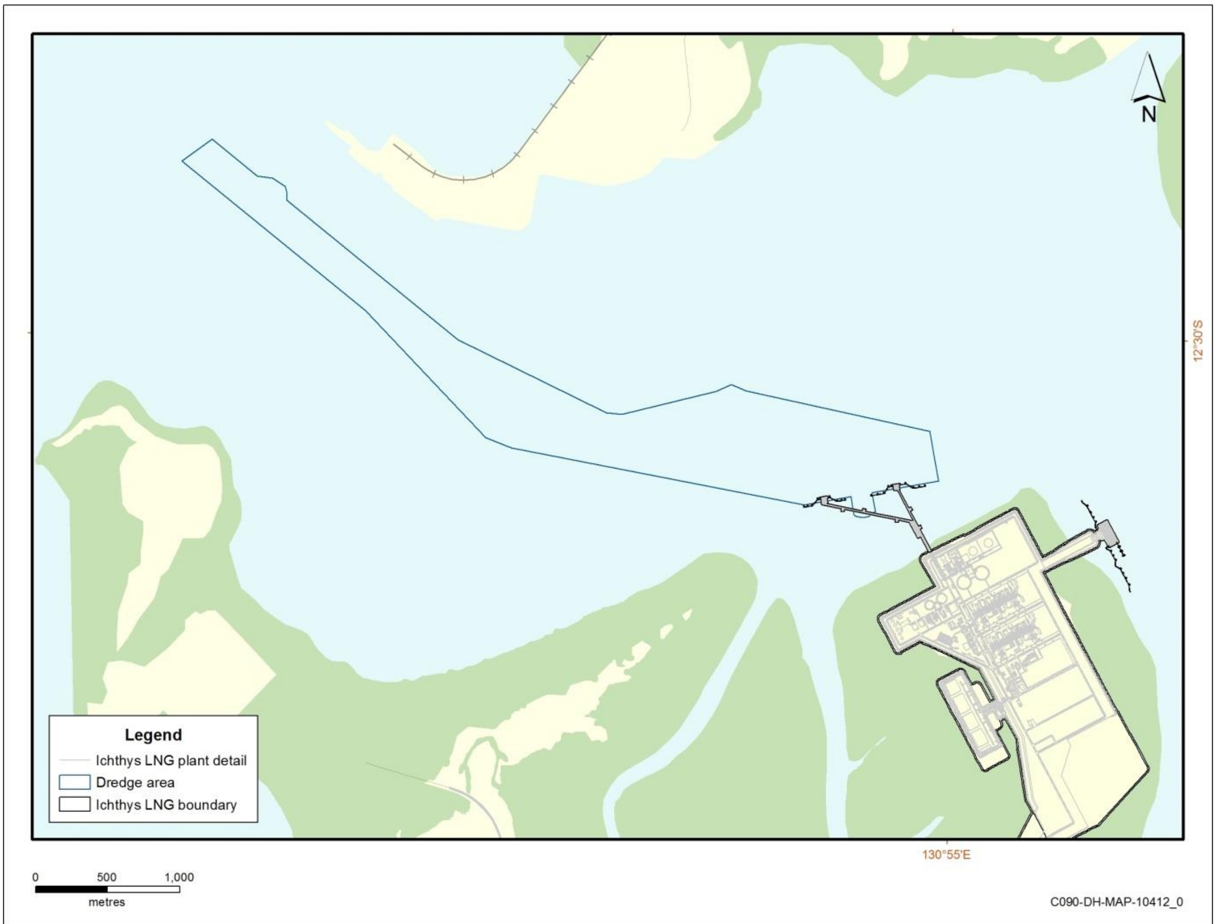


Figure 3-1: Dredge area

3.2.2 Dredge spoil disposal area

The dredge spoil disposal area (DSDA) is located to the north of Darwin Harbour, within the Beagle Gulf, approximately 12 km north-west of Lee Point (Figure 3-2). It is located approximately 45 km from the dredge area in water depths between 15 m and 20 m below LAT (lowest astronomical tide).

The DSDA is 12.5 km^2 (5 km by 2.5 km) and is to be filled progressively so that the full volume of dredged material can be accommodated within the nominated area. The DSDA proposed is the same one that was used for the capital dredging program. Based on review of the post-capital dredging hydrographic survey of the DSDA in mid-2014 the

[2] Note there is a margin of error with regards to the accuracy of dredging equipment, which is in the order of ±0.5 m.

remaining capacity is calculated to be approximately 7 Mm^3. Further information regarding the original site selection process for the DSDA and observations since are provided in Appendix B.2.

The DSDA is located within Northern Territory waters and consequently the *Environment Protection (Sea Dumping) Act 1981* (Cwlth) does not apply, negating the need for a sea dumping permit.

Hydrographic surveys will be used to verify that spoil disposal has occurred within the designated location and to ensure no navigation hazards have been created.

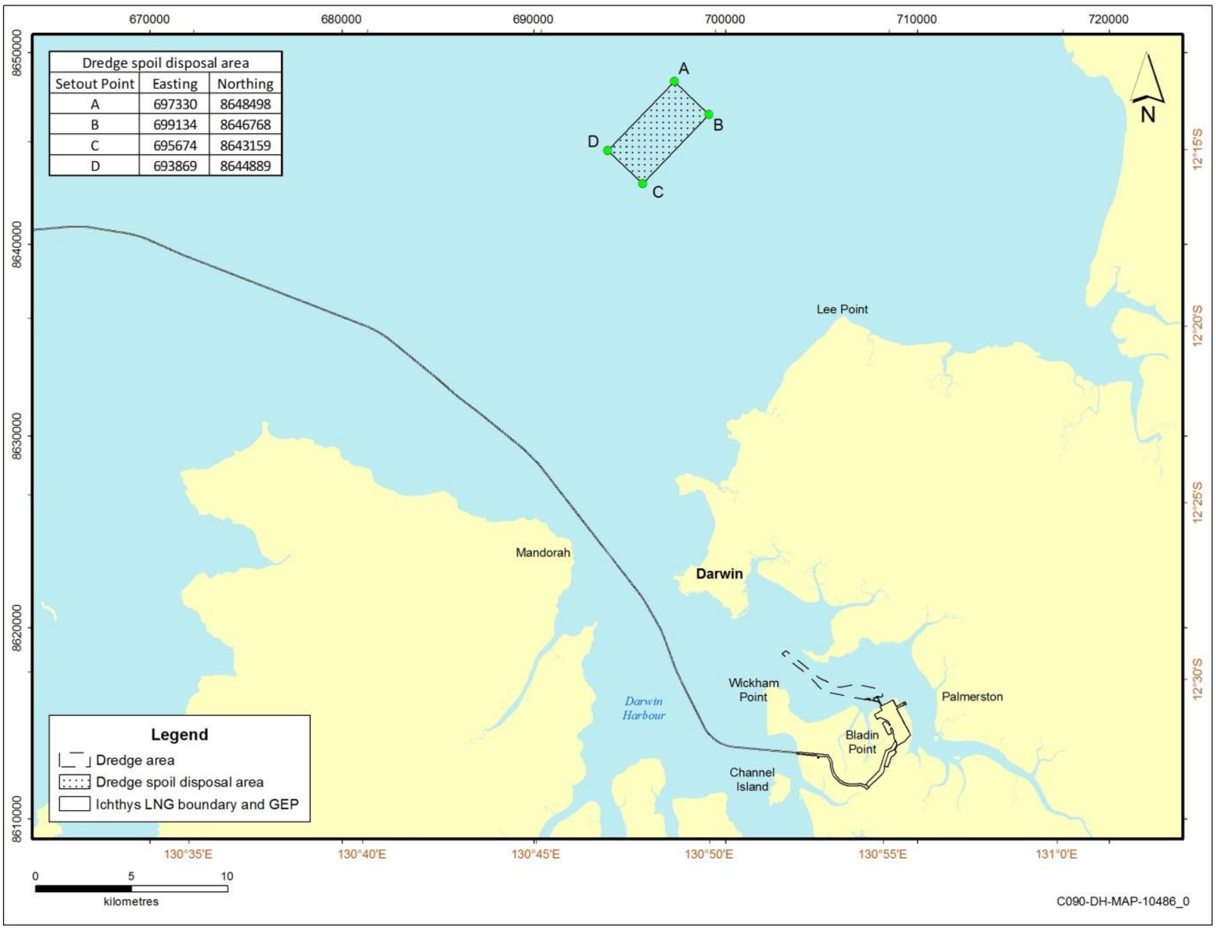


Figure 3-2: Location of the DSDA

3.3 Work method and rationale

Maintenance dredging is a repetitive activity that typically involves the removal of variable quantities of material that are normally weak, unconsolidated sediment of various thicknesses across an operational area (Netzband et al. 2009).

Dredging equipment and method selection for this Maintenance DSDMP considered the content provided in the PIANC 100 Report[3] (Netzband et al. 2009) and where relevant,

[3] The PIANC 100 Report (Netzband et al. 2009) was published by an international working group convened by the Environmental Commission of the World Association for Waterborne Transport (PIANC). Members of the working group are acknowledged experts in their profession from several countries. The PIANC 100 Report provides information and recommendations on best practice and should be viewed as expert guidance for environmental management of dredging. It includes guidance on the selection of appropriate best management practices for dredging operations in order to manage environmental impacts as required by procedures such as the Dredged Material Assessment Framework of the London Convention.

the outputs from the capital dredging PIANC 100 assessment, which was undertaken to review and determine dredging option/s based on best management practices. The PIANC 100 Report defines a management practice (MP) as a practice intended to improve the environmental performance of a dredging project, inclusive of excavation, transport, and placement of dredged material (Netzband et al. 2009). A list of MPs related to the different phases of the dredging activity (e.g. planning, management, equipment selection, contracting, etc.) are provided in the Toolbox Data Base appended to the PIANC 100 Report (Netzband et al. 2009) and are referenced within the text of the following sections.

3.3.1 Equipment selection

The selection of dredging equipment (applicable MP E1 to E12) is influenced by a number of variables. This includes, but not limited to, the volume to be dredged, cost and availability of equipment, dredging and spoil disposal site characteristics, environmental considerations related to the duration of the activity (i.e. directly correlated to the dredging production rate) and the levels of turbidity generated relative to background levels. The equipment selection also influences the applicability and effectiveness of other (related) management practices (Netzband et al. 2009).

The selection of dredging equipment for this maintenance dredging activity also needed to consider the potential for restricted operational windows associated with aspects such as simultaneous operations, including the presence of product tankers and other vessels frequenting the area.

A single trailing suction hopper dredge (TSHD) was determined to be the most suitable dredge for maintenance dredging in East Arm, Darwin Harbour. TSHDs are self-propelled hydraulic dredges typically used for dredging sand, silts and soft clays via a draghead and suction pipe. Dredged material is then subsequently stored in its cargo hold (the hopper) for transport and disposal afield (Foster et al. 2010). The rationale supporting the selection of dredging equipment is as follows:

- The volume of material to be dredged is up to 0.75 Mm^3 per campaign. Hydraulic dredges typically have higher production rates than mechanical dredges (i.e. backhoe dredges) (MP E2, E4). As a result, the duration of the dredging campaign is likely to be reduced when using a TSHD, which thereby minimises associated effects to environmental, social and cultural values (Netzband et al. 2009).
- The dredge area is located within East Arm, Darwin Harbour (Section 3.2.1). The sediment that has deposited and migrated into the dredge area since the completion of the capital dredging program was found to be uncontaminated and consists of predominantly sands and silts, with a small proportion of clays and gravels (INPEX 2016; Section 4.1.5). Given the sediment to be dredged is already considered unconsolidated, no additional fines (relative to mechanical dredges) are likely to be generated through the hydraulic dredging process of a TSHD (i.e. no further breakup of material when transported through pumps, pipes, etc.).
- The dredge area is characterised by soft-bottom benthos; however, hard coral communities are known to occur in proximity to the dredge area at South Shell Island and Northeast Wickham Point, although at a fairly low coral cover (i.e. 8% and 2% respectively; Table 4-2). Mechanical dredging typically results in higher turbidity impacts throughout the entire water column as compared to hydraulic dredges (MP E2, E4; Netzband et al. 2009). However, for hydraulic dredges, such as a TSHD, turbidity at the point of dredging can be significant through other mechanisms such as overflow (MP E4; Netzband et al. 2009). Darwin Harbour is a naturally turbid environment; however, in consideration of the potential environmental impacts, overflow is proposed to be managed as further described in Section 3.3.2.

- The DSDA is located approximately 45 km from the dredge site (one-way) and is characterised by soft-bottom benthos communities that are well represented regionally. Given TSHDs are self-propelled dredges that load sediment directly in their hoppers, no other support barges are required for transport and hence there is less shipping traffic. From an environmental perspective, it also means that dredging and associated disposal is intermittent, thereby reducing the overall intensity of dredging and spoil disposal induced turbidity plumes.
- Product tankers will frequent the operational area and remain alongside the jetty during loading activities. To maximise dredging periods and minimise potential disruption to product export, TSHDs are considered the most suitable as they are self-propelled and thereby mobile during operations. In contrast, mechanical dredges, which are generally stationary, are more likely to cause localised obstruction in navigable waters (MP E2; Netzband et al. 2009).

3.3.2 Dredging method

A TSHD will dredge the unconsolidated sediment using draghead/s and a suction pipe, which will then be directly loaded into its hoppers. Once loaded, the dredged material will be transported to the DSDA and released via bottom doors. Prior to the restart of dredging, any residual water (containing some fine sediment), which remains within the hopper will be pumped out into the dredge area prior to the recommencement of loading.

The loading of the TSHD will be optimised using overflow. Overflow is the release of predominantly water with some fine sediment, and is used to maximise the quantity of sediment within the hopper and as such dredged material loaded.

The overflow funnel/s of the TSHD will be fitted with “green valves" (Figure 3-3). These valves restrict the entrainment of air into the overflow mixture thereby minimising fines dispersal and associated turbidity (MP E18; Netzband et al. 2009). Further, the overflow material sinks more rapidly due to density effects allowing better settlement of overflow material. The green valve is considered most effective when a relatively large portion of fines is present within the dredged mixture (MP E18; Netzband et al. 2009).

A maximum overflow of 60 minutes is proposed per cycle. To manage overflow, the funnel will be lowered (maximum 0.5 m)[4] in order for the Dredging Contractor to accurately record the overflow time for regular reporting to INPEX. The use of overflow will depend on the actual conditions encountered and will be at the discretion of INPEX in consultation with the Dredging Contractor.

[4] The overflow height refers to the level within the hopper, below the waterline, that overflow may commence. For example, 0.5 m overflow height means that the overflow funnel can be lowered 0.5 m below the waterline in the hopper.

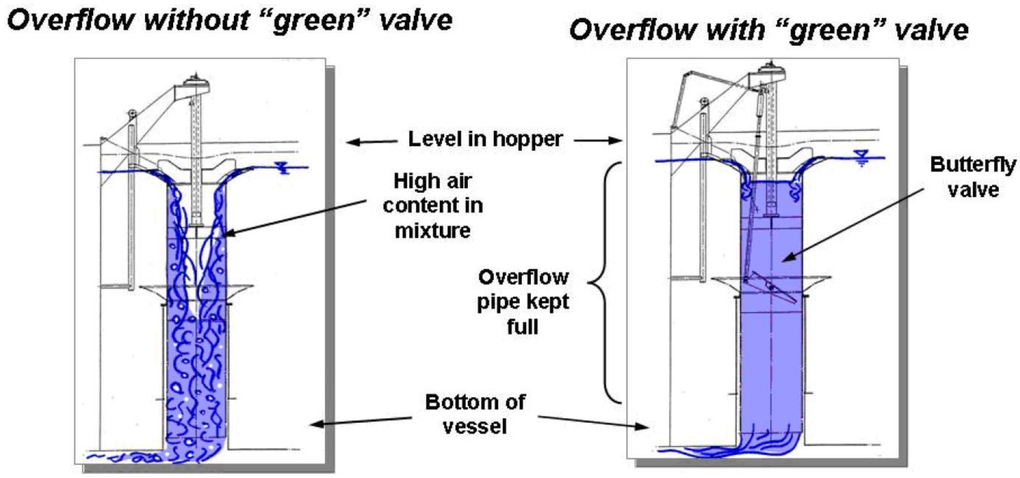


Figure 3-3: Overflow fitted with green valve

The overall aim of any dredging works is to minimise the water content of the dredged material. This is typically achieved by reducing the flow velocity in the suction pipe and increasing the mixture density. These two criteria also maximise the settling of solids in the hopper, as low flow velocity will minimise turbulence in the water mixture and higher density material will increase settling of solids through density currents.

A typical TSHD is equipped with an array of sensors that monitor relevant dredging process information in real-time. Key factors used in determining the loading production and overflow losses, are the sensors recording the draught of the vessel and the water level inside the hopper. These values combined with a number of vessel's characteristics allow the vessel's computer system to determine the Tonnes of Dry Solids (TDS) value in the hopper. Generally, overflow will cause the TDS production to decrease and monitoring this will allow the crew to determine the optimum point in time to cease overflowing (when not limited by a pre-determined duration; i.e. one hour maximum overflow).

The dredge area is located in Darwin Harbour, where green, hawksbill and flatback turtles are known to frequent (Section 4.3.2). Therefore, depending on the size of the draghead, it is possible that turtles residing on the seafloor could potentially be pumped up and become entrained in the hopper.

To prevent entrainment of turtles during the dredging process, turtle protection chains (otherwise referred to as tickler chains or turtle deflector chains) will be attached to the draghead (MP E17; Netzband et al. 2009; Section 7.2.3). The objective of the chains is to prevent turtles and other marine fauna from entering the suction zone of the draghead and encouraging them to move before the draghead passes over. Further, to reduce the risk of faunal entrainment the dredge pumps will only be engaged at full force when as close as reasonably practicable to the seabed at the commencement or end of dredging operations or during turning of the vessel. The operation of the TSHD pumps will cease as soon as possible after the completion of dredging (Section 7.2.3).

3.3.3 Spoil disposal method

The optimal method for unconfined ocean disposal of dredged sediment in high-energy environments is via TSHD bottom doors as identified in the PIANC 100 workshop undertaken for the capital dredging program (INPEX 2013).

Bottom door placement involves the direct release of sediment from the hopper by opening of the bottom doors, gates or by hopper splitting. The sediment is then released into the upper part of the water column, from where it quickly descends towards the bottom and subsequently settles and deposits on the seafloor of the DSDA.

The optimal sediment placement method was selected based on environmental, operational and safety considerations. Alternative disposal methods such as hydraulic placement of materials at the DSDA were eliminated on the basis that these type of filling methods would cause further break up of dredged materials.

Hydraulic placement of materials via the use of a diffuser or tremie pipe would not be advantageous in comparison with conventional bottom dumping, as it would require mixing the material with additional water in order to pump it, resulting in a lower density when disposed and therefore a potential higher resuspension factor. Further, it would require a barge or pontoon to be located at the disposal site from which the equipment would be operated. Given the offshore location and high-energy hydrodynamic conditions, anchoring and use of such equipment would impose unnecessary safety and operational risk.

3.4 Seabed leveller

Seabed levelling may be required in the dredge area, in order to attain design requirements and aid safe and effective navigation. Seabed levelling is used to level high spots, for example from dredge tracks or naturally occurring sand waves or sediment deposition.

A seabed leveller is a piece of auxiliary equipment that consists of a sweep bar connected to a vessel, which essentially just moves sediment from one location to another in a proximate area. This is expected to produce localised elevation in turbidity in vicinity of the sweep bar, which is not expected to spatially extend beyond the dredge area.

The PIANC 100 Report (Netzband et al. 2009) considers seabed levelling as a best management practice that is commonly used during dredging campaigns, nearshore construction projects and ongoing maintenance programs. For this Maintenance DSDMP seabed levelling will be used on an as needs basis.

4 Description of the environment

This section provides a description of the environment, including where relevant results from the nearshore environmental monitoring program (NEMP) as described in the *Nearshore Environmental Monitoring Plan* (Cardno 2014a), which was developed and subsequently implemented to monitor for potential environmental impacts associated with the capital dredging program.

4.1 Physical environment

4.1.1 Climate

Darwin Harbour lies in the monsoonal (wet–dry) tropics of northern Australia and experiences two distinct seasons, a hot wet season from November to April and a warm dry season from May to October, with October and April considered the transitional months.

Maximum temperatures are defined as hot all year round. November is the hottest month with a range of 25 °C minimum to 33 °C maximum, while June and July normally experience the lowest average daily temperatures with a range of 19 °C minimum to 30 °C maximum (BOM 2016a). The mean annual rainfall for Darwin is 1,728 mm, with rain falling on an average of 94 days, predominantly in the wet season. A range of monthly rainfall averages received at Darwin International Airport is provided in Table 4-1 (BOM 2016a).

Table 4-1: Average monthly rainfall for Darwin (measured as mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	424	371	315	100	22	2	1	5	15	70	141	252
Max	940	1110	1014	396	299	51	27	84	130	339	371	665
Min	136	103	88	1	0	0	0	0	0	0	17	19

Source: BOM 2016a, based on data collected over 75 years (1941-2016)

During the wet season (November to April), Darwin is dominated by westerly and west-north-westerly winds (INPEX 2010). During the dry season (May to October) the winds vary from south-easterly through to northerly. These trends are illustrated in Figure 4-1 using represented wet season and dry season months (February and August respectively).

The strongest winds and heaviest rainfall are associated with the passage of tropical cyclones and tropical storms (moderate-strength low-pressure systems), which typically occur in Darwin during the period of November to April (i.e. wet season).

The Gulf of Carpentaria averages two cyclones per year, while the Arafura and Timor seas average one cyclone per year. Cyclones in the Gulf of Carpentaria move very erratically, whereas those in the Arafura and Timor seas tend to follow more regular tracks to the south-west (BOM 2016b). Darwin is indirectly affected by cyclones in the north-eastern Indian Ocean and Timor Sea, which generate large swell waves that propagate eastwards into the Beagle Gulf. Tropical cyclones situated in the Arafura Sea and Coral Sea have less of an influence on Darwin's wave climate due to the protection afforded by the eastern coastline of Van Diemen Gulf.

Tropical cyclones cause the most damage within a distance of 50 km from the coast. A storm surge 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 an associated cyclone, the angle at which the cyclone crosses the coast and the bathymetry of the affected area (BOM 2016c).

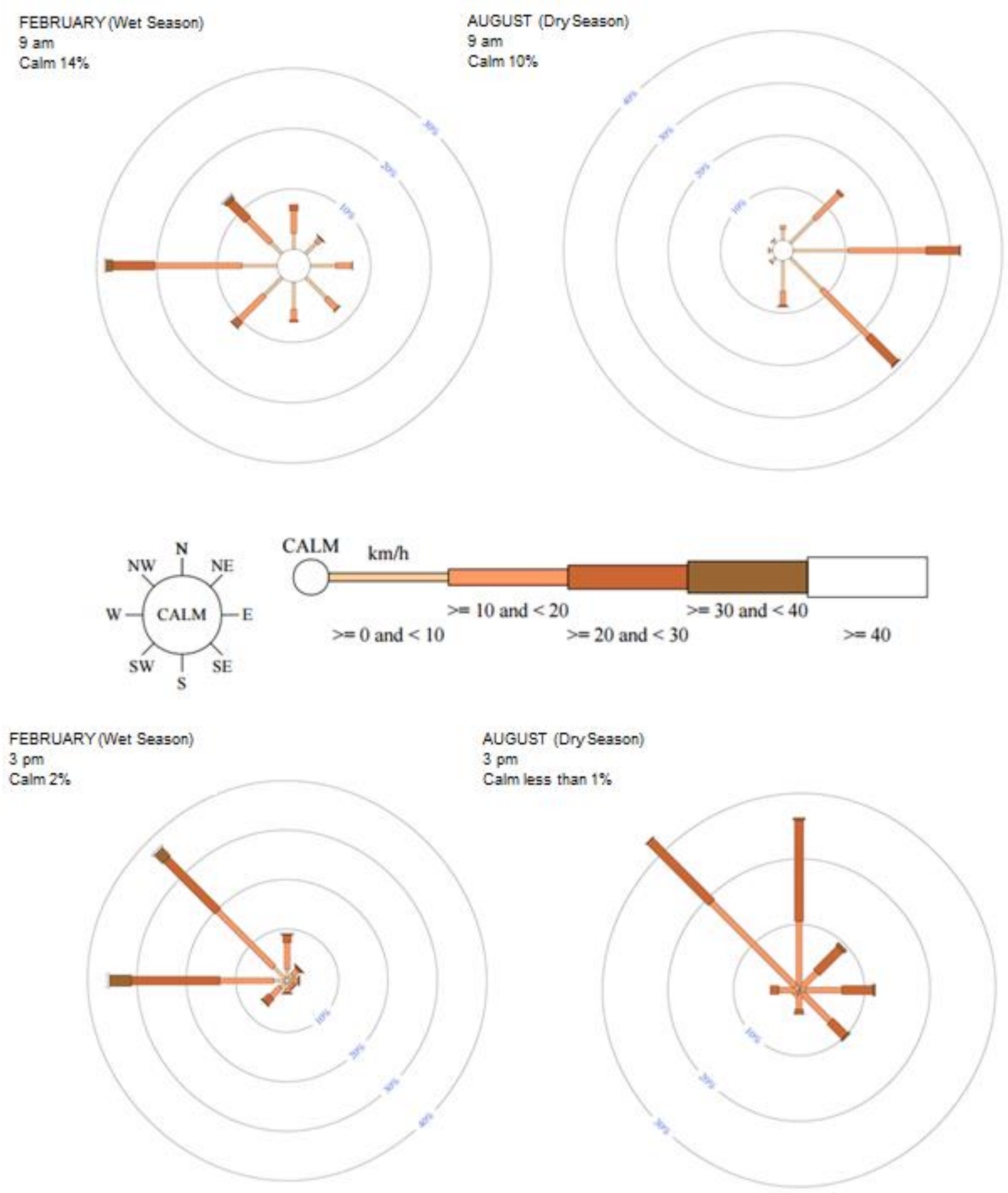


Figure 4-1: February (indicative wet season) and August (indicative dry season) wind roses for Darwin Airport based on data from 1942 to 2016 (BOM 2016d)

4.1.2 Bathymetry and seafloor geology

Darwin Harbour is a large ria (drowned river valley) system with an area of approximately 500 km^2. It has three main components (East Arm, West Arm and Middle Arm) that merge into a single unit, along with the smaller Woods Inlet, before opening into the Beagle Gulf to the north (INPEX 2010).

The main channel for the Port of Darwin is around 15 to 30 m deep, with a maximum depth of 36 m (Figure 4-2; INPEX 2010). The channel favours the eastern side of the Harbour, with broader shallower areas occurring on the western side. The channel continues into East Arm, towards Bladin Point, at water depths of more than 10 m below LAT and leads into the Ichthys LNG Plant access channel and turning basin, which was dredged to 13.5 m below LAT. A slightly deeper channel extends into Middle Arm, up to the western side of Channel Island (INPEX 2010).

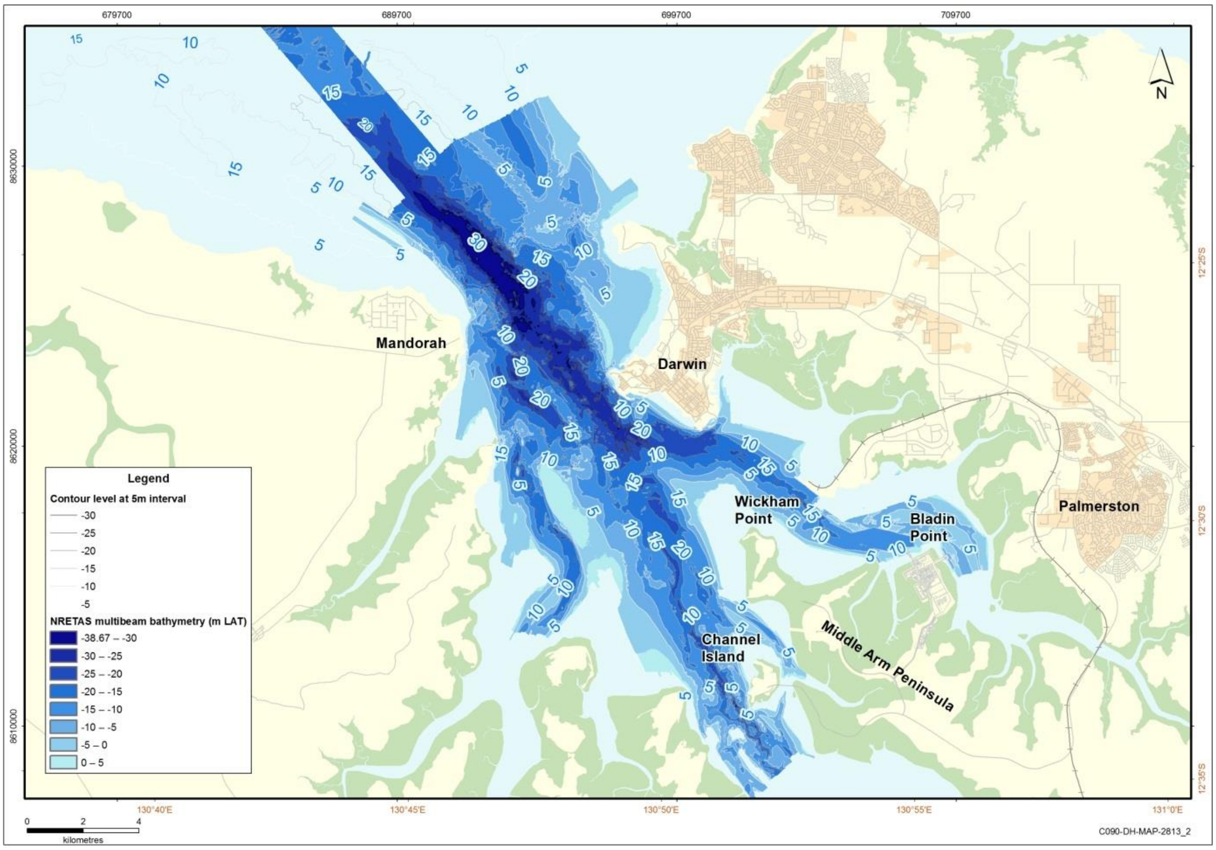


Figure 4-2: Bathymetry of Darwin Harbour

4.1.3 Oceanography

Tides and currents

The Darwin region marine environment encompasses the open ocean of the Beagle Gulf and the estuarine-dominated Darwin Harbour. Tidal forces have the greatest control over the sea level and water currents in Darwin Harbour.

Darwin Harbour is classed as a macro-tidal estuary, with maximum tidal range reaching 7.8 m (Padovan 2003). The Darwin region experiences a semidiurnal tidal cycle (i.e. two highs and two lows per day) with a slight diurnal inequality between the successive tides (INPEX 2010). The daily tidal range is characterised by a pronounced variation in magnitude, repeating approximately every 15 days (spring-neap tide cycle). The average daily tidal range is ~6 m during the spring phase and ~3 m during neap phase of the

tidal cycle (Cardno 2014b). There is also considerable annual variability, with the largest spring tides typically occurring in March and September/October.

Tidal excursions range from 8 to 15 km during spring tides and 2 to 8 km during neap tides (Hanley & Caswell 1995; Semeniuk 1985). Within East Arm, model results show large tidal ranges produce strong currents that peak at 1.5 to 2.0 ms^{-1} during spring tides (HRW 2013a) (Figure 4-3).

The volume of water in Darwin Harbour (outer extent defined by a line between East Point and Mandorah) at mean sea level is approximately 2,100 Mm^3. At high spring tides, the volume is approximately 3,400 Mm^3 and at low spring tides is approximately 1,400 Mm^3. The tidal volume (difference between high and low water) represents a significant percentage of the Harbour volume, indicating the importance of the tides for the transport and mixing of waters within it (Cardno 2014b).

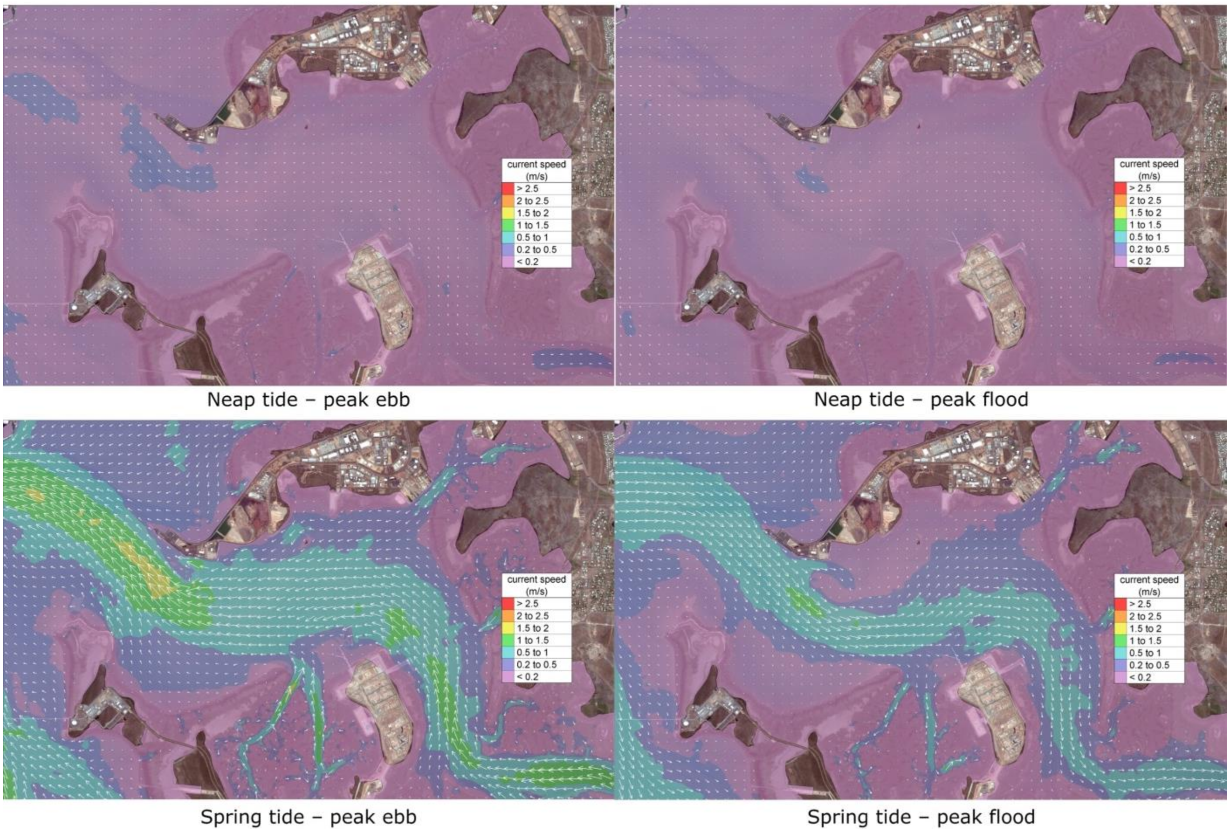


Figure 4-3: Modelled peak current speeds for each tidal state

Waves

Wave activity is a key driver of sediment resuspension, particularly in the shallow nearshore zone. Wave activity in the Beagle Gulf generally consists of two different types: short-period sea waves that are generated by local winds, and long-period swell waves that are generated by winds over the Indian Ocean/Timor Sea. These long-period swell waves can propagate into the Beagle Gulf from the west and are more capable of stirring seabed sediments in deeper water than locally generated short-period sea waves (Cardno 2014b).

During the dry season, waves in the Beagle Gulf are predominantly generated by easterly winds. Due to the relatively short fetch distance and comparatively low wind speeds, these waves are generally small, with a daily average wave height typically below 0.5 m. The daily dry season sea breeze cycle typically consists of calm sea conditions in the

mornings, with increases in the sea state and peak wave heights (up to 0.9 m) occurring in the afternoon before declining again overnight (Cardno 2014b).

During the wet season, tropical storms and cyclones that track close to Darwin can produce rough seas in the Beagle Gulf with very large, short period wind waves (up to ~3.5 m wave height and ~6 to 8 s periods). Tropical cyclones located in the northern Indian Ocean can also produce longer period swell waves that propagate into the Gulf (up to 2 m wave height and ~10 to 12 s periods). At other times during the wet season, daily average wave heights in the Beagle Gulf are 0.8 to 0.9 m, roughly twice the height of those in the dry season, and tend to arrive from a westerly direction (Cardno 2014b).

4.1.4 Water quality

Water temperature

Water temperature variations in Darwin Harbour are driven by seasonal variations in ambient air temperature that drive heat exchange between the water surface and atmosphere. They are also influenced by mixing of differing water masses, for example oceanic waters entering from the Beagle Gulf and fresh water inflow from creeks and rivers. During the NEMP, wet season water temperatures were generally between 30 °C and 32 °C whereas dry season temperatures varied between 24 °C and 26 °C (Cardno 2015a).

High water temperatures (>32 °C) are known to occasionally occur during the wet season. However, these are often short-lived due to significant rainfall events or the influx of cooler water into the Harbour from the Beagle Gulf, typically during the passage of a tropical cyclone or significant tropical storm (Cardno 2015a).

Salinity

Salinity (measured as practical salinity unit (PSU)) within Darwin Harbour is generally slightly lower in the wet season when compared to the dry season due to rainfall; however, in either season there can be strong local gradients in salinity.

During the wet season, salinity can range from approximately 30 PSU in the mid-Harbour down to near 0 PSU further up rivers, where there are significant freshwater inflows. As salt water is denser than fresh water, the Harbour can also become temporarily stratified at locations close to significant freshwater inflow. Vigorous tidal stirring has been observed to facilitate rapid mixing such that stratification is generally short-lived (Cardno 2015a) and typically restricted near the source (i.e. the location of freshwater inflow).

During the dry season, a lack of rainfall and increased evaporation can lead to salinities greater than 35 PSU in shallow waters where there is limited tidal flushing (Cardno 2014b).

Turbidity

Turbidity is a measure of the amount of light scattering through the water column caused by particles of suspended sediment (Stoddart & Anstee 2004). Turbidity is typically measured in nephelometric turbidity units (NTU) and is determined by the shape, size and refractive index of the particulate material. Turbidity is often used as a proxy for the concentration of total suspended solids (TSS) in the water column (Cardno 2013a). A Harbour-wide NTU/TSS relationship of 1:1 was derived during the capital dredging program for the purposes of validating the sediment transport model (Cardno 2013a) and has therefore been used in modelling for this Maintenance DSMDP (Section 5.4).

Darwin Harbour is a naturally turbid environment. The key processes that control the level of turbidity in Darwin Harbour include resuspension, transport and settling of

sediment. Turbulent energy generated by waves and tidal currents near the seabed, in addition to the relative sediment particle size, determine the rate at which bed sediments are mobilised and their residence time within the water column (Cardno 2015a) (Figure 4-4).

Tides are a primary driver of turbidity within Darwin Harbour. The relationship between turbidity and short term (e.g. hourly) tidal variations is complex due to the relative timing of processes controlling sediment dynamics. In general, the fast current speeds and high turbulence levels, relatively short periods of slack water, together with an abundance of fine sediment, tend to result in high background levels of turbidity in Darwin Harbour (Cardno 2015a).

Turbidity varies over the spring-neap cycle, with the maximum daily-averaged turbidity coinciding closely with spring tides and the minimum coinciding with neap tides. Without the influence of episodic events and rainfall, the spring-neap cycle explained approximately 80% of the measured daily average turbidity in Darwin Harbour (Cardno 2015a). Composite MODIS imagery for September 2008 to 2012 (shown in Figure 4-5) illustrates the region wide differences in turbidity between spring and neap tides.

Turbidity is typically a magnitude greater during the passage of episodic tropical cyclones and monsoonal storms in the wet season due increased winds and wave heights, in addition to sediment-laden runoff from high rainfall. Over the NEMP measurement period (2012-2015), these events were found to result in elevated turbidity levels (>150 NTU daily average) in coastal waters outside the Harbour, while the more sheltered waters within the Harbour typically experienced lower turbidity levels. Where these events coincided with spring tides, tidal currents entrained the highly turbid offshore coastal waters into the Harbour thereby increasing local turbidity (>100 NTU daily average) (Cardno 2014b).

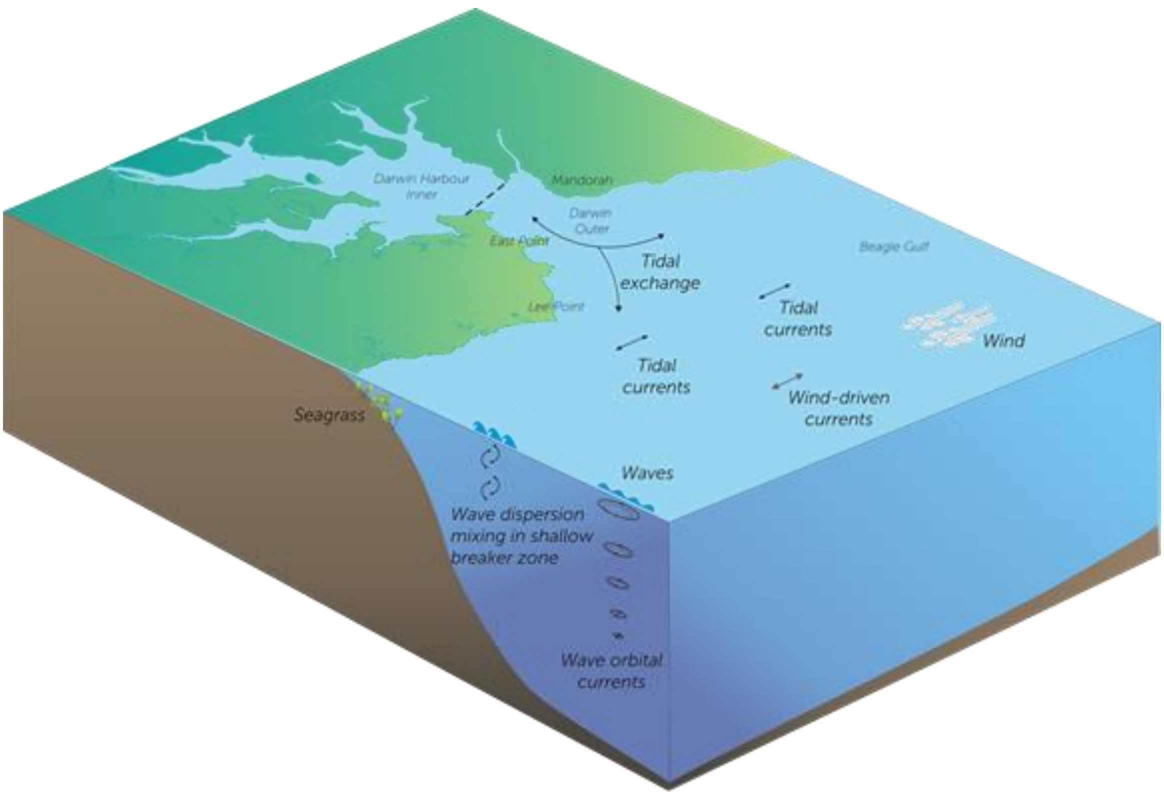
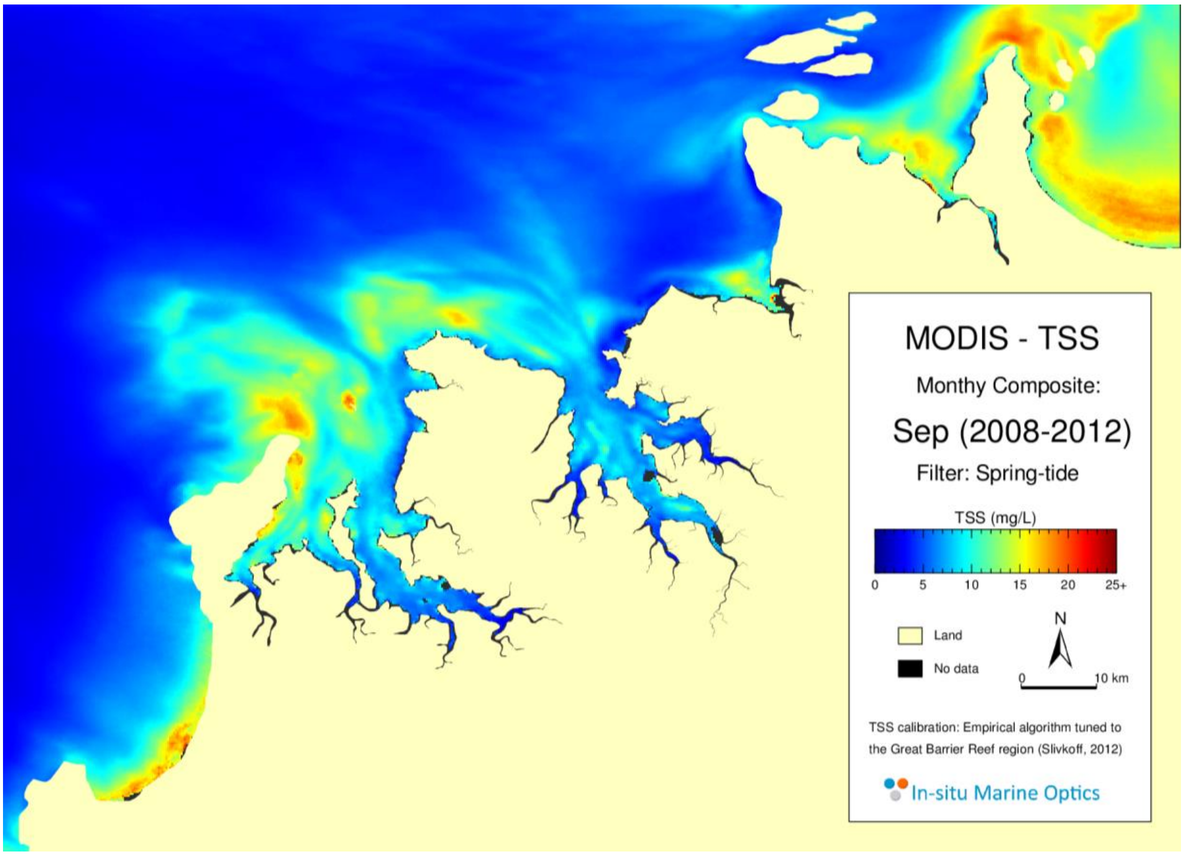


Figure 4-4: Key oceanographic processes that affect turbidity in Darwin Harbour and the Beagle Gulf (Cardno 2014b)



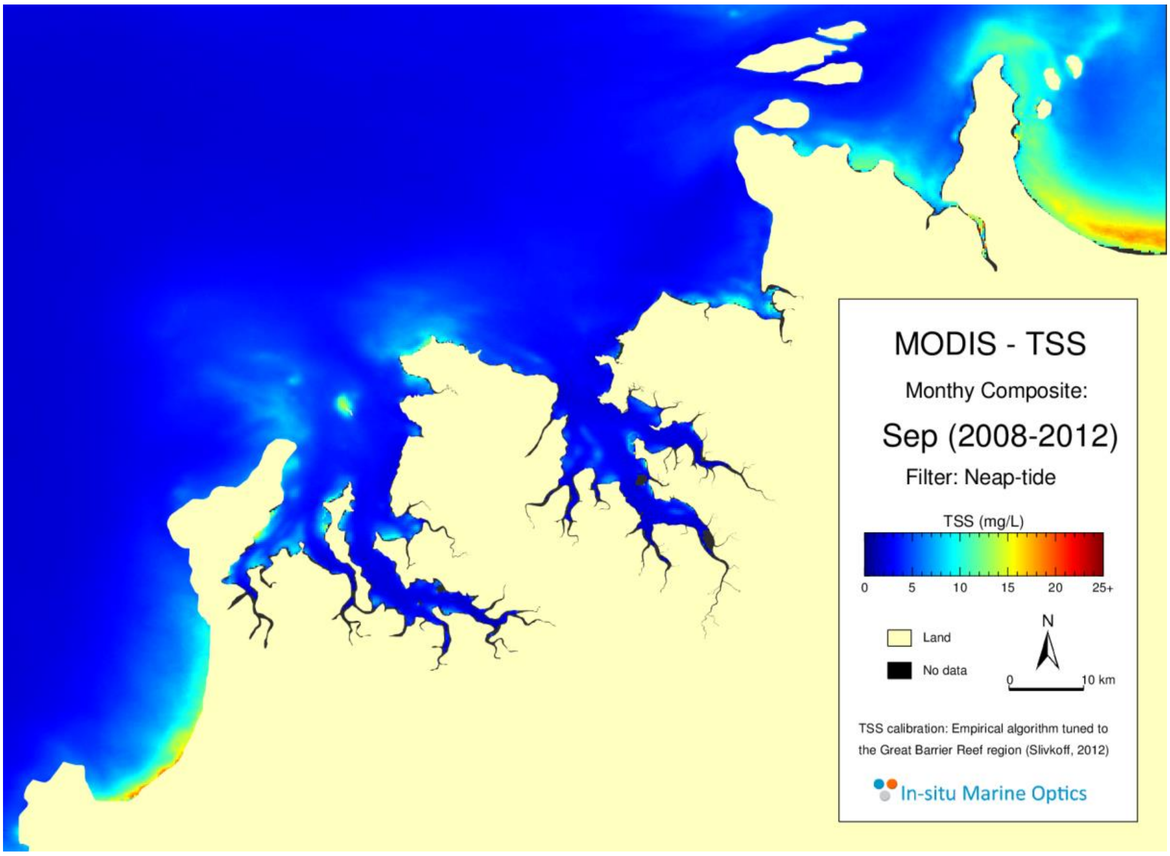


Figure 4-5: Composite MODIS imagery for September (2008-2012) spring tide (top) and neap tide (bottom) periods

Light availability

The intensity of underwater light (measured as photosynthetic active radiation (PAR)) decreases exponentially with increasing depth in the water column. Light attenuation is further enhanced by the presence of suspended sediments in the water column resulting in light scattering and absorption. Therefore, the amount of surface light that reaches the seabed depends upon the surface light intensity, the water depth and the turbidity (Cardno 2015a).

The amount of light reaching the seabed is influenced by the daily tide cycle in relation to solar noon. Light levels at the seabed are typically highest when the low water level (i.e. minimum depth) occurs around solar noon (Cardno 2015a). The height and timing of the low water level varies within any month and throughout the year. In consideration of water depth alone, potential light levels at the seabed are generally highest from October to February, when the sun is highest (and most intense) and the lower of the two daily low tides during springs occur around solar noon. However, during this period in Darwin Harbour wet season cloud cover is often extensive, which reduces the amount of surface light and hence light reaching the seabed (Cardno 2015a).

Suspended sediments reflect and scatter light reducing the distance surface light penetrates into the water column. While tidal effects on the water depth tend to work to maximise light in the wet season, these effects are typically counteracted by elevated turbidity driven by tidal currents, increased winds and waves, and sediment-laden runoff from increased rainfall. Turbidity tends to be the dominant influence on light penetration, with maximum light levels observed during minor spring tides and the end of the dry season/start of the wet season when turbidity is at its lowest (Cardno 2015a).

Turbidity and the associated seabed light levels vary spatially and temporally across the Darwin region. Overall, the effect of tides on turbidity is broadly consistent throughout the year, with the effects typically more pronounced within Darwin Harbour. During the wet season, turbidity outside of the Harbour is typically dominated (through sediment resuspension) by increases in wind and waves associated with episodic weather events (Cardno 2015a). Consequently, seasonal differences in light and turbidity levels were most pronounced at sites outside of Darwin Harbour (Cardno 2015a).

Low benthic light levels are known to occur at any time throughout the Darwin region, typically due to the coincidence of high tides and elevated turbidity. Extended periods of naturally low light levels and ‘blackout’ conditions (i.e. no light) are most prevalent during episodic events in the wet season; however, these occur variably. For example, averaged across all monitoring sites, 10% of the days during the 2013/14 wet season experienced blackouts at a depth of 3 m below LAT compared to only 1% of the days during the 2013 dry season (Cardno 2015a). Natural low light events extended for periods of around 2 to 16 consecutive days (and sometimes longer), which can ultimately influence photosynthesis and subsequent primary production of seagrass and corals (Cardno 2015a).

4.1.5 Sediment quality

Dredge area

A sediment quality assessment within the dredge area was undertaken in May 2016, to assess the suitability of the accumulated sediment for open water disposal (INPEX 2016).

The particle size distribution (PSD) of sediment samples showed that silt and fine sands were the dominant fractions overall, with an average of 57% and 29% for all sites combined respectively. Sediment particle size within the Jetty Pocket was homogenous in nature predominantly consisting of silts and clays (~90% combined). In contrast, the particle size within the Turning Basin was more heterogeneous and reflected the position

of individual site locations relative to the prevailing hydrodynamic flows. The particle size became coarser moving from the Jetty Pocket towards the northern towline and west towards the Approach Channel, which contained relatively equal proportions of silts, sands fractions (i.e. fine, medium and coarse) and gravel.

The sediment samples were found to contain very low levels of organic compounds. The polycyclic aromatic hydrocarbons (PAH; sum) were all below limits of reporting (LOR; 4 µg/kg) with the exception of one individual site (5 µg/kg) and were all significantly below the respective Screening Level (10,000 µg/kg) prescribed in the National Assessment Guidelines for Dredging (NAGD; Commonwealth of Australia 2009). Total petroleum hydrocarbon (TPH) concentrations for all sites combined (39.6 mg/kg) were also well below the respective Screening Level (550 mg/kg) and benzene, toluene, ethylbenzene and xylene (BTEX) compounds were below the laboratories LOR.

The assessment also confirmed that metal and metalloid concentrations for all sites combined were below their respective NAGD Screening Levels. At an individual site level, arsenic was recorded above the Screening Level at two sites, while nickel and lead were both recorded above their respective Screening Levels at a site. The arsenic and nickel results were within the measured background range for Darwin Harbour, while the result for lead is likely to be related to an anthropogenic source (e.g. paint flake from a vessel or lead associated with recreational fishing activities).

Although nutrients were not included in the analysis, previous sampling within the dredge area and adjacent areas found Total Nitrogen to be low (mean 359.2 mg/kg) and primarily comprised of Total Kjeldahl Nitrogen (mean 355.6 mg/kg) (URS 2009). Similarly, Total Phosphorus levels were also found to be low (mean 508.5 mg/kg) (URS 2009; Munksgaard et al. 2013).

Based on the assessment, the sediment that has deposited within the dredge area was found to be uncontaminated and therefore considered suitable for dredging and open water disposal at the DSDA.

Darwin Harbour

Numerous monitoring and research programs have been undertaken in Darwin Harbour and in particular East Arm to characterise sediments in the area. Results from published monitoring studies in East Arm (Munksgaard et al 2013; URS 2009; Fortune 2006) have found the sediment to be primarily comprised of sand with varying amounts of gravel, silt and clay, depending on the sample location (e.g. intertidal areas or channels).

Analysis of potential contaminants in Darwin Harbour such as metals (including metalloids) found that arsenic concentrations commonly exceed the low (20 mg/kg) and high (70 mg/kg) interim sediment quality guidelines Screening Levels (ANZECC and ARMCANZ 2000a). However, these high concentrations have been attributed to local geology (weathering of arsenic rich coastal substrata) rather than anthropogenic sources (Fortune 2006). Furthermore, previous bioavailability testing has indicated that only a small proportion is bioavailable indicating that it is unlikely to be toxic in the marine environment.

A range of other metals (e.g. chromium, mercury, nickel and silver) have also been recorded to exceed Screening Levels for individual samples; however, their mean concentrations have always remained below Screening Levels.

Few programs in East Arm have analysed samples for other contaminants such as organic compounds. The sampling undertaken during the EIS phase of the Project (URS 2009) is the most comprehensive in the area and found that tributyltin (TBT), BTEX, polychlorinated biphenyls (PCBs) and organochlorine pesticides (OCPs) were all below the laboratories LOR. The majority of samples analysed for PAHs and TPHs have also been below LOR.

DSDA

The most recent DSDA PSD data is from July 2015, which was collected approximately one year after the completion of the capital dredging program as part of the NEMP (Cardno 2015g). Sediment particle size within the DSDA consisted predominantly of fine sand (53%), with relatively equal proportions of fines (i.e. clay and silt), medium and coarse sands making up the remainder (Cardno 2015g).

Sediment characterisation of the DSDA was undertaken in September 2012 for metals, nutrients and organic compounds (INPEX 2012) for the capital dredging program. Metal analysis found that for all sites antimony, cadmium and silver were below the LOR, while mercury was below the LOR at 86% of the sites. Metals were below the NAGD Screening Levels for all sites combined with the exception of arsenic, in which 71% of sites were above the Screening Level. The levels of arsenic recorded in the DSDA were within those recorded previously for Darwin Harbour (e.g. Fortune 2006; URS 2009).

All samples collected for TBT, TPH and BTEX were below the LOR and their respective Screening Level, where specified (INPEX 2012). The majority of PAHs samples were also below LOR with only two samples slightly above (≤2 mg/kg) the LOR. Regardless PAHs were all significantly below their Screening Level.

Similar to the dredge area and Darwin Harbour, nutrient levels (total nitrogen and total phosphorus) at the DSDA were found to be low.

4.1.6 Underwater noise

The soundscape within Darwin Harbour reflects its unique biological and physical environment, in addition to the range of human activities associated with recreation, fishing, tourism, defence and port operations, and construction works (Salgado-Kent et al. 2015).

In order to characterise the acoustic environment in East Arm, Darwin Harbour, noise monitoring was undertaken in 2009 (SVT 2009). The readings obtained during the monitoring program can be broadly broken into three general frequency spectra, namely 0–50 Hz, 50–2000 Hz and >2000 Hz. Within the low-frequency spectrum (0–50 Hz) most of the noise recorded was below 20 Hz. This low frequency spectrum is generally below the hearing range of most of the marine fauna that occur in Darwin Harbour.

The mid-frequency spectrum between 50 and 2000 Hz shows very wide variations in the ambient noise levels recorded, which is a result of the acoustic complexities of the area (INPEX 2010). Factors such as shallow water, variable depth of water, high tidal range (and the turbulence created by tidal flows) and variable seabed types cause wide variations in the propagation of noise through the water column. It was noted that noise spectral levels in the Elizabeth River were distinctly lower than those in the broader parts of East Arm (around 100 dB re 1 $\mu Pa^2/Hz$, compared with around 150–170 dB re 1 $\mu Pa^2/Hz$), as the shallower water, more complex landform and soft-bottom substrate in the Elizabeth River all reduce noise propagation (INPEX 2010).

The high-frequency spectrum (>2000 Hz) of ambient noise in the Harbour is dominated by the sound of snapping shrimp. This typically has a peak frequency of 5000–7000 Hz (INPEX 2010).

As a part of the NEMP, long-term underwater noise monitoring was conducted using stationary autonomous sea noise recorders from November 2012 to January 2015. The noise measurements made during the program confirmed that the underwater noise profile within Darwin Harbour is noisy as a result of biological, physical and anthropogenic sources (Salgado-Kent et al. 2015).

During periods in which there was no pile driving or dredging in East Arm, the most intense noise dominating the soundscape was from a range of vessels and to a lesser

extent machinery operating in the area. Underwater noise levels from vessels was broadband, with most energy ranging from tens of Hertz to several Kilohertz and often reaching close to 130 and 140 dB re 1 μPa (SPL) when at close range. The total number of vessels using and visiting Darwin Harbour has increased significantly in recent years and is expected to continue to increase (Salgado-Kent et al. 2015).

Noise from biological origin including fish chorusing and snapping shrimp was present in East Arm and Middle Arm throughout most of the monitoring program. Fish choruses, which are formed by individual sounds produced by many animals at the same time, were highly diverse in Darwin Harbour. A total of nine chorus types were described and attributed to finfish. The chorus described as 'Chorus I' was the most common chorus, present at all sites, across all seasons and years and exhibited clearly defined patterns of calling. Choruses often raised ambient noise levels between 50 Hz and 3000 Hz, typically from 100 dB re 1 μPa (SPL) to 125 to 130 dB re 1 μPa (SPL), though on occasion as high as 140 dB re 1 μPa (SPL). Noise from snapping shrimp occurred in all data sets. Snapping shrimp produced broadband, intense 'snapping' sounds which were short in duration with most energy above 1000 Hz (Salgado-Kent et al. 2015).

4.2 Marine benthic habitats

Darwin Harbour has a complex assemblage of marine habitats and there are large differences in the extent, diversity and significance of the associated biological communities. Rocky intertidal areas are found where headlands protrude into the Harbour. Extensive mangrove communities dominate in the bays and other protected areas throughout the intertidal zone. Seaward of the mangroves, extensive flats occur in the lower intertidal zone. Many of these flats are mud, but some areas are basement rock that may have thin veneers of sand or mud (INPEX 2010). Seaward of the mangroves, a range of intertidal and subtidal habitats occur supporting seagrass, coral and macroalgae communities.

As part of the EIS Supplement, a comprehensive baseline marine habitat survey was completed, which informed the original benthic habitat layer (INPEX 2011). The benthic habitat layer include both "high-confidence" and "inferred" habitat areas as described in the EIS Supplement (INPEX 2011). High-confidence habitat areas were defined by interpolating subtidal substrate and biological community maps from the original benthic habitat survey, as well as information from digital imagery and acoustic surveys. The proportion of benthic habitats in the survey areas (high-confidence areas) were then used to represent the remaining areas outside the high-confidence area to produce inferred habitat areas. The default percentage cover of the benthic habitats in the inferred habitat areas was classified using the percentage cover of the biological communities and substrate type in the high-confidence area for different water-depth classes.

Following completion of the NEMP and in particular the additional seagrass habitat mapping undertaken as part of the seagrass monitoring program (Cardno 2012), this baseline layer was updated (Figure 4-6 and Figure 4-7). Further, where appropriate, the benthic habitat maps (and associated habitat impact assessment) will be refined as new spatial habitat layers become available.

The following sections describe in more detail the benthic habitats found with Darwin Harbour and the Darwin region.

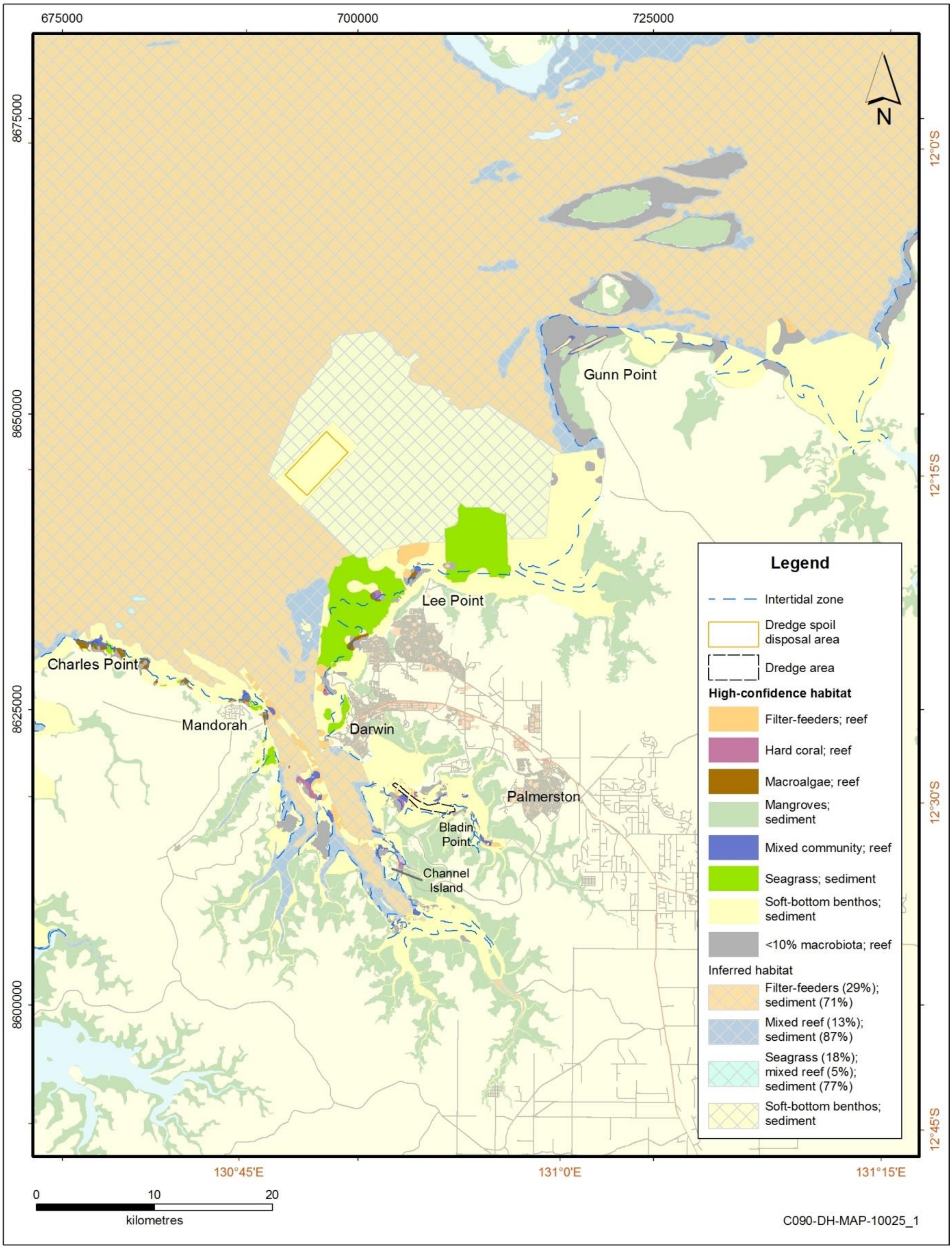


Figure 4-6: Benthic habitat map of the greater Darwin region

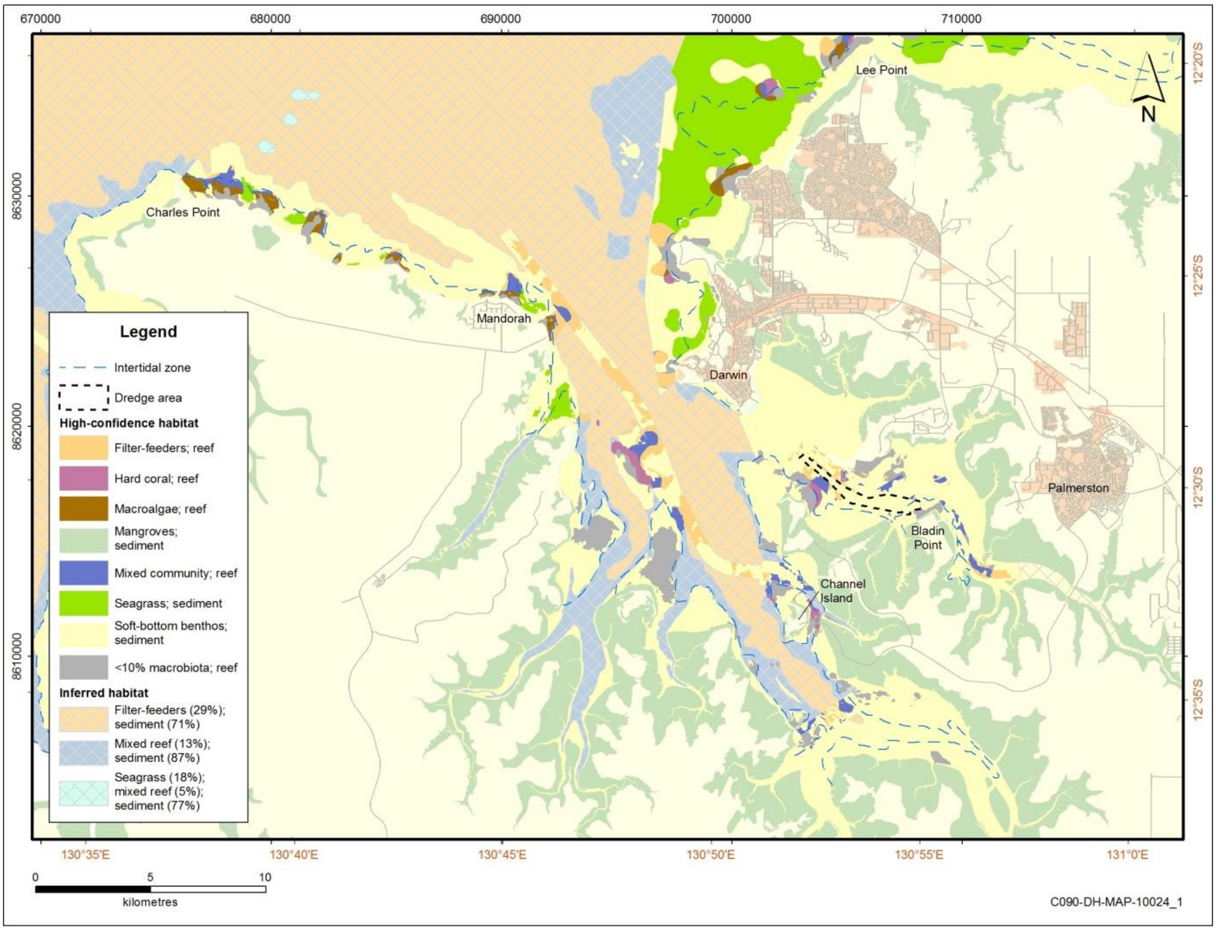


Figure 4-7: Benthic habitat map of Darwin Harbour

4.2.1 Mangroves

Mangrove communities are important to the ecological health of Darwin Harbour and provide food and shelter for a wide range of animals (e.g. nursery grounds for juvenile fish and crabs). Mangroves in the Darwin Harbour area constitute approximately 44% of the mangrove communities in the Darwin Coastal Bioregion and about 5% of the total mangrove area of the Northern Territory, with 80% of these mangroves found in the "inner" Harbour between Sadgroves Creek and Mandorah (INPEX 2010). As a part of the NEMP, the aerial extent of mangrove was determined (based on WorldView II imagery) to be 25,199 ha between Tapa Bay (Charles Point) and Shoal Bay (Cardno 2014c).

Darwin Harbour is also recognised for its mangrove diversity, containing 36 of the 50 known mangrove species worldwide.

In Darwin Harbour there are four key mangrove assemblages distributed along the tidal profile as illustrated in Figure 4-8 (Cardno 2014b). The seaward assemblage grows between 3 and 4 m LAT (typically between mean low water neaps (MLWN) and mean sea level (MSL)) and experiences tidal inundation twice every day at high tide. It is most commonly found adjacent to the open Harbour next to expansive mud flats rather than in riverine or creek system settings. It is dominated by open woodland of mature *Sonneratia alba* trees and in many places an understorey of the river mangrove *Aegiceras corniculatum* (Cardno 2014b).

Further, up the tidal profile, the tidal creek assemblage is typically found between MSL and mean high water neaps (MHWN) and is inundated at least once every day. This assemblage is dominated by *Rhizophora stylosa* and is found throughout Darwin Harbour often fringing creeks that lack a seaward assemblage (Cardno 2014b). Adjacent to the

tidal creek assemblage, is the tidal flat assemblage (typically located between MHWN and mean high water springs (MHWS)) is only inundated during spring high tide and as such and contains hyper saline salt flats. The tidal flats support a low closed but patchy forest dominated by *Ceriops australis*, while the surrounding the salt flats typically occupied by the most salt tolerant species *Avicennia marina* (Cardno 2014b).

At the landward edge of the mangroves, above the MHWS, lies the generally narrow Hinterland Margin assemblage, which is inundated only a few times a year during the highest spring tides. This assemblage is commonly dominated by *C. australis*; however, contains a greater variety of mangrove species than in other assemblages, including *Lumnitzera racemosa* and varieties of the deciduous *Excoecaria sp*.

Harbour-wide mangrove health monitoring using remote sensing (normalised difference vegetation index) as part of the NEMP showed a distinct seasonality in mangrove condition. Mangroves are typically healthiest in the late wet (February to April) to early dry (May to July) season and most stressed in the late dry (August to October) to early wet (November to January) season. This seasonality in mangrove condition is likely to be linked to the effects of increased wet season rainfall and lower evaporation and inversely low rainfall and higher evaporation during the dry season, along with other seasonal changes in temperature, light regime and salinity (Cardno 2015b).

Mangrove recruitment follows the same seasonal pattern as with mangrove condition, in that peak recruitment occurs in the late wet season (April) when mangroves are healthiest and is lowest in the late dry season (October/November) when mangrove condition is weakest (Cardno 2015b). Mangrove productivity has also been found to be highly seasonal, peaking in the late dry/early wet season and lowest in the early to mid-dry season (Cardno & EcoScience 2014; Metcalfe 1999).

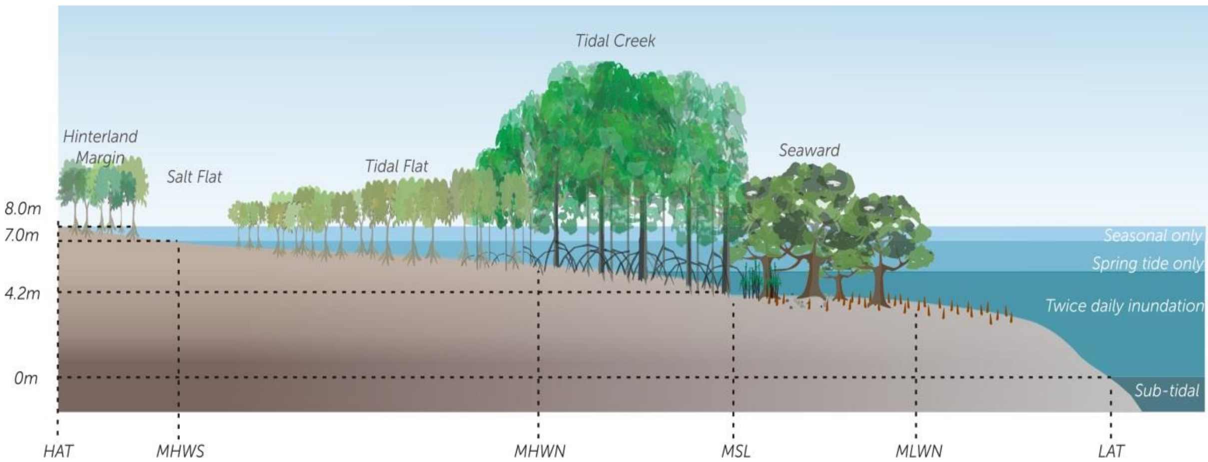


Figure 4-8: Major mangrove assemblages of Darwin Harbour and their position in the tidal profile (adapted from Brockelhurst and Edmeades 1996) (Cardno 2014b)

4.2.2 Coral

Hard coral communities in Darwin Harbour are located in the lower intertidal (less than 1 m above LAT) to upper subtidal zone, down to approximately 5-10 m below LAT (INPEX 2010). Coral communities in Darwin Harbour are unique as they are exposed to fluctuations in salinity and higher levels of turbidity and sedimentation that would not normally be associated with coral communities. Corals living in the lower intertidal zone may also be exposed during extreme spring low tides that typically occur in the late dry to early wet season (September to December), making them vulnerable to potential desiccation and freshwater impacts if low tides coincide with heavy rainfall events (INPEX 2010).

In waters deeper than approximately 5 m below LAT, hard coral communities diffuse into sparsely distributed soft coral and sponge-dominated filter-feeder communities. All three of these communities are restricted to areas of hard substrate, where they can gain a holdfast on exposed rock or hard substrate under a thin veneer of benthic sediment.

Coral communities in Darwin Harbour are known to occur at Channel Island, Weed Reef, Northeast Wickham Point, South Shell Island and Mandorah. Table 4-2 provides the percentage of hard coral cover for each family group from transects undertaken in the final post capital dredging survey in December 2014 (Cardno 2015c). Notably, the family composition and therefore potential susceptibility to environmental pressures differs between sites, even at a local scale (i.e. between Weed Reef 1 and Weed Reef 2).

Of these known coral communities, Channel Island has been declared and is protected under the *Heritage Act 2011* (NT) for its unique position and species diversity in a large ria (drowned river valley) system characterised by stressors (high turbidity, currents, sedimentation and depressions in salinity) that are not normally considered conducive to coral growth or presence (DEE 2016a).

Reproductive data for coral assemblages in the Darwin region is limited. Coral gravidity assessments undertaken as a part of the NEMP indicated that Faviidae colonies may have an autumn (April/May) spawning window in Darwin Harbour (Cardno 2015c), while operators of the Darwin-based Indo Pacific Marine (aquarium) have observed coral spawning within their tanks around full moon in October and November (TWP 2006).

Annual coral bleaching events were recorded throughout the NEMP coral monitoring program, although the magnitude and intensity varied temporally and spatially. These bleaching events are thought to occur when water temperatures rise above 30°C. It is likely that the rate at in which temperatures rise, the duration of increased water temperatures and the timing, frequency, intensity and duration of wet season tropical storms all have an influence on the timing and intensity of coral bleaching in Darwin Harbour (Cardno 2015c).

Between February and March 2016, record ocean temperatures have led to record widespread coral bleaching on Australian coral reefs. This bleaching is part of the ongoing third global bleaching event, declared by the National Oceanic and Atmospheric Administration in 2015 (AIMS 2016). Although no coral bleaching surveys have been undertaken in Darwin Harbour during 2015-2016, sea surface temperatures measured monthly within East Arm were high, with a median (across sites) of 31.6 °C in February 2016 (Greencap 2016). Given the 2015/2016 wet season was relatively benign and well below average in terms of rainfall (150.4 mm compared to 371.3 mm), there is a real possibility that bleaching may have occurred, as was seen at other coral reefs in early 2016 off the coast of Arnhem land (Wild 2016) and in north-western Australia, including those near the Kimberley, Christmas Island, Scott and Seringapatam Reefs (AIMS 2016).

Table 4-2: Hard coral composition (%) in the final post dredging survey (Cardno 2015c)

Coral Family	Channel Island	Weed Reef 1	Weed Reef 2	South Shell Island	Northeast Wickham Point	Mandorah
Acroporidae	0.01	0.14	0.12	0.00	0.00	0.00
Agariciidae	0.00	0.19	0.26	0.00	0.00	0.00
Dendrophylliidae	0.54	0.97	2.68	0.17	0.27	7.19
Euphyllidae	0.00	0.00	0.43	0.00	0.00	0.00
Faviidae	3.14	1.69	2.80	0.19	0.77	1.41

Coral Family	**Channel Island**	**Weed Reef 1**	**Weed Reef 2**	**South Shell Island**	**Northeast Wickham Point**	**Mandorah**
Fungiidae	0.49	2.55	0.30	0.16	0.20	0.07
Merulinidae	0.13	0.09	0.11	0.00	0.00	0.00
Mussidae	0.00	0.05	0.04	0.00	0.00	0.00
Oculinidae	0.00	0.00	0.06	0.00	0.00	0.05
Pectiniidae	6.60	6.25	2.43	2.36	0.64	0.02
Pocilloporidae	0.00	0.00	0.00	0.01	0.00	0.00
Poritidae	3.05	0.88	3.78	5.03	0.54	0.22
Siderastreidae	0.00	0.02	0.25	0.00	0.00	0.02
Total	13.96	12.83	13.26	7.92	2.42	8.98

4.2.3 Seagrass

Seagrass monitoring undertaken for the NEMP identified large seagrass beds along the Darwin coastal region between Fannie Bay and Lee Point, and smaller isolated patches at Woods Inlet and off Charles Point along the Cox Peninsula (Cardno 2015d). No seagrass was identified within Darwin Harbour itself during the monitoring program, although other environmental surveys have identified isolated sparse patches of seagrass at Weed Reef and Wickham Point (INPEX 2010).

The NEMP seagrass monitoring program identified distinct genus-specific spatial and temporal patterns for the two common genera found in the Darwin region, *Halodule* and *Halophila*, in addition to the overarching seasonal cycles of distribution as illustrated in Figure 4-9 (Cardno 2014b, 2015d).

Halodule is typically found in the lower intertidal (+2 m LAT) and subtidal (-1 m LAT) zone. The spatial distribution of *Halodule* typically remains stable through the seasons, although the density/percentage cover varies between 5% and 20% with the lowest values typically recorded during the wet season (November to April).

Conversely, *Halophila* is typically found in the deeper subtidal areas (down to 9.5 m LAT), although distribution can extend into the intertidal zone (up to +2 m LAT). *Halophila* also displays considerable changes in seasonal distribution, with expansion of beds throughout the dry season and extreme reductions in the wet season, to the extent that it may be completely absent at monitoring sites. Subsequently, percentage cover in survey areas can range from complete absence during the wet season to more than 50% cover in the dry season.

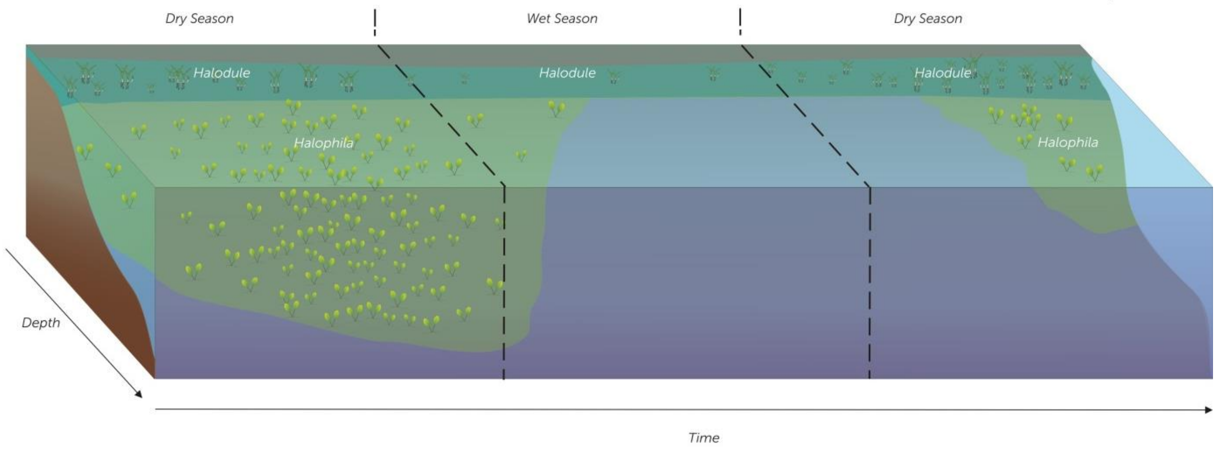


Figure 4-9: Temporal and spatial dynamics of *Halodule uninervis* and *Halophila decipiens* seagrass habitat in Darwin found through the capital dredging program (Cardno 2014b)

4.2.4 Macroalgae

Macroalgae dominated communities in Darwin Harbour are often located on platform crests and in the intertidal–subtidal interface zone, generally a few metres either side of the low water mark and often in association with coral or sponge dominated communities. Known localities of these communities are East Point Reef and Weed Reef (Smit 2003). Marine habitat investigations by URS (INPEX 2010) recorded a sparse though diverse macroalgal community on the rubble covered pavement at Weed Reef, which included browns (*Sargassum* and *Padina* spp.), foliose reds (*Laurencia* spp.), greens (*Caulerpa*, *Ulva* and *Udotea* spp.) and calcareous greens (*Halimeda* spp.) (INPEX 2010).

Algal composition is highly seasonal and seems to be regulated by the amount of time the community is exposed during spring low tides and other factors such as rise in water temperature. During the build-up season (October to December) when water temperatures rise to over 30 °C and the tidal range is at its largest, exposing the lower intertidal zone, the larger macroalgae die back and turf algae dominates. During the earlier dry season, when the tidal range is not so extreme, the larger macroalgae are more abundant (INPEX 2010).

4.2.5 Soft-bottom benthos

Soft substrates, which make up the largest habitat within Darwin Harbour, consist mainly of muds and fine sand and are found in front of (seaward of) mangroves and in intertidal and subtidal areas between the hard substrates and the main drainage channels.

Intertidal and subtidal soft substrates support a range of marine invertebrates live buried within and on the surface of the sediments, respectively referred to as infauna and epifauna. Infaunal assemblages vary largely depending on the type of sediment they are associated with, but generally contain a variety of burrowing organisms such as polychaete worms, amphipod crustaceans, bivalve and gastropod molluscs, and nemerteans and nematodes, etc. These animals are an important source of food for wading birds and fish that live in the Harbour and also help in nutrient cycling. The species richness and abundance of these assemblages is likely to vary both annually and seasonally (Metcalfe & Glasby 2008), likely related to the intensity of the monsoon season and recruitment success (Cardno 2014b).

Intertidal areas within Darwin Harbour were surveyed as part of the NEMP. Sediments generally consisted of a high proportion of clay and silt (ranging from 4.5% to 58%) with

varying amounts of fine sand and small proportions of gravel at some sites. A diverse range of taxa were collected including (in order of abundance) polychaete worms (from a variety of families), crustaceans (including isopods, amphipods, cumaceans, crabs and burrowing shrimp), molluscs (gastropods, bivalves and opisthobranchs), echinoderms (ophiuroids and holothuroids) and other worm taxa such as nematodes, nemerteans, oligochaetes, phoronids, platyhelminthes and sipunculids. Other groups recorded included anemones, hydrozoans, sponges and pycnogonids (sea spiders) (Cardno 2013b).

Subtidal areas within Darwin Harbour and within and adjacent to the DSDA were also surveyed as a part of the NEMP. The overall percentage cover of epifauna in these areas was sparse, with ascidians, sponges, hydroids, anemones, bryozoans, macroalgae and filamentous algae collectively accounting for less than 1% of the total mean cover in both the Darwin Harbour and offshore. In contrast, the infaunal assemblages sampled were diverse, including several types of crustaceans (amphipods, isopods, tanaids, cumaceans, penaeids, copepods, ostracods, shrimp, hermit crabs, ghost shrimp and brachyuran crabs), polychaete worms (from a variety of families), molluscs (gastropods, bivalves and opisthobranchs), echinoderms (ophiuroids, echinoids, holothurians and seastars) and other worm taxa such as nematodes, nemerteans, oligochaetes, phoronids, platyhelminthes and sipunculids. Other taxa recorded but identified to broader groups included anemones, bryozoans, hydrozoans, sponges, and pycnogonids (sea spiders) (Cardno 2013c).

4.3 Pelagic environment

Darwin Harbour supports a number of pelagic marine species including marine reptiles, mammals and fish/sharks these are described further in the following sections.

4.3.1 Marine mammals

A number of marine mammal species frequent or are known to inhabit Darwin Harbour and its surrounds, including coastal dolphins, dugongs and whales. Of these, the most commonly recorded marine mammals in Darwin Harbour are dolphin species.

The Australian snubfin (*Orcaella heinsohni*), the Australian humpback (*Sousa sahulensis*) and the Indo-Pacific bottlenose (*Tursiops aduncus*) are all dolphin species known to have resident populations within Bynoe Harbour, Darwin Harbour and Shoal Bay. Overall, approximately 150 dolphins (all species combined) are thought to inhabit the Darwin region (Brooks & Pollock 2015a). Of the three species that frequent the region the Australian humpback dolphin is the most abundant, followed by Australian snubfin and bottlenose dolphins. In addition to the previously described dolphin species, occasional pods of false killer whales (*Pseudorca crassidens*) are also known to frequent Darwin Harbour (INPEX 2010).

Whale species such as the sperm whale (*Physeter macrocephalus*), the pygmy sperm whale (*Kogia simus*) and the humpback whale (*Megaptera novaeangliae*) have historically been recorded in the Northern Territory. However, recent recordings of these species are rare and represent vagrant individual sightings. A review of the Northern Territory Marine WildWatch database identified that the most recent sightings of humpback whales were in areas around Fog Bay, the Peron Islands and Bathurst Island; with no recent sightings recorded for pygmy sperm whales or sperm whales (Northern Territory WildWatch 2016).

Dugongs (*Dugong Dugon*) are also known to occur in the Darwin region. Dugong monitoring using aerial surveys was undertaken as part of the NEMP, population estimates calculated from sightings observed during these surveys suggest that approximately 180 to 300 individuals inhabit the Darwin Region (Cardno 2014b).

Dugongs feed almost exclusively on seagrass and their distribution is broadly coincident with seagrasses in tropical and sub-tropical waters (DEE 2016b). The greatest densities of dugongs were typically observed off Casuarina Beach and Lee Point, and coincided with the greatest spatial extents of seagrass (Cardno 2015e). Few dugongs were sighted in Darwin Harbour itself during these surveys; this is not surprising given the paucity of seagrass in the Harbour. Most sightings within the Harbour were recorded around the Weed Reef area (Cardno 2015e).

The conservation status of marine mammal species that may occur within the Darwin region is presented in Table 4-3.

Table 4-3: Conservation status of marine mammals, which may occur within the Darwin region

Scientific name	Common name	Listing status	
		EPBC Act	TPWC Act
Kogia simus	Pygmy sperm whale	Cetacean	Data deficient
Physeter macrocephalus	Sperm whale	Migratory Cetacean	Data deficient
Megaptera novaeangliae	Humpback whale	Vulnerable Migratory Cetacean	Least concern
Pseudorca crassidens	False killer whale	Cetacean	Least concern
Orcaella brevirostris (*Orcaella heinsohni*)	Australian snubfin dolphin	Migratory Cetacean	Data deficient
Sousa chinensis (*Sousa sahulensis*)	Indo-Pacific humpback dolphin	Migratory Cetacean	Data deficient
Tursiops aduncus	Spotted bottlenose dolphin (Arafura/Timor Sea)	Migratory Cetacean	Least concern
Dugong dugon	Dugong	Migratory	Near threatened

4.3.2 Marine reptiles

Six species of marine turtles are known to occur in Northern Territory waters, although the green (*Chelonia mydas*), hawksbill (*Eretmochelys imbricata*) and flatback (*Natator depressus*) turtles are the only species known to frequent Darwin Harbour regularly.

Green turtles inhabit areas of coral and rocky reefs and inshore seagrass and algal beds. Adult green turtles are herbivorous feeding primarily on seagrasses and algae, while juveniles are carnivorous (NRETAS 2006a). The hawksbill turtle prefers rocky and coral reef habitats where it feeds on a wide variety of plants and animals including sponges, gastropods, seagrass and algae (DLRM 2012a). Flatback turtles inhabit shallow, soft-bottomed seabeds and feed on soft corals and soft bodied animals such as jellyfish and sea cucumbers (DENR 2006).

Aerial turtle surveys undertaken for the NEMP estimated a population size of between 500 and 1,000 for the Darwin region (Cardno 2014b). Turtles were primarily observed in shallow waters (<10 m), with the highest densities recorded between East Point and Lee Point, and near Gunn Point (Cardno 2015e). Turtles were also sighted throughout Darwin Harbour, although at lower densities. It is likely that the majority of turtles observed in

the Harbour during these surveys were green turtles, as they accounted for 74% of sightings during fine scale land-based observations.

No turtle nesting sites are known to occur in Darwin Harbour, with the closest nesting site in the Darwin region located at Casuarina Beach. Other turtle nesting sites include Bare Sand Island and Quail Island located near the mouth of Bynoe Harbour (~50 km from Darwin). Within the Darwin region most turtle nesting is associated with flatback turtles, with only small numbers of other turtle species occasionally nesting in the area. A study undertaken by Chatto and Baker (2008) found that flatback turtle nesting predominately occurred between May and October; however, it was noted that at locations such as Casuarina Beach nesting was recorded in small numbers throughout the year.

The saltwater crocodile (*Crocodylus porosus*) is a common resident of Darwin Harbour and surrounds. In 2015 a total of 280 crocodiles were removed from Northern Territory waters with a majority of these being caught within Darwin Harbour (NTG 2016a). Saltwater Crocodiles breed during the wet season between October and May. Preferred nesting habitat of the saltwater crocodile includes elevated, isolated freshwater swamps that do not experience the influence of tidal movements (DEE 2016c). Nesting within Darwin Harbour is limited (INPEX 2010).

The conservation status of marine reptile species that may occur within the Darwin region is presented in Table 4-4.

Table 4-4: Conservation status of marine reptiles, which may occur within the Darwin region

Scientific name	Common name	Conservation status	
		Commonwealth	Northern Territory
Caretta caretta	Loggerhead turtle	Endangered/Migratory	Vulnerable
Chelonia mydas	Green turtle	Vulnerable/Migratory	Near threatened
Dermochelys coriacea	Leatherback turtle	Endangered/Migratory	Critically endangered
Eretmochelys imbricata	Hawksbill turtle	Vulnerable/Migratory	Vulnerable
Lepidochelys olivacea	Olive ridley turtle	Endangered/Migratory	Vulnerable
Natator depressus	Flatback turtle	Vulnerable/Migratory	Data deficient
Crocodylus porosus	Saltwater crocodile	Migratory	Least concern

4.3.3 Fish and sharks

Darwin Harbour supports an abundance of both resident benthic and transient pelagic fish species with 415 species documented (Larson & Williams 1997). Of all these species, barramundi (*Lates calcarifer*) is the most targeted species by recreational anglers and accounts for 26% of total catch in the Northern Territory, although in Darwin Harbour it only accounts for 5% of total catch (Cardno 2015f; INPEX 2010). Golden snapper (*Lutjanus johnii*) are the second most targeted species, while jewfish (*Protonibea diacanthus*) are also commonly targeted by anglers in Darwin Harbour (Cardno 2015f).

Barramundi have a distinct spawning cycle, with peak spawning in marine bays and river mouths between October and December. The juvenile barramundi move with the tides into the mangroves and wetland habitats and into freshwater billabongs as the wet season comes to an end (Allsop et al. 2003). As there is limited access to freshwater billabongs in Darwin Harbour, juvenile barramundi are likely to remain in the coastal and

estuarine waters, which is why small barramundi can be caught all year round in Darwin Harbour (Allsop et al. 2003).

Three protected sawfish species may occur within Darwin Harbour including the dwarf sawfish (*Pristis clavata*), freshwater sawfish (*Pristis pristis*/*Pristis microdon*) and green sawfish (*Pristis zijsron*).

The dwarf sawfish generally occur in shallow waters (2-3 m) in coastal and estuarine areas of tropical Australia, extending some distance up rivers almost into freshwater. In the Northern Territory, it has been recorded in several catchments, including the Keep River, Victoria River, South Alligator River and in Buffalo and Rapid Creek located in Darwin Harbour (DLRM 2012b).

The freshwater sawfish generally occur in waters >1 m, preferring muddy substrate in the upper reaches of estuaries and freshwater areas. It is primarily a marine/estuarine species, that spends its first 3 to 4 years in freshwater. In the Northern Territory, it has been recorded in a number of rivers including the Victoria River, Darwin River, Adelaide River, East and South Alligator River (NRETAS 2006b).

The green sawfish is the most commonly encountered sawfish species in Australian tropical waters. It occurs in shallow waters in areas with a muddy substrate. The species has been reported to inhabit marine inshore waters, estuaries, lagoons and freshwater, but most records are from marine and estuarine areas. In the Northern Territory, it has only been recorded in Buffalo Creek in Darwin Harbour (NRETAS 2006c).

The conservation status of sawfish species that may occur in the Darwin region is presented in Table 4-5.

Table 4-5: Protected marine sharks which may be present in Darwin Harbour

Scientific name	**Common name**	**Conservation status**	
		Commonwealth	Northern Territory
Pristis clavata	Dwarf sawfish	Vulnerable/Migratory	Vulnerable
Pristis pristis (*Pristis microdon*)	Freshwater sawfish	Vulnerable/Migratory	Vulnerable
Pristis zijsron	Green sawfish	Vulnerable/Migratory	Vulnerable

4.3.4 Phytoplankton

Phytoplankton communities in East Arm, Darwin Harbour have been described by DLRM (2013) based on sampling undertaken between mid-2010 and mid-2012. Two hundred and thirty five phytoplankton taxa were identified from nine major taxonomic groups including Bacillariophyceae, Chlorophyceae, Chrysophyceae, Euglenophyceae, Dictyochophyceae, Prasinophyceae, Dinophyceae and Cyanobacteria (DLRM 2013).

Typical of tropical marine waters, diatoms (Bacillariophyceae) comprised >50% of the overall summed cell density of phytoplankton, and >70% of the total number of taxa (DLRM 2013). The extent and duration of freshwater inflows in the wet season had a marked effect on the abundance and composition of phytoplankton communities. At the upper estuarine site a reduction in phytoplankton abundance and a shift in dominance from Bacillariophyceae were observed during wet season flows (DLRM 2013).

Higher phytoplankton concentrations, as indexed by the concentration of chlorophyll *a*, occurred erratically but predominantly in the early or mid-wet season. At these times samples tended to be dominated by few taxa (DLRM 2013).

During the primary productivity baseline survey undertaken as part of the NEMP, phytoplankton productivity estimates ranged between 76 and 203 mg C m^{-2} d^{-1} and were within the range of values reported by Burford et al. (2008, 2012) for the Harbour (Cardno 2013d). Phytoplankton primary production in the water column is generally driven by a complex relationship between light available for photosynthesis, nutrients (primarily nitrogen and phosphorus), temperature, salinity and physical conditions. The combination of a highly dispersive environment, low nutrients and variable light penetration due to spring-neap turbidity appears to limit phytoplankton production as reflected in the low chlorophyll *a* concentrations (Cardno 2013d).

4.4 Parks and reserves

The Northern Territory Parks and Wildlife Commission are responsible for the conservation care, control and management of parks and reserves in the Northern Territory. Parks and reserves located in the Darwin Harbour region, and a summary of their environmental, cultural and social values are described in Table 4-6.

In addition to these parks and reserves, two Aquatic Life Reserves have been established under the *Fisheries Act* (NT): East Point Aquatic Life Reserve (~365 ha) and Doctors Gully Aquatic Life Reserve (~14 ha). The primary purpose of these reserves is to provide for the protection of marine life and habitat. Commercial fishing is prohibited within the East Point Aquatic Life Reserve with restricted recreational fishing permitted; in contrast all fishing is prohibited within the Doctors Gully Aquatic Life Reserve (NTG 2016b).

Table 4-6: Darwin Harbour parks and reserves

Name	Description
Charles Darwin National Park	The Park comprises an area of approximately 1040 ha and is located in Frances Bay, Darwin Harbour. It includes the western bank of Sadgroves Creek, Reichardt Creek and part of Blessers Creek (PWC NT Undated). While primarily used for recreation, the reserve also protects natural, cultural and historical values. The key natural values protected in the Park include mangrove communities and sections of relatively undisturbed woodland/grassland communities, which host a wide diversity of flora and fauna and the intertidal mudflats that are rich in bird life (PWC NT undated). In addition to the natural values, the Larrakia people maintain strong links with the land, which includes several Aboriginal shell middens. The Park also has historical significance with the area forming part of network of World War II military sites, which were established during the development of Darwin as Australia's northern defence (PWC NT Undated).
Casuarina Coastal Reserve	The Reserve comprises an area of approximately 1361 ha between Rapid Creek and Buffalo Creek. It includes areas of sandy beaches, mangroves, paperbark forests and monsoon vine thickets (PWC NT 2016). While primarily used for recreation, the reserve also protects natural, cultural and historical values. The key natural values protected in the Reserve include important feeding and roosting sites for migratory waders and shorebirds, significant seagrass beds and nesting sites for three marine turtle species (PWC NT 2016). In addition to the natural values, the Larrakia people maintain strong links with the land and its sacred sites. The Reserve also has historical significance as it was developed as part of a coastal defence strategy after World War I (PWC NT 2016).
Shoal Bay Coastal Reserve	The Reserve comprises an area of approximately 12,300 ha and incorporates an area between the Howard River and the eastern boundary near Gunn Point (Tourism Top End 2016). Extensive mud and sand flats are the major feature of the Reserve, with much of Shoal Bay exposed at low tide. The Reserve also includes a number of swamps and remnants of monsoon vine forest. The extensive tidal flats in Shoal Bay provide an important feeding and roosting area for migratory shorebirds in their non-breeding season (NRETAS Undated). In addition to the natural values, the Larrakia people maintain strong links with the land, which includes several Aboriginal shell middens (NTG 2016c).

4.5 Cultural environment

Darwin Harbour contains a variety of historic, spiritual and heritage values that are significant to the people of the Northern Territory and Australia. These can be broadly categorised into Aboriginal and non-Aboriginal values and are described in more detail in the following sections.

4.5.1 Aboriginal sacred sites

Sacred sites are places within the landscape that have a special meaning or significance under Aboriginal tradition. In coastal and sea areas, sacred sites may include features that lie both below and above the water (AAPA 2016). There are a number of sacred sites in Darwin Harbour and the surrounding waters. All sacred sites within the Northern Territory are protected under the *Northern Territory Aboriginal Sacred Sites Act* (NT).

Anyone proposing to use or work on land in the Northern Territory may apply to the AAPA for an Authority Certificate to cover their proposed activities. Authority Certificates are issued following consultation with traditional custodians and include conditions on what can and cannot be done in and around identified sacred sites. The Larrakia people are acknowledged as the traditional owners of the area in and around Darwin.

INPEX holds three AAPA Authority Certificates, which cover activities required to be undertaken during a maintenance dredging campaign, these are described in Table 4-7.

Table 4-7: AAPA Authority Certificates relevant to maintenance dredging activities

Certificate reference	Subject land	Proposed work or use
C2011/166	Section1813 Hundred of Ayres, Section 1814 Hundred of Ayers, NT Portion. 2367 and Middle Arm, inclusive of adjacent areas of mangroves and Darwin Harbour waters.	All works necessary to plan, develop, operate and maintain an industrial estate for gas-based industry, including but not limited to seabed dredging activities.
C2012/138	An area of open sea located about ~19 km north-west of Lee Point.	Disposal of spoil generated by the Ichthys Projects initial and maintenance dredging programs.
C2014/007	Part of Darwin Harbour.	Environmental monitoring programs involving one or more of the following general activities: soft bottom benthos monitoring, water quality and sedimentation, marine pest monitoring, fish and invertebrate monitoring.

4.5.2 Non-Aboriginal heritage sites

A number of shipwrecks and sunken aircraft are present within Darwin Harbour, some of which have been afforded protection under the *Heritage Act 2011* (NT) and/or the *Historic Shipwrecks Act 1976* (Cwlth). Most of these wreck sites are associated with two significant events in Darwin's history, the bombing of Darwin in 1942 and Cyclone Tracy in 1974.

Another important heritage site located in Darwin Harbour is the Channel Island leprosarium and reefs. The remains of the leprosarium provide evidence of a unique period in Australia’s history, and the surrounding reefs (Section 4.2.1) are considered significant due to their relatively diverse coral community, which is not consistent with their location well inside a large ria system (DTC 2016).

In addition to known protected heritage sites, prior to the commencement of the capital dredging program an extensive heritage survey and relocation program was undertaken within the dredge area. During the course of the program, a total of 6,897 artefacts were

assessed, yielding 490 culturally significant objects, with 69 cultural objects (mostly aircraft components, gun mounts and accessories) assessed as being of high cultural heritage significance (Coroneos 2014).

In consultation with the relevant authorities, recovered heritage objects were relocated to suitable locations within Darwin Harbour. Whilst it is highly unlikely, given the extent of this program, it is possible that previously unidentified heritage objects may still be present within the dredge area.

The locations and legislated heritage protection zones of all known shipwrecks and sunken aircraft in Darwin Harbour, and the Channel Island leprosarium and reefs are shown in Figure 4-10.

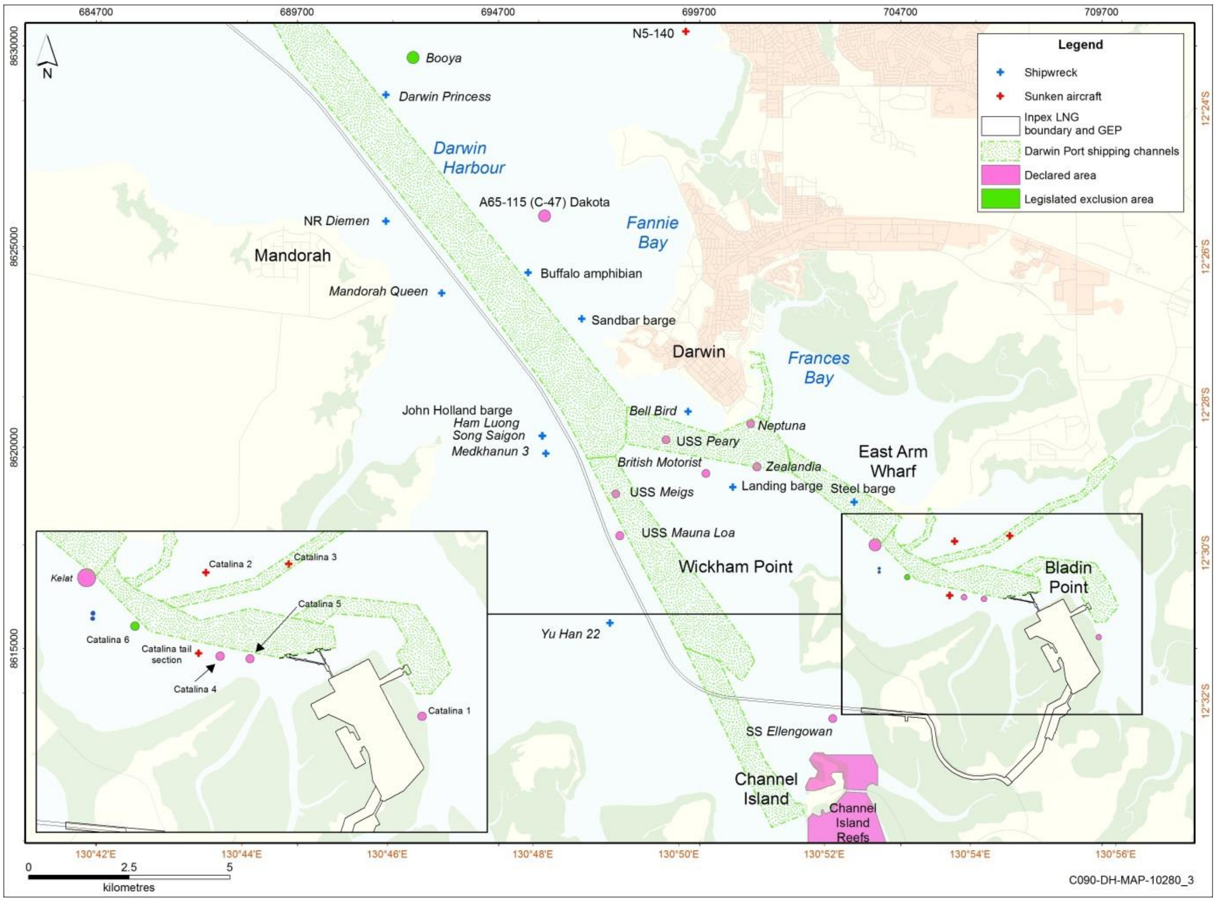


Figure 4-10: Shipwrecks and sunken aircraft in Darwin Harbour

4.6 Social and economic environment

The following sections describe the social and economic environment of Darwin Harbour.

4.6.1 Beneficial uses

The *Water Act* (NT) defines several beneficial uses for water bodies in the Northern Territory. Beneficial uses describe how a community values and uses a water resource. These are then used to set water quality objectives relevant to the beneficial uses declared for a particular water body. The dredge area falls within the beneficial use area for the Darwin Harbour region. The declared beneficial uses for the Darwin Harbour region (NTA 2010) are as follows:

- aquaculture: to provide water for commercial production of aquatic animals
- environment: to provide water to maintain the health of aquatic ecosystems

- cultural: to provide water to meet aesthetic, recreational and cultural needs
- agriculture: to provide irrigation water for primary production including related research
- rural stock and domestic: to provide water for specific uses.

The DSDA is located in open ocean outside of any declared beneficial use areas.

4.6.2 Darwin Port operations

Darwin Harbour is a working port and is developing into a major service centre for the mining and energy sectors. Darwin Port operations consist of marine traffic of non-commercial vessels (e.g. recreational anglers) and trading vessels, including commercial ships carrying cargo and passengers, rig tenders, tankers and bulk-cargo vessels that regularly utilise East Arm Wharf and Hudson Creek.

In 2014/2015 the Port of Darwin serviced 195 general cargo (container) vessels and a total of 1,715 trading vessels (import and export) (Darwin Port Corporation 2015).

4.6.3 Tourism

Tourism is a large economic driver of the Northern Territory economy. During 2015/2016 there were 1,735,000 visitors to the Northern Territory (Tourism NT 2016). In 2015, visitors to the Territory contributed an estimated $2.0 billion to the local economy (NTG Undated).

Darwin Harbour is a prime tourism resource for the region due to its high recreational values. Fishing, boating, sailing, water-skiing and beach use are popular activities for tourists. Fishing tours are frequently undertaken at Fenton Patches, located approximately 30 km north-west of Darwin Harbour. Recreational users also visit the sandy beaches along Casuarina Bay and Lee Point (INPEX 2010).

4.6.4 Commercial fishing and aquaculture

A number of commercial fisheries operate within Northern Territory waters; however, most are prohibited from operating within Darwin Harbour (DPIF 2015). The following fisheries are permitted to operate within Darwin Harbour in areas that are not designated protected areas[5]:

- Coastal Line Fishery
- Aquarium Fish/Display Fishery.

Little to no commercial fishing is undertaken in Darwin Harbour.

The Darwin Aquaculture Centre is situated on Channel Island, west of Middle Arm Peninsula. It is a research and development facility, which primarily focusses on the research into tropical marine aquaculture (NTG 2016d). The centre is currently researching ways to farm black-lipped oysters, giant clams, and sea cucumbers (NTG 2016d).

4.6.5 Recreational and traditional fishing

Results from a recreational fishing survey undertaken between April 2009 and March 2010 indicate that waterways within Darwin Harbour account for 27% of the recreational fishing effort for the Northern Territory, with zones immediately adjacent to Darwin (Darwin surrounds, Bynoe Harbour and Finniss areas) attracting a further 28% (West et al. 2012).

[5] Protected areas include Aboriginal sacred sites, reef fish protection areas, sanctuary zones and aquaculture farm leases.

During the NEMP, monitoring of recreational fishing activities identified distinct seasonal target behaviour of recreational anglers with barramundi commonly targeted during the wet season, while reef species (golden snapper and black jewfish) and pelagic (mackerel and tuna) are more commonly targeted during the dry season. Further, monitoring results indicated that catch rates also varied seasonally, particularly at more exposed sites where decreased catches were recorded during the wet season (Cardno 2015f).

In addition to the recreational fishermen, Aboriginal people living in the Darwin area frequently fish and forage for food and other resources in intertidal areas at low tide. These activities are common around Nightcliff, Coconut Grove, Kulaluk, Sadgroves Creek and Lee Point.

5 Environmental risk assessment

A systematic risk assessment process has been adopted for the environmental management of maintenance dredging and spoil disposal activities. The risk assessment process has been developed in line with Australian Standard AS/NZS ISO 31000:2009, risk management principles and guidelines, and aligns with the systematic approach that was applied throughout the Final EIS (INPEX 2010, 2011).

This process aligns with INPEX's Environmental Policy, which requires the identification of environmental hazards and risks associated with our business, and management of these to levels that are 'as low as reasonably practicable' (ALARP).

During the development of the Final EIS (INPEX 2010, 2011) an environmental aspect register was generated as a result of a series of environmental risk assessment workshops. The risk assessment undertaken for maintenance dredging and spoil disposal activities has considered, where relevant, the activities and environmental aspects applicable to the capital dredging program as identified within the Final EIS (INPEX 2010, 2011).

The following sections provide an overview of the risk assessment process and outcomes.

5.1 Conceptual site model

A conceptual site model is a written or illustrated representation of the predicted relationships between receptors or resources in the environment and the stressors to which they may be exposed. Conceptual site models are used in the preliminary phases of the risk assessment process to identify the linkages between hazards (i.e. sources of/mechanisms for potential harm), exposure pathways/routes and receptors. Further, it can be used to screen out impossible or implausible hazards in scenarios where there is no exposure pathway/route or receptor.

The development of the conceptual site model for maintenance dredging and spoil disposal activities has relied upon the activity description presented in Section 3 to determine the mechanisms/sources of potential environmental impact, while the information provided in Section 4 (existing environment) was used to determine the key receptors. The overarching conceptual site model for maintenance dredging and spoil disposal activities is presented in Figure 5-1.

Further, from an environmental perspective, the key risk factor of a maintenance dredging campaign is related to the mass of sediment mobilised by dredging activities in context of the receiving environment. As such, in addition to the broader conceptual site model an illustrative conceptual site model of the effects of dredging-induced turbidity in the Darwin region, in context of the natural processes driving sediment dynamics, is provided in Figure 5-2. The key interacting factors that drive sediment dynamics in Darwin Harbour and the natural cycles of light availability are described in Sections 4.1.1 (Climate), 4.1.3 (Oceanography) and 4.1.4 (Water Quality).

Mechanism	Pathway	Exposure route	Environmental receptors			Cultural receptors		Social receptors	
			Benthic habitat	Protected marine megafauna	General environment	Heritage site	Sacred site	Community/ people	Commercial
Sediment released during dredging and disposal	Suspended sediment in water (turbid plume)	• Reduced photosynthesis • Visual amenity • Reduced water quality	✓ (primary)	✓ (secondary)	✓			✓	
	Settling of suspended sediment (sedimentation)	• Smothering of aerial roots and benthic habitats • Visual amenity	✓ (primary)	✓ (secondary)				✓	
Presence of dredge and auxiliary vessel	Vessel movements	• Accidental vessel collision causing injury or mortality to protected marine megafauna		✓					
Operation of TSHD draghead	Use of draghead/ suction pipe	• Entrainment of protected marine megafauna • Discovery of UXO		✓				✓	
Dredge movements	Vessel movements (propulsion)	• Scouring of heritage wreck sites • Entering sacred sites or heritage exclusion zones				✓	✓	✓	
Auxiliary vessels	Unplanned anchoring	• Disturbance to sensitive benthic habitat • Physical contact to wrecks or sacred sites	✓			✓	✓	✓	
Dredging operations	Dredging and spoil disposal	• Vessel safety exclusion zone • Creation of shipping navigation hazards						✓	✓
		• Disturbance to benthic areas outside dredge and DSDA footprint	✓			✓		✓	
Generation of food scraps and sewage	Liquid discharges to water	• Nutrient enrichment		✓	✓				
Generation of waste	Accidental release to water	• Pollution of the marine environment • Ingestion by marine fauna • Visual amenity		✓	✓			✓	
Underwater noise	Dredging and spoil disposal	• Behavioural changes to protected marine megafauna		✓	✓				
Chemical and hydrocarbons	Accidental release to water	• Pollution of the marine environment	✓	✓	✓			✓	
International vessel movements	Biofouling/high-risk ballast water	• Accidental introduction and establishment of marine pests	✓	✓	✓			✓	✓

Figure 5-1: Maintenance dredging conceptual site model

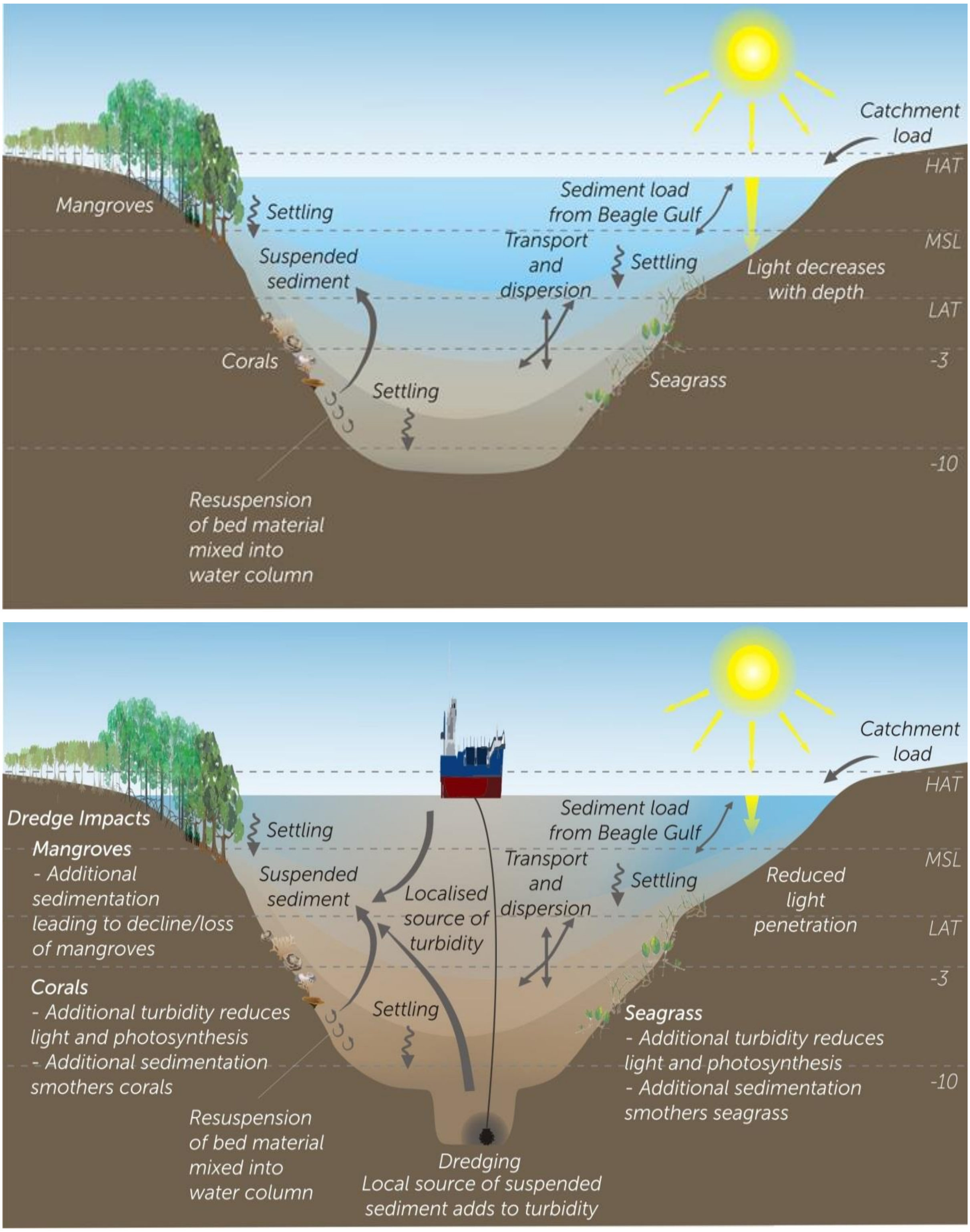


Figure 5-2 Conceptual site model related to the natural (top) and dredging derived (bottom) turbidity and sedimentation on sensitive receptors (Cardno 2014b)

5.2 Summary of risk assessment outcomes

The maintenance dredging risk assessment was informed by the conceptual site models described in Section 5.1. For the purposes of the risk assessment, an environmental aspect is defined as a feature or characteristic of the maintenance dredging or spoil disposal activities that has the potential to affect the environment.

Following the identification of activities, which could result in a particular environmental aspect, the potential environmental impacts associated with each aspect were identified. For each source of environmental risk, control measures were then identified for evaluation. Where the level of risk reduction achieved by these control measures was determined to be grossly disproportionate to the "cost"[6] of implementing them, the control measure was not included, and the risk was considered to be managed to ALARP. Justification for these is presented in Section 5.3.

The consequence and likelihood of each impact was then assessed to determine the residual risk that remained after controls to be implemented were taken into consideration.

The consequence is defined as an outcome or impact from an event occurring. For the purposes of the assessment, the consequence level applied was based on the credible worst-case scenario and assumed no control measures were in place. The category of environmental consequence and the detailed definitions for each severity level are described in Figure 5-3.

The likelihood can be described as the level of probability that, or the frequency with which, the described consequence will impact upon the environment. When determining the likelihood of a consequence occurring, any proposed control measures identified to mitigate the potential impact were taken into account.

The risk matrix used to determine the risk of impact for maintenance dredging and spoil disposal activities is provided in Figure 5-4.

The outcomes of the risk assessment are presented in Table 5-1, and where relevant includes reference to the environmental management frameworks within this Maintenance DSDMP used to manage individual environmental aspects.

[6] Cost includes financial cost, time or duration, effort, occupational health and safety risks, or environmental impacts associated with implementing the control.

ENVIRONMENTAL CONSEQUENCE TABLE										
	Biodiversity and ecological diversity			Environmental quality				Societal considerations		
	Protected species	Marine primary producers	Ecological diversity	Water quality	Marine sediment quality	Air quality	Soil and groundwater contamination	Protected areas	Cultural matters	Compliance
	B1	B2	B3	E1	E2	E3	E4	S1	S2	S3
A Catastrophic	Eradication of local population. Loss of critical habitats or activities.	Permanent loss of primary producers on a large or regional scale.	Significant and permanent effects on ecological diversity on a regional scale.	Continuous or regular contamination of water quality above background and/or national or international standards and/or known biological effect concentrations on a regional scale.	Permanent to long-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a regional scale.	Continuous exceedance over national or international air-quality standards. Human fatalities possible.	Extensive off-site contamination of groundwater and/or soil on a regional scale. Cost of effective treatment not possible. Sustained damage to the environment; human health risks likely.	Significant permanent effect on one or more of protected-area values.	Significant permanent impact on aesthetic, heritage, economic or recreational values. Overall societal benefits do not outweigh impacts.	Significant and continuous licence or regulatory or internal target exceedances. Fines and/or prosecutions incurred or expected.
B Major	Extensive impact on population(s). Significant impact on critical habitats or activities.	Recoverable loss of primary producers on a large scale.	Significant and permanent effects on ecological diversity on a large scale.	Continuous or regular contamination of water quality above background and/or national or international standards and/or known biological effect concentrations on a large scale.	Permanent to long-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a large scale.	Frequent and sustained exceedance over national or international air-quality standards. Human fatalities possible.	Extensive off-site contamination of groundwater and/or soil on a medium scale. Treatment difficult and/or expensive. Damage to the environment and risk to human health possible.	Significant long-term effect on one or more of protected-areas values.	Significant long-term impact on aesthetic, heritage, economic or recreational values. Overall societal benefits do not outweigh impacts.	Frequent and significant licence or regulatory or internal target exceedances. Fines or prosecutions likely.
C Significant	Minor disruptions to a significant portion of the population. Minor impacts on critical habitats or activities. No threat to overall population viability	Permanent loss of primary producers on a medium scale.	Significant and permanent effects on ecological diversity on a medium scale.	Continuous or regular discharge with contamination above background and/or national or international standards and/or known biological effect concentrations on a medium scale.	Permanent to long-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a medium scale.	Frequent, short-term exceedances over national or international air-quality standards. Human illness and effects on the environment possible.	Extensive contamination of groundwater and/or soil on a medium scale. Limited threat to the environment or human health.	Moderate long-term or permanent effect on one or more of protected-areas values.	Moderate impact on aesthetic, heritage, economic or recreational values. Overall societal benefits do not outweigh impacts.	Frequent, minor to moderate licence or regulatory or internal target exceedances. Fines or prosecutions possible.
D Moderate	Minor disruptions or impact on a small portion of the population. Minor temporary impact on critical habitat or activity. No threat to overall population viability.	Recoverable loss of primary producers on a medium scale.	Loss of ecological diversity on a medium scale. Community or habitat maintains ecological integrity through some change in species composition or abundance may occur. Community, habitats and species well represented regionally.	Continuous or regular discharge with contamination above background and/or national or international standards and/or known biological effect concentrations on a local to medium scale.	Short to medium-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a local to medium scale.	Frequent temporary exceedances over national or international air-quality standards. Human illness and effects on the environment possible.	Moderate contamination to groundwater or soil, contained within site boundary and readily treated. No significant threat to the environment or human health.	Moderate medium-term effect on one or more of protected-areas values. Full recovery expected.	Moderate impact on aesthetic, heritage, economic or recreational values. Overall societal benefits outweigh impacts.	Occasional significant licence or regulatory or internal target exceedances. Fines or prosecutions possible.
E Minor	Minor and temporary disruption to a small portion of the population. No impact on critical habitat or activity.	Permanent loss of a small proportion of primary producers on a localised scale.	Loss of ecological diversity on a localised scale. Community or habitat maintains ecological integrity through some change in species composition or abundance may occur. Community, habitats and species well represented regionally.	Continuous or regular discharge, with contaminants reduced to below background and/or national or international standards and/or known biological effect concentrations within a small mixing zone.	Short to medium-term contamination above background and/or national or international quality standards and/or known biological effect concentrations on a localised scale.	Occasional and temporary exceedance over national or international air-quality standards. No effect on human health or the environment.	Minor contamination of soil and/or groundwater, contained within site boundary and readily treated. No threat to the environment or human health.	Minor medium-term effect on one or more of protected-areas values. Full recovery expected.	Minor impact on aesthetic, heritage, economic or recreational values.	Occasional minor licence or regulatory or internal target exceedances. No fines or prosecutions.
F Insignificant	Behavioural responses of inconsequential ecological significance.	Recoverable loss of a small proportion of primary producers on a localised scale.	Minor loss of ecological diversity on a localised scale. Communities, habitats and species well represented on a medium scale.	Occasional discharge, with contaminants reduced to below background and/or national or international standards and/or known biological effect concentrations within a small mixing zone.	Short contamination above background and/or national or international quality standards and/or known biological effect concentrations over a very small area (<1 km²).	Very infrequent and temporary exceedance over national and international air-quality standards. No effect on human health or the environment.	Minor contamination of soil within site boundary and readily treated. No effect on groundwater. No threat to the environment human health.	Negligible impact on protected-area values.	Negligible impact on aesthetic, heritage, economic or recreational values.	Very infrequent minor licence or regulatory or internal target exceedances.

Figure 5-3: INPEX Environmental consequence table

INPEX

Risk Matrix

LIKELIHOOD TABLE

Time Frame Could be experienced	100 year timeframe or less	50 year timeframe	10 - 20 year timeframe	5 year strategic planning time frame	1 -2 year budget timeframe	Once or more during the next year
Experience History of occurrence in Company or Industry	Unheard of in the industry or in Projects	Has occurred once or twice in the industry or rarely occurs in Projects	Has occurred many times in the industry but not in the company or in <1 out of 100 Projects	Has occurred once or twice in the company or in <1 out of 10 Projects	Has occurred frequently in the company or in many Projects	Has occurred frequently at the location or in every Project
Frequency Continuous Operation	Once every 10 000 – 100 000 years at location	Once every 1,000 – 10 000 years at location	Once every 100 - 1000 years at location	Once every 10 - 100 years at location	Once every 1 - 10 years at location	More than once a year at location or continuously
Probability Single activity	1 in 100 000 – 1 000 000	1 in 10 000 – 100 000	1 in 1000 – 10 000	1 in 100 - 1000	1 in 10 - 100	>1 in 10

CONSEQUENCE TABLE

CONSEQUENCES				Severity	Likelihood Level					
Severity Level	Health & Safety	Environment	Cultural & Social Heritage		6 Remote	5 Highly Unlikely	4 Unlikely	3 Possible	2 Likely	1 Highly Likely
A	>20 fatalities or permanent total disabilities	Regional scale event, permanent impact on environment. Eradication of local populations of protected species	Permanent, long-term impact on social structure, and destruction of highly-valued heritage, aesthetic, economic or recreational items	A Catastrophic	6	5	4 Critical Risk	3	2	1
B	2 – 20 fatalities or permanent total disabilities	Large scale event, long term impact on environment. Extensive impact on populations of protected species	Widespread disruption to a number of communities with damage to highly-valued heritage, aesthetic, economic or recreational items	B Major	7	6	5	4	3	2
C	Single fatality or Permanent Total Disability	Medium to large scale event, medium term impact on environment. No threat to overall population viability of protected species	Significant impact to regional communities, and to heritage, aesthetic, economic or recreational items of significant value	C Significant	8	7	6 High Risk	5	4	3
D	Major injury or illness, permanent partial disability, lost time injury	Local to medium scale event with short to medium term impact on environment. No threat to overall population viability of protected species	Regional community disruption with moderate impact on heritage, aesthetic, economic or recreational values	D Moderate	9	8	7	6	5	4
E	Minor injury or illness, alternative duties injury, medical treatment injury	Local scale event with short term impact on the environment. Minor and temporary impact on a small portion of the population of protected species	Isolated community disruption with limited adverse impact on heritage, aesthetic, economic or recreational values	E Minor	10	9	8 Moderate Risk	7	6	5
F	Slight injury or illness, first aid injury	Local scale event with temporary impact on environment. Behavioural responses inconsequential ecological significance to protected species	Minor impact on heritage, aesthetic, economic or recreational values	F Insignificant	10	10	9 Low Risk	8	7	6

INPEX Risk Matrix
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Figure 5-4: INPEX Risk Matrix

Table 5-1: Summary of risk assessment outcomes

Aspect	Activity	Potential impacts	Management controls and mitigating factors	Residual risk summary		
				Consequence	Likelihood	Risk
Turbid plumes	Dredging and spoil disposal activities	• Elevated turbidity and associated low light conditions resulting in mortality of coral and seagrass communities	Risk is considered ALARP, refer to Section 5.3.1 For adaptive management refer to Section 7.1: Management of sediment-related effects	Insignificant (B2)	Highly unlikely	Low
		• Coral reproductive cycles may be affected by elevated turbidity and associated sedimentation resulting in loss of recruitment	Risk is considered ALARP, refer to Section 5.3.1 For adaptive management refer to Section 7.1: Management of sediment-related effects	Insignificant (B2)	Unlikely	Low
		• Reduction in access to food resources for dugongs, dolphins and turtles	Risk is considered ALARP, refer to Section 5.3.1 For adaptive management refer to Section 7.1: Management of sediment-related effects	Insignificant (B1)	Highly unlikely	Low
Coastal sedimentation	Dredging and spoil disposal activities	• Sediment accumulation in intertidal areas resulting in a decline of mangrove community health	Risk is considered ALARP, refer to Section 5.3.1 For adaptive management refer to Section 7.1: Management of sediment-related effects	Insignificant (B2)	Highly unlikely	Low
		• Low level deposition of sediments on subtidal and intertidal marine habitats causing mortality of coral and seagrass communities	Risk is considered ALARP, refer to Section 5.3.1 For adaptive management refer to Section 7.1: Management of sediment-related effects	Insignificant (B2)	Highly unlikely	Low
Dredge and support vessel	Dredging and spoil disposal activities	• Vessel collision causing injury or mortality to protected marine megafauna	Refer to Section 7.2.2: Protected marine megafauna management framework	Moderate (B1)	Remote	Low

Aspect	Activity	Potential impacts	Management controls and mitigating	Residual risk summary		
movements. Operation of the TSHD draghead		• Entrainment of marine turtles or sawfish causing injury or mortality	Refer to Section 7.2.2: Protected marine megafauna management framework	Moderate (B1)	Highly unlikely	Moderate
		• Disturbance or damage to protected heritage wrecks or sacred sites	Refer to Section 7.2.4: Heritage and sacred site management framework	Significant (S1, S2)	Highly unlikely	Moderate
		• Discovery and damage to previously unidentified heritage objects	Risk is considered ALARP, refer to Section 5.3.3: Unexploded ordnance and heritage objects For chance find procedure refer to Section 7.2.4: Heritage and sacred site management framework	Insignificant (S2)	Remote	Low
		• Discovery and disturbance of unexploded ordnance (UXO) potentially posing a risk to personnel and members of the public	Risk is considered ALARP, refer to Section 5.3.3: Unexploded ordnance and heritage objects	Significant	Remote	Moderate
Maritime traffic and navigation	Dredging and dredge disposal activities	• Localised displacement of port users as a result of temporary safety zone around TSHD	Refer to Section 7.2.2: Dredge materials management framework	Insignificant	Possible	Low
		• Creation of shipping navigation hazards resulting from accidental disposal of spoil outside of the DSDA	Refer to Section 7.2.2: Dredge materials management framework	Insignificant	Remote	Low
Dredge material	Dredging and dredge disposal activities	• Accidental removal of coral in the event dredging occurs outside designated areas	Refer to Section 7.2.2: Dredge materials management framework	Insignificant (B3)	Remote	Low
		• Accidental smothering of coral or seagrass in the event spoil is disposed of outside of the DSDA	Refer to Section 7.2.2: Dredge materials management framework	Insignificant (B3)	Remote	Low
Dredge material	Seabed levelling activities	• Accidental disturbance to coral in the event seabed levelling occurs outside designated areas	Refer to Section 7.2.2: Dredge materials management framework	Insignificant (B3)	Remote	Low

Aspect	Activity	Potential impacts	Management controls and mitigating	Residual risk summary		
Sewage/food scraps discharges	Routine operation of TSHD vessel	• Localised nutrient enrichment of marine environment	Refer to Section 7.2.5: Waste and liquid discharge management framework	Insignificant (E1)	Remote	Low
Waste	Generation of hazardous/non-hazardous wastes during routine vessel operations	• Accidental loss of hazardous/non-hazardous wastes to the water resulting in localised pollution to the marine environment or ingestion by marine fauna	Refer to Section 7.2.5: Waste and liquid discharge management framework	Insignificant (B3)	Unlikely	Low
Underwater noise	Operation of the draghead during dredging General dredge and support vessel movements	• Localised avoidance of the area by protected marine megafauna	Risk is considered ALARP, refer to Section 5.3.2: Underwater noise	Insignificant (B1)	Unlikely	Low
Chemical and hydrocarbons	Storage and handling of chemicals during dredging activities	• Accidental loss of chemicals to the water resulting in localised pollution to the marine environment	Refer to Section 7.2.6: Hydrocarbon and chemical management spill response framework	Insignificant (B3)	Highly unlikely	Low
	Minor hydrocarbon spills associated with equipment failure (e.g. burst hydraulic hose)	• Accidental loss of hydrocarbons to the water resulting in localised pollution to the marine environment	Refer to Section 7.2.6: Hydrocarbon and chemical management spill response framework	Insignificant (B3)	Unlikely	Low
	Major hydrocarbon spills associated with equipment/ operator failure (e.g. loss of containment during bunkering)	• Accidental loss of hydrocarbons to the water resulting in: – exposure of nearshore water to moderate levels of hydrocarbons causing pollution – localised areas of mangroves and intertidal communities exposed to moderate levels of hydrocarbons resulting in mortality	Refer to Section 7.2.6: Hydrocarbon and chemical management spill response framework	Minor (B3)	High unlikely	Moderate

Aspect	Activity	Potential impacts	Management controls and mitigating	Residual risk summary		
Introduction of marine pests	Import of dredge vessel from overseas locations	• Accidental introduction of marine pests resulting in: – displacement of native species – alteration and/or degradation of habitats and ecosystems – potential impact on maritime-based industries	Refer to Section 7.2.1: Introduced marine pest management framework	Moderate (B3)	Remote	Low

5.3 ALARP Justification

5.3.1 Sediment-related impacts

Sensitive receptors (mangroves, coral and seagrass)

Sediment-related impacts associated with dredging and spoil disposal activities can be separated into direct and indirect effects (Erftemeijer et al. 2012; Jones et al. 2016; Mills & Kemps 2016). Direct effects include the removal of substrate within the dredge area and smothering of substrate at the DSDA during disposal. The substrate within and directly adjacent to both the dredge area and the DSDA is classified as soft-bottom benthos, and is well represented over large areas regionally (Section 4.2.5). Following completion of maintenance dredging activities, rapid recolonisation by fauna is expected to occur in these areas, similar to what was reported for the capital dredging program (Cardno 2015g).

Dredging and spoil disposal activities also have the potential to indirectly impact sensitive receptors such as coral, seagrass and mangrove communities through the release of additional sediments into the water column, which can be dispersed, resuspended and allowed to settle through oceanographic and sediment transport processes. Indirect effects to sensitive receptors associated with the mobilisation of sediment can be divided into chemical or physical effects (Jones et al. 2016).

The potential for chemical effects largely relate to the contamination status of the sediment, which if contaminated may cause acute and chronic toxicological effects, cellular and physiological effects as well as bioaccumulation effects (Jones et al. 2016). Based on the sediment quality assessment (Section 4.1.5; INPEX 2016), the deposited sediment to be dredged during a maintenance dredging campaign was found to consist of uncontaminated silt and fine sands. The risk of chemical effects is therefore considered ALARP and not discussed further.

Physical effects relate to elevated concentrations of suspended sediment (turbidity), changes in light quality and quantity, and sedimentation (Jones et al. 2016). Elevated turbidity within the water column reduces light penetration and therefore the availability of light for photosynthesis (Erftemeijer et al. 2012). This has the potential to impact water column producers (e.g. phytoplankton) and benthic primary producers (e.g. seagrasses and autotrophic corals), with impact severity dependent upon the life history of the receptor affected and the intensity, duration and frequency of adverse events relative to the natural background conditions to which the receptors are adapted.

Deposition and accumulation of sediments within intertidal and subtidal areas also has the potential to affect sensitive receptors. Excess deposition of sediment (>50 mm; INPEX 2010) may cause stress to mangroves (particularly in the seaward assemblage) due to smothering and burial of aerial root systems, with impacts ranging from reduced vigour to mortality, depending on the species and sediment characteristics (Cardno 2015b). Elevated sedimentation rates in intertidal and subtidal areas may also suppress coral growth and survival when energy expenditure is redirected to actively clear settled sediments from coral tissue (Erftemeijer et al. 2012; Jones et al. 2016). Corals and seagrasses can also be impacted through smothering due to excessive sedimentation, with consequences depending on the depth of burial and life history of species affected (Duarte et al. 1997; Erftemeijer & Lewis 2006).

The likelihood of indirect physical effects associated with a maintenance dredging campaign is directly related to the type and size of dredge vessel proposed and its operating profile with regards to the mass fraction of fines (<75 µm)[7] lost to the environment. An increase in the amount of fines released to the marine environment from dredging activities will generally lead to an increase in the spatial extent and magnitude of sediment plumes, as well as an increased rate of sediment deposition and associated resuspension (Mills & Kemps 2016).

As described in Section 3.3, a TSHD is proposed to carry out the maintenance dredging activities. At the dredging site, the predominant source of fine sediment released by TSHD operations is from the overflow of water (containing some fine sediments), while by comparison sediment release rates at the draghead are typically insignificant (Mills & Kemps 2016). As such it is proposed that overflow funnel/s are fitted with green valves (as per best practice), and overflow duration is managed to a maximum of 60 minutes (Section 3.3.2), as was approved for the capital dredging program. This is to limit the amount of fines released into the Darwin Harbour environment when compared to unrestricted overflow. At the DSDA, the dominant source of fine sediment is associated with disposal, which as per the rationale provided in Section 3.3.3 is via bottom door placement.

To determine the likelihood for indirect effects to sensitive receptors, predictive modelling of fine sediment released by TSHD operations and a subsequent habitat impact assessment (using ecological tolerance limits) has been completed for the worst-case credible scenario (Section 6.1), as recommended in Mills and Kemps (2016). Results from the sediment plume modelling and impact assessment are described in Section 6.8. Overall it was found that <1 ha of coral (as a component of Mixed Community; Reef habitat[8]) is simulated to be indirectly impacted due to maintenance dredging operations. No impacts to high-confidence or inferred seagrass or mangrove communities are predicted.

The risk of sediment-related effects to sensitive receptors and hence protected marine megafauna foraging habitat is found to be ALARP. This is in consideration of the modelling outcomes and the fact that no dredging-attributable mortality of sensitive receptor communities was measured at monitoring sites during the much larger capital dredging program, even at sites where 100% loss had been predicted (Cardno 2015b, 2015c, 2015d), for example at South Shell Island which was immediately adjacent to the capital dredging footprint.

Further, adaptive management of the maintenance dredging activity based on water quality monitoring is proposed (Section 7.1). One of the key objectives of adaptive management is to use monitoring data to inform the management of the dredging operations, to minimise the potential for impacts to the sensitive receptors (if any) through timely implementation of responsive and contingency management practices.

[7] The Australian Standard (Geotechnical site investigations) AS 1726-1993 defines fine sediment as a particle size less than 75 µm.

[8] Based on the outcomes of habitat mapping and classification undertaken for the Final EIS (INPEX 2010; 2011), Mixed Community; Reef habitat consists of macroalgae (8%), hard coral (15%), filter-feeder (29%) and <10% macrobiota (47%). Note these percentages do not refer directly to percent cover but rather are an allocated attribute based on biota classification definitions. Mixed Community; Reef habitat in the Darwin region comprises 8,231 ha, of which only 8% is high confidence and the remainder inferred. As such 1,235 ha of coral habitat could be assumed as a component of Mixed Community; Reef.

Reproductive cycle of corals

In a recent review undertaken by Jones et al. (2015a)[9], it was found that elevated concentrations of suspended sediment (associated light attenuation) and excess sedimentation both have the potential to cause adverse effects to early life stages of corals, including gametogenesis, timing and synchronisation of spawning, egg-sperm bundle buoyancy, fertilisation success, embryogenesis, early larval development, settlement and post-metamorphosis survival. Thus, Jones et al. (2015a) concluded that conducting maintenance dredging activities outside of coral spawning and settlement periods would constitute a best management practice. As such, the potential for sediment-related effects on the reproductive cycle of corals has also been specifically considered.

Information pertaining to the location, family composition and likely spawning period of coral communities in Darwin Harbour is provided in Section 4.2.1. There is limited reproductive data for coral assemblages in the Darwin region and in terms of timing for specific families, information is limited to Faviidae, where mature eggs were detected in April (Cardno 2015c), which is consistent with broadcast spawning following the April full moon. The Faviidae were represented at all sites monitored during the NEMP (Cardno 2015c).

High-confidence Hard Coral; Reef habitat at South Shell Island and Northeast Wickham Point in proximity to the dredge area are characterised by a low cover (<1%) of Faviidae corals, suggesting these habitats and the naturally prevailing background conditions, may not be conducive to recruitment. In contrast, Channel Island and Weed Reef located further afield have a higher relative percent cover of Faviidae at 3.1% and 2.3%, respectively. At these sites, Faviidae contributed 15% to 25% of the live coral cover, with corals in the families Pectinidae and Poritidae also important (Cardno 2015c).

As a group, these three families contribute the major components of coral cover in the various communities throughout the Harbour. Although no data is available for sexual reproduction of the Pectinids or Poritids in Darwin Harbour, corals in those families are also known to reproduce via broadcast spawning in seasonal synchrony with Favid species (Gilmour et al. 2016), suggesting that the April spawning period may be relevant to many of the dominant corals in the Harbour.

The risk of interaction between the excess (i.e. dredging-related) suspended sediment plume and the various reproductive stages of coral has been assessed in context of the modelling results discussed in Section 6. Specifically, larvae present in the water column that may interact with the highest suspended sediment plume concentration (in the dredge area), and gametes and newly settled juveniles that will only interact where the sediment plume extends over benthic habitat known to support coral communities (e.g. Hard Coral; Reef and Mixed Community; Reef).

Modelling simulates maximum concentrations of 100 to 200 mg/L (excess SSC) to occur for no more than 5% of the time within a localised portion of the dredge area, and concentrations of 20 to 50 mg/L to occur for no more than 10% of the time within and directly adjacent to (upstream) the dredge area. These areas are characterised by soft-bottom benthos (Section 6.5.1).

Studies undertaken by Gilmour (1999) and Humphrey et al. (2008) found no effect to early embryonic development at the highest concentrations tested on *Acropora digitifera* (100-150 mg/L) and *Acropora millepora* (200 mg/L) respectively (Jones et al. 2015a).

[9] Review undertaken as a part of the Western Australia Marine Science Institution (WAMSI) Dredging Science Node, which is a strategic research initiative that aims to enhance capacity within government and the private sector to predict and manage the environmental impacts of dredging in Western Australia.

While, with respect to larval survival Gilmour (1999) found that it may be affected at concentration as low as 50 mg/L.

To the extent that these studies can be used as a surrogate for deriving impact thresholds for coral life history stages within Darwin Harbour, it may be inferred that if maintenance dredging is undertaken around the time of coral spawning that within the dredge area, where SSC is highest, there is potential for indirect effects to coral larvae. No effects to early embryonic development are expected; however, larval survival in the immediate dredge area may be effected.

In context of the localised area of maximum SSC (i.e. dredge area), the short duration and the intermittent nature of the maintenance dredging activity, the overall risk to larval development and survivorship in the broader Darwin Harbour is considered low.

To assess the potential effects of suspended sediment plumes and sedimentation on coral gametes and newly settled juveniles, modelling outcomes were also interrogated. Modelling results suggest that net sedimentation is unlikely to occur in subtidal areas in East Arm due to the fine nature of the sediment and the prevailing hydrodynamics. Therefore, the potential for effects, to these life stages are related to the concentration of the suspended sediment plumes.

Only a minor proportion of Mixed Community; Reef habitat directly upstream of the dredge area is predicted to be affected by elevated SSC of 10 to 20 mg/L for no more than 10% of the time. Hard Coral; Reef habitat at South Shell Island (8% coral cover) and Northeast Wickham Point (2% coral cover) in East Arm are predicted to experience elevated SSC of 3 to 5 mg/L for no more than 10% of the time. While Weed Reef coral communities (average 13% coral cover) and nationally recognised Channel Island coral communities (14% coral cover) are not predicted to experience any elevated SSC as a result of maintenance dredging activities.

A study by Te (1992) found that there was no significant difference in settlement of *Pocillopora damicornis* when exposed to 0, 10, 100 and 1,000 mg/L, with the exception of reversed metamorphosis (e.g. polyp bailout) at 100 and 1,000 mg/L (Erftemeijer et al 2012; Jones et al 2015a). Given the modelled SSC over known coral communities is well below these levels, it is unlikely that significant effects to settlement will occur. It is noted that a reduction in light associated with elevated suspended sediment may also effect settlement; however, given the modelled spatial extent of the suspended sediment plume and the naturally turbid water experienced in Darwin Harbour, the risk is considered low.

Overall in review of the modelling results and in context of the spatial extent and intensity of the suspended sediment plumes, the short duration and intermittent nature of the maintenance dredging activities, the risk from excess suspended sediment plumes on the reproductive cycle of corals in Darwin Harbour is considered low, particularly at high confidence Hard Coral; Reef habitat areas within Darwin Harbour.

Further, the potential additional "costs"[6] of temporally restricting maintenance dredging (e.g. outside of spawning and settlement periods) would be grossly disproportionate to the risk. The risk from excess suspended sediment plumes on the reproductive cycle of corals is therefore considered ALARP. Noting that the adaptive management strategy described in Section 7.1 provides for changes to the dredging operations based on measured water quality (i.e. turbidity) should they significantly differ from modelling prediction.

Fish

Suspended sediments from dredging and spoil disposal activities can have both positive and negative impacts on fish species. Some species (e.g. barramundi, mangrove jack and jewfish) may be attracted to disturbed areas to feed on suspended invertebrates or

other fish attracted to the disturbance (INPEX 2010). Suspended sediment may also adversely affect some species through indirect or direct pathways (Kerr 1995); however, this typically occurs at very high concentrations (>300 mg/l and 4,000 mg/l respectively) (Gregory & Northcote 1993; Jenkins & McKinnon 2006).

Research has also shown that estuarine species are more tolerant of suspended sediments, in addition to adult fish in comparison to fish larvae and eggs (Michael & Partridge 2011). Impacts to fish larvae and eggs may occur at lower concentrations relative to adult fish (e.g. Jenkins & McKinnon (2006) study indicates 100 mg/l); however, these concentrations are still very high relative to the natural concentrations in Darwin Harbour (Section 4.1.4).

Fish health (e.g. physical condition, lesions, parasites, etc.), catchability (e.g. catch per unit effort) and other fish data (e.g. abundance, diversity, size, etc.) were monitored before, during and after the capital dredging program. Monitoring results recorded no impacts on fish health from dredging or spoil disposal activities (Cardno 2015f, 2015h).

Sediment transport modelling undertaken to inform this Maintenance DSDMP simulates maximum concentrations of SSC of 100 mg/l to 200 mg/l to occur in a localised portion of the dredge area (Section 6.5.1). As such, fish larvae or eggs that drift through or fish that swim through this localised plume in proximity to dredging activities have the potential to be indirectly impacted. However, given the expected short duration (in consideration of the dredge volume) of the maintenance activities, and the intermittent nature of the dredging, fish are unlikely to be impacted as they can actively avoid the plume and the plume will not form a barrier across East Arm. Therefore, the overall risk to fish is considered low and ALARP.

5.3.2 Underwater noise

Dredging activities in Darwin Harbour will generate additional underwater noise to the existing sound-scape (Section 4.1.6). The Central Dredging Association position paper on underwater noise in relation to dredging (CEDA 2011) provides a summary of anthropogenic noise sources of which those relevant to Darwin Harbour are provided in Table 5-2. This summary indicates that the source level range of TSHDs is within the range of large vessels. Sources of noise are most likely to be associated with cavitation noise from TSHD propellers and bow thrusters (de Jong et al. 2010), rather than other sources associated with TSHDs as illustrated in Figure 5-5.

Table 5-2: Overview of anthropogenic noise sources

Noise source	Source level	Bandwidth	Major amplitude	Duration	Directionality
Echo sounders*	230–245 dB re 1μPa @ 1m (RMS)	11.5–100,000 Hz	Variable	0.01–2 ms	downwards
Large vessels*	180–190 dB re 1μPa @ 1m (RMS)	6 Hz ->30,000 Hz	>200 Hz	continuous	omni-directional
TSHD*	186–188 dB re 1μPa @ 1m (RMS)	30 Hz->20,000 Hz	100–500 Hz	continuous	omni-directional
Small boats and ships†	160–180 dB re 1μPa @ 1m (RMS)	20 Hz ->1,000 Hz	>1,000 Hz	continuous	omni-directional

* Source: CEDA 2011; † Source: UNEP 2012

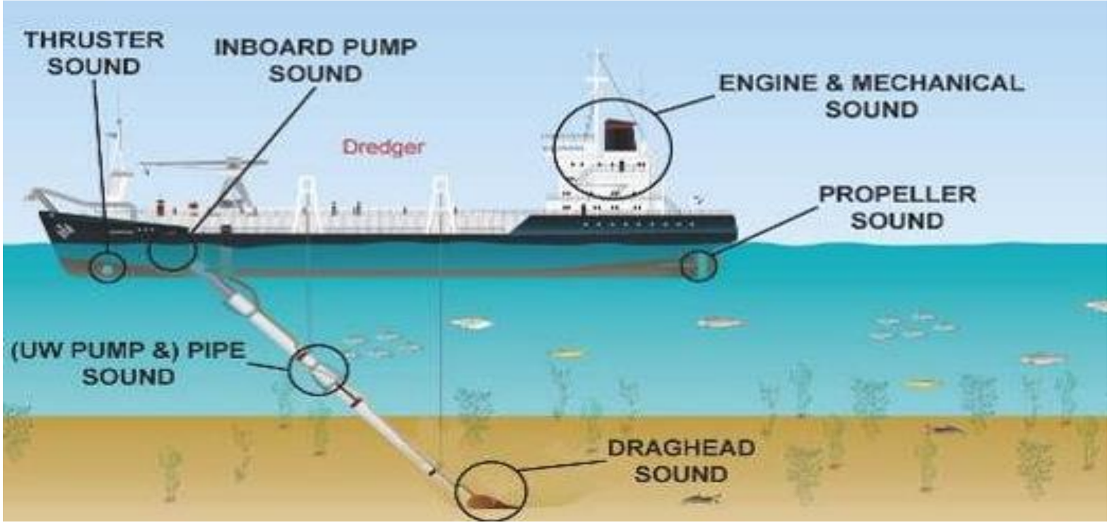


Figure 5-5: TSHD sound sources (CEDA 2011)

When assessing the potential effects of anthropogenic sources of underwater noise on marine fauna Richardson et al. (1995) developed a "zone of influence model" which is based on the distance between the source and receiving fauna. This is premised on the fact that underwater sound reduces in intensity with increasing distance from the source, which can be influenced by a range of variables (e.g. substrate type, suspended sediment load, depth of source, etc.) (WODA 2013). As such, potential effects may range from masking important biological functions (e.g. communication and echolocation of prey), behavioural responses (e.g. avoidance) through to temporary or permanent threshold shifts (TTS and PTS) (e.g. physiological effects). All of which can vary between species depending on their sensitivity to underwater sound and their hearing range.

Darwin Harbour noise exposure modelling was undertaken for the capital dredging program based on cutter suction dredge activities at Walker Shoal (hard conglomerate rock). This was considered the greatest risk for the generation of underwater noise during the capital dredging program as it involved the grinding of hard rock, while in contrast TSHD operations involved dredging up loose sediments (URS 2011). Modelling indicated cutter suction dredging noise exposure levels were within the safe hearing ranges of marine fauna that frequent Darwin Harbour and that any impacts would likely be behavioural responses (e.g. avoidance of the immediate area). In addition, the greater part of the Harbour would be unaffected by noise associated with dredging activities (URS 2011).

Marine fauna (i.e. turtles, dugongs, dolphins and fish) monitoring undertaken during the capital dredging program, found that there had been no impacts to marine fauna as a result of noise associated with dredging operations (Cardno 2015h; Cardno 2015e; Brooks & Pollock 2015b). Dolphins were observed in East Arm throughout the capital dredging program (Brooks & Pollock 2015b) as were turtles (Cardno 2015e), while dugongs were primarily observed outside Darwin Harbour in association with seagrass beds with very few sightings within the Harbour (Cardno 2015g). This is expected given that noise generated in the middle area of East Arm attenuated rapidly and was mostly masked by other man made noises at the mouth of East Arm opposite the East Arm Wharf. Sources of noise generated from vessels could not be distinguished between dredge related or other sources (Gavrilov & Salgado-Kent 2015).

In context of the modelling and monitoring results, underwater noise generated by maintenance dredging is unlikely to impact marine fauna given a single TSHD is proposed, which in terms of underwater noise is similar to large vessels that already frequent Darwin Harbour and hence the risk is considered low and ALARP.

5.3.3 Unexploded ordnance (UXO) and heritage objects

The dredge area is located in a part of Darwin Harbour that was subject to bombing activity in World War II.

Prior to the execution of the capital dredging program a detailed study was undertaken to assess the likely presence of unexploded ordnances (UXOs) and explosive ordnances (EOs). The study identified that the north-western section of the proposed dredge area was a high risk in terms of the existence of UXOs and EOs.

Following this initial assessment, INPEX appointed Tek Ventures Pty Ltd (TV), in consultation with Cosmos Maritime Archaeology (CA), to undertake gradiometer and side scan sonar surveys within the capital dredge area to determine the presence of ferrous and magnetic anthropogenic anomalies (up to one metre below the seabed). The surveys identified ~1000 anomalies located on and under the seabed. These anomalies were then inspected by TV divers, with CA archaeologist assisting, to determine if these anomalies were natural or cultural in origin.

During diving inspections, only one object was identified as potentially being a UXO. In May 2012, this was further assessed and inspected by Royal Australian Navy divers, and subsequently raised and disposed of.

A total of 6,897 artefacts were assessed, yielding 490 culturally significant objects, with 69 cultural objects (mostly aircraft components, gun mounts and accessories) assessed as being of high cultural heritage significance (Coroneos 2014). In consultation with the relevant authorities, 506 heritage objects were relocated to suitable locations within Darwin Harbour.

With consideration of the UXO clearance works undertaken prior to the capital dredging program and the fact that no UXOs were encountered during the execution of the capital dredging program, it would be highly unlikely that UXOs would be encountered during the execution of a maintenance dredging campaign and the risk is therefore considered low and ALARP.

Further, given the extensive heritage recovery and relocation program undertaken, it is highly unlikely that any further (previously unidentified) heritage objects would be discovered during the course of the maintenance dredging program. However, a chance find procedure will be in place in the event such a discovery is made (Section 7.2.4; Figure 7-6).

5.4 Assessment of potential for cumulative impacts

The following sections describe the assessment of the potential for cumulative impacts due to sequential Project-related maintenance dredging campaigns and concurrent Harbour-wide campaigns, in addition to the potential long-term effects on the sediment balance of East Arm, Darwin Harbour.

5.4.1 Sequential Project-related maintenance dredging campaigns

The potential for cumulative impacts is related to the intensity, duration and frequency of the activity. With respect to maintenance dredging this type of activity, in most cases, is significantly reduced in comparison to capital dredging programs.

Maintenance dredging by definition is a repetitive activity (Netzband et al. 2009). As described in Section 3.1, this Maintenance DSDMP has been prepared to allow for a maximum of 1.5 Mm^3 of material to be dredged at any time during the life of the approval (i.e. nominally five years), with no single campaign to exceed 0.75 Mm^3 (as modelled). The total volume is considered worst-case and includes a planned maintenance dredging campaign and up to four contingency campaigns.

In terms of the potential for cumulative impacts, the worst-case (not credible) scenario would be back-to-back maintenance campaigns up to the total volume of 1.5 Mm^3, using a single TSHD (hence intermittent dredging). The capital dredging program was approximately 10 and 11 times greater in duration and volume respectively, and near-continuous operations. Environmental monitoring during the capital dredging program recorded only minimal dredging-related effects to sensitive receptors at sites in proximity to dredging[10] and no dredging-related effects to protected marine megafauna[11]. Therefore, given the short duration and lower relative intensity, it is highly unlikely that even back-to-back maintenance campaigns would result in impacts to receiving sensitive receptors or protected marine megafauna.

Further, the potential for back-to-back maintenance dredging campaigns is unlikely, as it would require a significant deposition event to occur immediately post completion of a planned campaign. Likely sources of sediment within Darwin Harbour are related to sediment-laden runoff from high rainfall, and increased magnitude of sediment transport through resuspension (and deposition) of seabed sediments as a result of increased wind speeds and wave heights associated with episodic weather events (e.g. tropical cyclone).

A review of BOM rainfall (BOM 2016a) and cyclone data (BOM 2016e) for the Darwin region[12] has been completed and as expected, Figure 5-6 shows that 95% of the annual rainfall and all tropical cyclone development occur in the wet season. This suggests that contingency campaigns, if required, would likely occur in the latter half of the wet season or early dry season as informed by hydrographic survey results.

Rainfall data has been further interrogated to assess the likelihood of a greater than average rainfall season, as a proxy measure for the potential of a significant deposition event. The occurrence of a greater than average rainfall season (defined as >2 standard deviations (SD) above the mean) are infrequent with only two wet seasons (1997/1998 and 2010/2011) having recorded rainfall exceeding this criteria between 1964 and 2015. Therefore, based on frequency of past occurrence, the probability that a contingency maintenance dredging campaign would be required shortly after a planned maintenance dredging campaign is low.

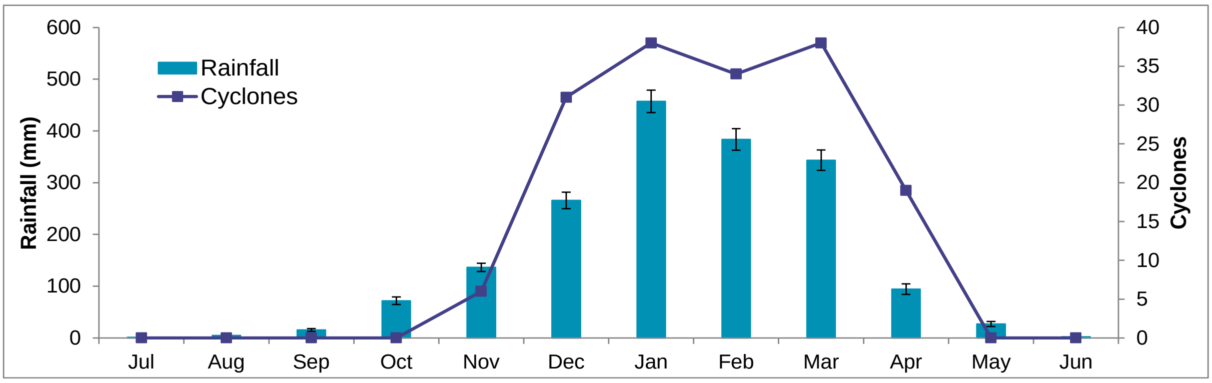


Figure 5-6: Darwin airport monthly average rainfall (mm ±SE) and number of cyclone[12] formation per month between 1964 and 2015

[10] No impacts to seagrass or mangroves were measured at monitoring sites (Cardno 2015d; Cardno 2015b). Some potential impacts to coral were recorded at South Shell Island only (Cardno 2015c), which is adjacent to the dredge area in East Arm. These potential impacts included 1) potential suppression of coral recruitment, and 2) temporary increase in sediment on corals after 66 weeks of capital dredging.

[11] No dredging related effects on the distribution and population sizes of turtles and dugongs in the Darwin region (Cardno 2015e). Dolphin populations in the Darwin region remained stable over the three and a half year monitoring program regardless of construction activity (Brooks and Pollock 2015b).

[12] Cyclones likely to influence Darwin region water quality through rainfall or waves were identified as having developed or passed within 500 km to the north, south and east or 1,000 km to the west of Darwin based on data sourced from BOM (2016a & e) and water quality observations during capital dredging (Cardno 2014b).

5.4.2 Concurrent Harbour-wide dredging campaigns

Cumulative impacts have the potential to occur in the event a number of dredging campaigns are undertaking concurrently. However, the realisation and extent of potential impacts would be influenced by the following:

- the proximity and location of the concurrent activities
- the timing and duration of concurrent activities
- the volumes and types of material to be dredged
- the methods of dredging
- the disposal method and locations.

INPEX has engaged with key stakeholders (both private enterprises and government bodies) in an attempt to identify if other dredging activities may occur within Darwin Harbour within in the 5-year timeframe applicable to the approval being sought for the Project-related maintenance dredging activity.

Initial feedback from relevant stakeholders indicated that some other dredging activities may occur within the 5-year timeframe. These included a combination of both capital and maintenance dredging programs, ranging in location spatially from East Arm, Darwin City, the Harbour mouth and outside of Darwin Harbour. In all cases, stakeholders advised the design of such campaigns were still in their infancy and information on dredging volumes, dredging and disposal methods and timing were still yet to be finalised. As such, specific information relating to individual campaigns is unavailable. Where indicative dredge volumes were provided by stakeholders these ranged from 0.03 Mm^3 to 1 Mm^3, with most campaigns only requiring removal of small volumes.

It is considered unlikely that any of the foreseeable dredging activities within Darwin Harbour, if undertaken concurrently with the Project-related maintenance dredging, would result in increased suspended sediment plume intensity and durations, that exceed levels measured during the capital dredging program. Therefore, the potential for cumulative impacts is considered unlikely. Supporting this statement, are the environmental monitoring results from the capital dredging program (~16.1 Mm^3), which at some stages occurred concurrently with the Marine Supply Base dredging program and the dredging undertaken for the GEP. During such concurrent dredging periods, only minimal dredging-related effects to sensitive receptors at sites in proximity to dredging[10] and no dredging-related effects to protected marine megafauna[11] were observed. Therefore, the risk of potential cumulative impacts during a maintenance dredging campaign resulting from concurrent activities is considered low.

5.4.3 Long-term effects on East Arm sediment balance

The potential effects of dredging and other development activities in Darwin Harbour, notably mangrove and mudflat reclamation have been addressed in recent modelling studies (Li et al. 2012; Li 2013; Andutta et al. 2014). These studies conclude that dredging is less likely to influence sediment transport than other processes within the Harbour, particularly tidal asymmetry and the trapping effect of mangroves and mudflats.

Within the Harbour, a combination of the complex circulation near headlands and embayments and the asymmetry of the tidal currents control the fate of fine sediment (Williams et al., 2006). Mangrove areas and tidal flats affect tidal asymmetry via their influence on the amplitudes and phases of the tides, and therefore affect net sediment transport (Williams et al. 2006). For example, the net sediment flux in the Harbour during the wet season is landward, at rates of 4.8 tonnes $m^{-1}d^{-1}$ near Wickham Point; however, in the dry season, the net sediment flux near Wickham Point is seaward, at a rate of 1.1 tonnes $m^{-1}d^{-1}$ (Williams et al. 2006; Li 2013).

Inside the Harbour, mangrove areas and tidal flats play key roles in modulating the tides and water-flow dynamics of an estuary (Li et al. 2012; Li 2013). Within East Arm fines are rapidly dispersed and preferentially transported upstream towards the tidal flats and mangrove communities where they settle, with the remaining small fraction transported to the ocean (Williams et al. 2006).

Two main rivers contribute to the sediment load in East Arm and surrounding areas of Darwin Harbour, primarily in the wet season. The largest of these is the Blackmore River that drains into Middle Arm, while East Arm is the estuary of the Elizabeth River (Li 2013; Williams et al. 2006). The Elizabeth and Blackmore catchments total an area of over 1150 km^2 (Cardno 2014d). In a once-in-a-hundred-year event, whereby both the Blackmore and Elizabeth rivers peak at the same time, the combined instantaneous runoff would be approximately 1,000 m^3s^{-1} (Li 2013). Only a small amount of fine sediment is transported to the upper arms by runoff, which is subsequently dispersed from the mangrove areas (Williams et al. 2006). In contrast to catchment input, the peak spring flood tidal flow, measured along a line from East Point to Mandorah, is 120,000 m^3s^{-1} (Williams et al. 2006; Li 2013), which is significantly greater than the river input (Li 2013).

The studies (Williams et al. 2006; Li 2013; Andutta et al. 2014) suggests that only a minor proportion of the total sediment load from Elizabeth river and surrounding catchment runoff is likely to settle and remain for any period of time with the dredge area. Fine material that settles during favourable conditions (i.e. slack water) is likely to be remobilised and redistributed into areas where hydrodynamics are less turbulent than the dredge area. This is evidenced by the latest hydrographic results (Appendix B.1), which favour settlement of mobilised sediment around the less energetic jetty pocket.

6 Sediment plume modelling and impact assessment

This section describes the modelling undertaken to determine the potential magnitude, spatial and temporal extent of dredging-induced (i.e. excess and above ambient) SSC and sedimentation associated with a maintenance dredging campaign, and how these results translate to areas of simulated impact and influence to sensitive receptor habitat.

6.1 Maintenance dredging scenario

Modelling is a tool that can be used to simulate and then estimate the potential environmental impacts associated with a dredging campaign. It is typically utilised during the planning stages of a project to ascertain whether the proposed activity is likely to be considered acceptable from an environmental perspective. During execution, modelling is generally superseded by operational and environmental monitoring, the results of which are used to inform the management of dredging activities.

For the current assessment, a worst-case credible maintenance dredging scenario has been modelled to illustrate the potential environmental impacts when dredging a maximum single campaign volume of 0.75 Mm^3. As maintenance dredging cannot be restricted to a particular season or period, the scenario has been modelled for both the wet and dry season using season-specific representative driving conditions (e.g. wind, water-levels, etc.)(Section 6.3).

A summary of the modelling aspects as relevant to the worst-case credible scenario is provided in Table 6-1. The percentage fines within the material to be dredged have been inferred from the 2016 sediment quality assessment (INPEX 2016; Section 4.1.5), in addition to the values considered during the capital dredging program based on geotechnical information (INPEX 2013). Depending on the actual conditions encountered, these aspects are subject to variation during execution of the dredging on the basis the activities remain within the predetermined limits (i.e. maximum overflow time per cycle 60 minutes; maximum single campaign volume of 0.75 Mm^3).

The modelled duration for the worst-case credible maintenance dredging scenario is 39 days and was derived based on the aspects presented in Table 6-1 and data inputs described in Section 6.4.2. This duration has been specified solely for the purpose of modelling and assessing risk to sensitive receptors. By modelling the worst-case credible scenario, it is anticipated that the greatest potential effects to sensitive receptors from a maintenance campaign have been assessed, even if the duration was to be extended. Noting that the duration during execution may be extended or reduced based on actual volume of material to be dredged, conditions encountered, production rates, size of the TSHD, any constraints due to simultaneous operations (e.g. tanker berthing), in addition to any adaptive management measures that may need to be undertaken (Section 7.1).

Table 6-1: Overview of modelling aspects for the worst-case credible scenario

Description	Fines content* (%)	Overflow (min)	Overflow height (m)	Volume (m^3)
Recently deposited sediments	66%†	0	0	250,000
Coarser material northern edge	40%‡	0	0	125,000
Potential sand wave inflow	25%§	60	0.5	125,000
Contingency	25%§	60	0.5	250,000
Total				**750,000**

*The Australian Standard (Geotechnical site investigations) AS 1726-1993 defines fine sediment as a particle size < 75 µm

†Fines (%) based on average of jetty pocket and turning basin sites as allocated in the sediment assessment (INPEX 2016)

‡Fines (%) based on average of Turning Basin 1 triplicate site as allocated in the sediment assessment (INPEX 2016)
§Fines (%) based on "loose sand" category based on geotechnical information from boreholes (INPEX 2013)

6.2 Synthesis of modelling assessment approach

The overall approach used for the assessment of impacts associated with maintenance dredging and disposal activities aligns with that used previously for the capital dredging program and is as described in the Draft EIS (INPEX 2010).

The assessment consists of three major components:

1. verified and validated two-dimensional hydrodynamic model (Section 6.3) that models the movement of water within the model domain (including flow speeds and free-surface levels)
2. verified and validated fine-grained sediment transport model (Section 6.4) that determines the potential fine-grained sediment transport pathways and generates outputs of excess SSC and excess sedimentation
3. a habitat impact assessment that uses GIS (Section 6.7) to quantify and depict potential impact on derived habitats on the basis of tolerance limits (Section 6.6).

A summary of the modelling approach as it relates to maintenance dredging is presented in Figure 6-1.

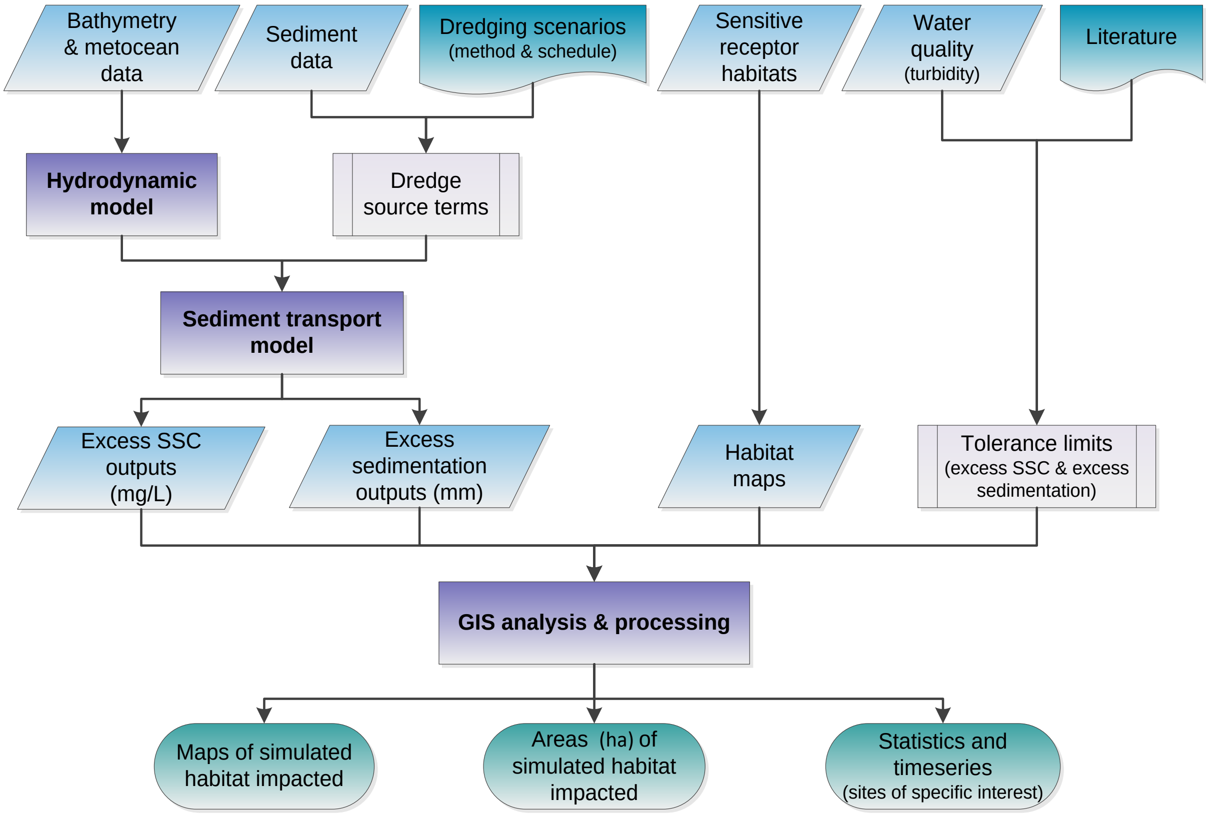


Figure 6-1: Synthesis of modelling assessment approach

6.3 Hydrodynamic model

6.3.1 General description

The hydrodynamic model uses the TELEMAC-2D numerical solver, which is a two dimensional (2D) hydrodynamic model that incorporates a third-generation wave transformation module. It is essentially the same model that was used in the Draft EIS

(INPEX 2010), which was further refined and extended prior to and during the capital dredging program to improve its accuracy (INPEX 2013). Figure 6-2 illustrates the boundary and mesh resolution of the calibrated model.

The 2D hydrodynamic model assumes that three dimensional (3D) estuarine circulation, resulting from high freshwater inflow events in the wet season, has a negligible influence on the dispersion of fine sediments released by the dredging operation into the far field. Following collection of the field data during the capital dredging program this assumption was evaluated and found to be valid (HRW 2013b). Field data on currents, salinity and temperature profiles as well as river discharge data collected during the 2012/2013 wet season, revealed that during the largest discharges into East Arm, density-induced 3D effects only persisted for short periods (less than a few tidal cycles and only during neap tides). These effects were confined to the upper reaches of East Arm and generally not apparent at the dredging location. The study concluded that the use of a 2D hydrodynamic model is appropriate for studying the transport of fine-grained sediment released by dredging in Darwin Harbour (HRW 2013b), and hence the same approach was used again here for modelling used to inform this Maintenance DSDMP.

Further, the model was also extensively calibrated and validated prior to and during the capital dredging program and therefore no further validation is proposed here. Overall, the validation results demonstrated that the model performance was good and fit for purpose (HRW 2013b), providing a good estimation of the dispersion patterns of dredged material (whether capital or maintenance) both within Darwin Harbour and offshore in the Beagle Gulf.

It is noted that AIMS have also developed a hydrodynamic model of Darwin Harbour; however, given HR Wallingford's extensive model validation, in addition to the differing objectives and spatial coverage between the models, the AIMS model was not considered in the context of impact prediction. Nevertheless, the outcomes of the AIMS modelling have been used to inform discussion of the sediment balances within Darwin Harbour (see Section 5.4.3).

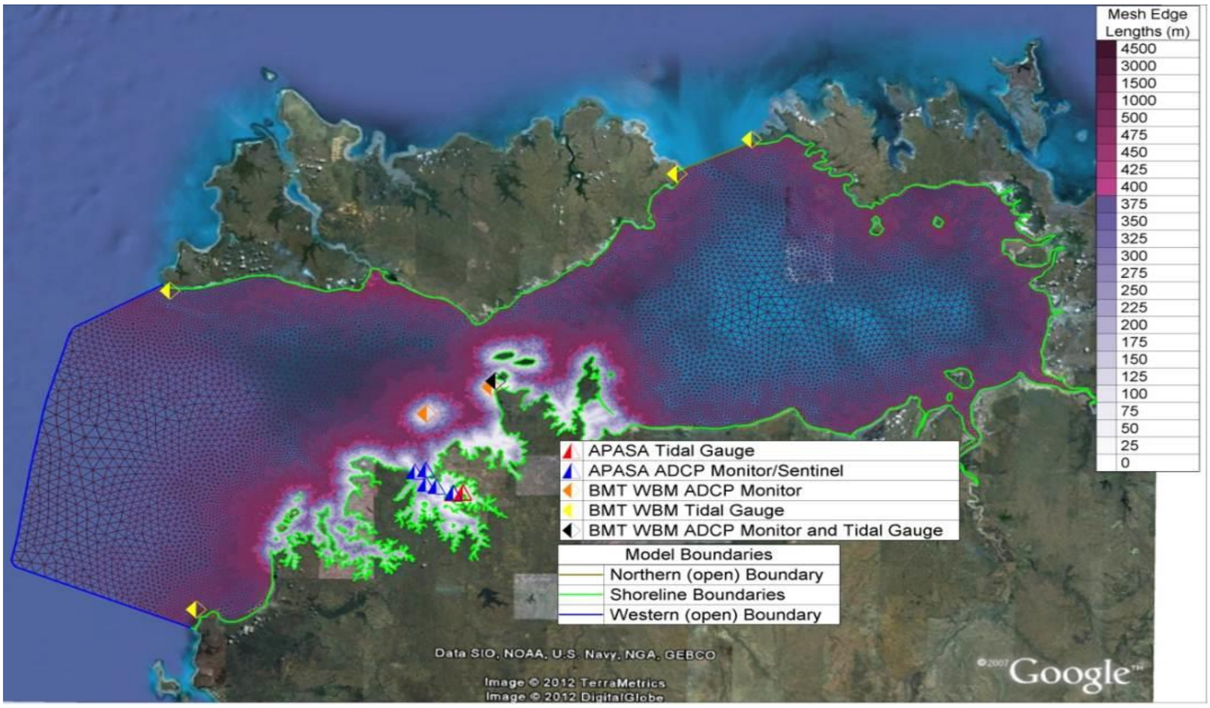


Figure 6-2: Model extent and mesh resolution of the revised hydrodynamic model and sediment transport model

6.3.2 Data inputs

For this Maintenance DSDMP, hydrodynamic model simulations incorporated the application of representative driving conditions, for both the wet and dry season. These included:

- the simulation of repeating spring/neap average tidal conditions based on the analysis of 20 years of water level data at Darwin Harbour
- the application of a representative offshore wind-field to account for seasonal wind-stress effects on water-levels. The appropriateness of the selected time period has been determined by statistical analysis
- the application of representative inshore wind data to generate fetch-limited waves within Darwin Harbour. The appropriateness of the selected time period has been determined by statistical analysis
- the inclusion of the fully dredged bathymetry.

6.4 Sediment transport model

6.4.1 General description

The dispersion and settling patterns of fine sediments (<75 μm)[7] released from the dredging activities was modelled using the DELFT-3D Water Quality Module (DELWAQ), which was coupled to the TELEMAC hydrodynamic model described in Section 6.3. The sediment transport model takes outputs from the hydrodynamic model (flows, levels and additional wave-induced stresses), and inputs relating to the characteristics of the sediment as well as the magnitude and duration of the dredging 'source-term' to simulate the advection and diffusion of the fine-grained sediment released by the dredging activity.

For practicality and timely processing, DELWAQ was applied in 2D mode. This was confirmed to be acceptable through the validation exercise undertaken for the capital dredging program, which found that overall the sediment transport model was demonstrated to be a robust tool for assessing the effects of the dredging activities on SSC within Darwin Harbour (HRW 2013b). As such, it is also considered appropriate here for assessing the potential far-field impacts that may be associated with the proposed maintenance dredging.

The model domain was the same as that used in the hydrodynamic model (refer to Figure 6-2).

6.4.2 Data inputs

A key input to the fine-grained sediment transport model is the magnitude and duration of the dredging 'source-term' (Mills & Kemp 2016). The source term parameters relate to several aspects and processes, including the breakup of the dredge material under mechanical action and its hydraulic transport, as illustrated in Figure 6-3. For this Maintenance DSDMP, the source term calculations were premised on the following:

- an upper volume limit of 0.75 Mm^3 for a single maintenance dredging campaign, divided into four portions of differing particle size, as described in Section 6.1
- a generic work method using a medium-sized TSHD
- dredge efficiency, production rates and cycle times based on expert knowledge and that reflect industry standard assumptions

- estimated primary[13] and secondary[14] losses of fines associated with TSHD activities, which align as far as practicable with the modelling for the capital dredging program (Table 6-2) and are considered conservative. It is noted that during the execution of the capital dredging program, the Dredging Contractor completed extensive plume characterisation campaigns, and the results of these campaigns were considered when selecting the estimated percentage of primary and secondary losses of fines.

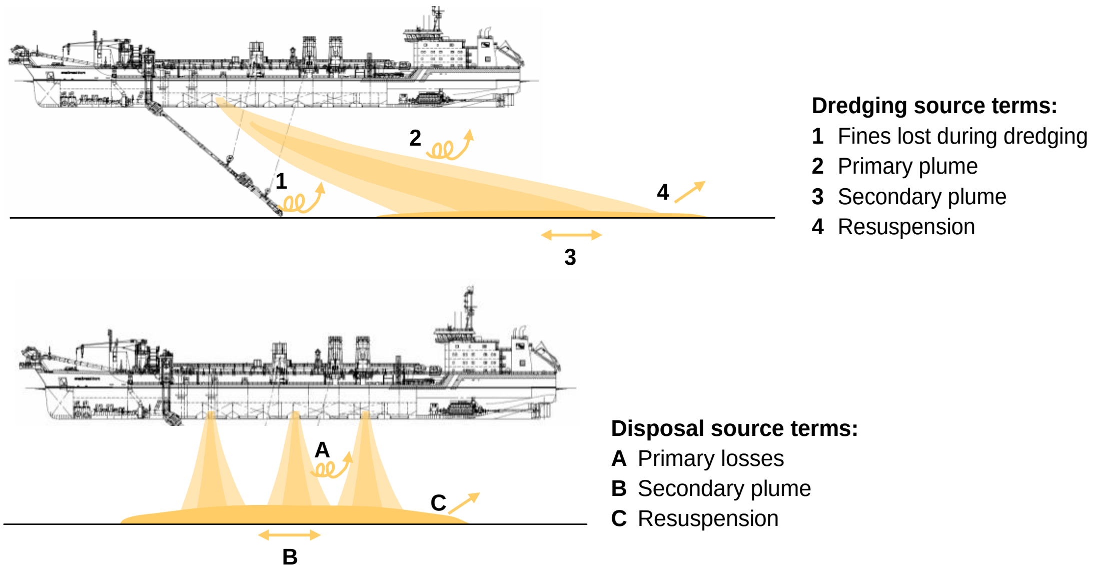


Figure 6-3: Visual representations of the source terms for fine sediment released into the environment during dredging and spoil disposal activities

Table 6-2: Assumed primary and secondary losses of fines during dredging, loading and disposal

Model Inputs	**Assumed % losses of fines**
Losses during dredging	
Primary losses of fines when dredging with TSHD (at draghead)	2%
Primary losses of fines when pumping empty the hopper	0.25%
Losses during loading of TSHD	
Primary losses of fines for 60 minute overflow when dredging with TSHD	31%
Primary plume (percentage of fines)	15%
Secondary plume (percentage of fines)	85%
Percentage of secondary plume available for resuspension	10%*

[13] Primary losses are direct losses of (fine) sediment during dredging (at the draghead), barge loading (overflow) or during disposal (upon release from barge or hopper).

[14] Secondary losses are indirect losses of fines (at either the dredging location or the disposal site) of deposited dredged material into the water column through the process of resuspension caused by tidal currents and wave actions.

Model Inputs	Assumed % losses of fines
Losses during disposal	
Primary losses during disposal of TSHD material	2%
Secondary plume TSHD material (percentage of fines)	98%
Percentage of secondary plume available for resuspension	20%†

*10% has been assumed as monitoring results during the capital dredging program suggested minimal resuspension.

† As per the capital dredging program, 20% re-suspension at the DSDA is assumed to represent a conservative estimate.

6.5 Model outputs

6.5.1 Excess SSC maps

The model results are presented as 50th, 90th and 95th percentile excess SSC colour maps. The 50th, 90th and 95th percentile values represent the magnitude (and extent on the map) where excess SSC is likely to be exceeded for no more than 50%, 10% and 5% of the time respectively. The 90th and 95th percentile results are representative of infrequently occurring excess SSC at the higher end of the simulated range. The excess SSC colour surface maps were produced for a range of differing temporal periods including:

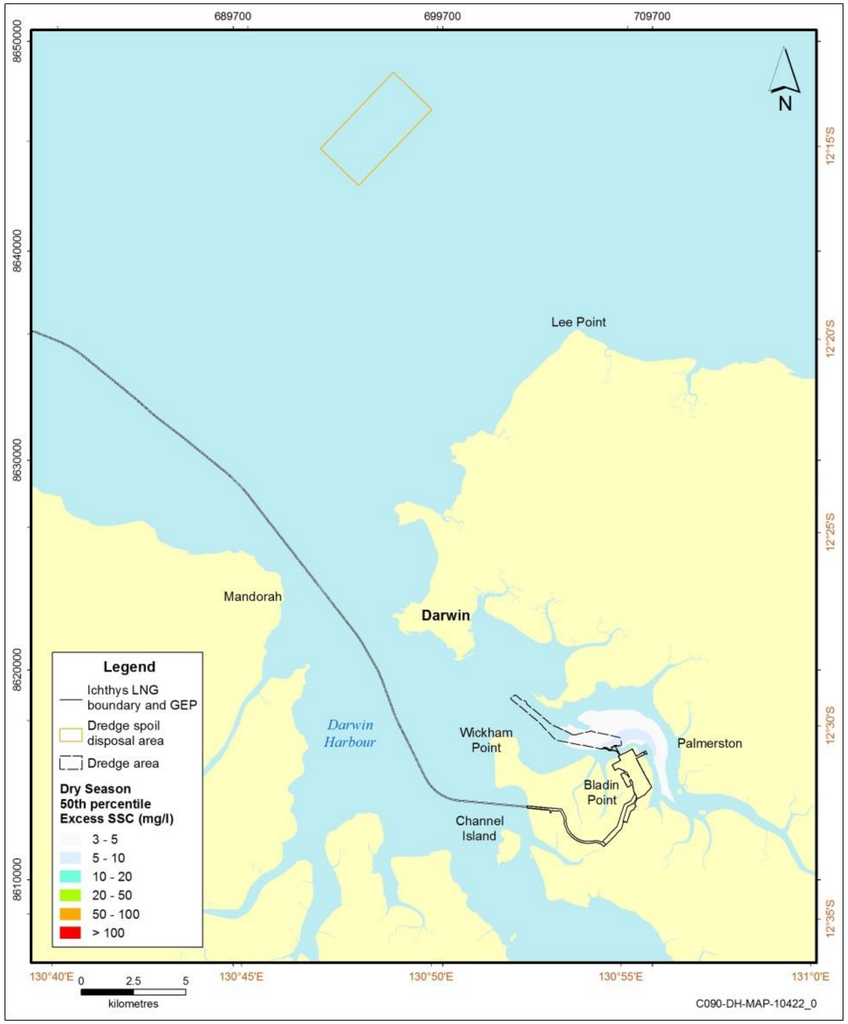
- the entire simulated dredging period (approximately three spring-neap cycles)
- phases consisting of two spring-neap cycles (i.e. 0 to 29 days and 30 to 59 days of the simulation), which is consistent with the forecast modelling undertaken during the capital dredging program.
- phases consisting of one spring-neap (SN) cycle (i.e. 0 to 14 days (SN1), 15 to 29 days (SN2), etc.).

Following review of the excess SSC colour maps at differing temporal scales, the highest intensity period with regards to the concentration and spatial extend of excess SSC, for both wet and dry season simulations was found to be SN2 (i.e. 15 to 29 days), which was used as the basis of habitat impact assessment (Section 6.7). For ease of reference, the outputs from this period are provided in Figure 6-4, Figure 6-5 and Figure 6-6, and are summarised as follows:

- The magnitude and spatial extent of excess SSC is dominated by the tidal flow patterns, with minor differences observed between seasons primarily due to changes in prevailing wind conditions (Sections 4.1.1 and 4.1.2). The 50th percentile results suggest that detectable elevations in SSC are confined to East Arm for at least 50% of the time. In the 90th and 95th percentile results, the simulated SSC plume appears to be elongated along the tidal axis from East Arm, out through the mouth of the Harbour towards to DSDA where interaction with the plume created by the disposal activity can occur at concentrations up to 5 mg/L.
- For both the wet and dry season model simulations, for each percentile, the highest excess SSC within Darwin Harbour is simulated to occur within the south eastern portion of the dredge area, where the majority of dredging is likely to occur. Excess SSC within this area is simulated to be no more than 5 to 10 mg/L for 50% of the time, and up to 100 to 200 mg/L for no more than 5% of the time within a highly localised area.
- One of the key differences between dry and wet season model simulations for the 90th and 95th percentile results is the presence of elevated excess SSC occurring on the north-western side of Darwin city. Within the model, during the wet season the prevailing west/north-westerly winds stimulate resuspension of temporary

sedimentation in this location, locally elevating excess SSC within the nearshore environment of Fannie Bay (southern section), typically in the range of 10 to 20 mg/L.

These maps only depict the modelled excess SSC associated with the release of fines during maintenance dredging and spoil disposal. They do not represent the potential impacted areas of habitat. In order to evaluate the potential effects of dredging related excess SSC and excess sedimentation on a particular habitat type, the application of habitat specific ecological tolerance limits, per season is required. The results of this assessment are provided in Section 6.8.



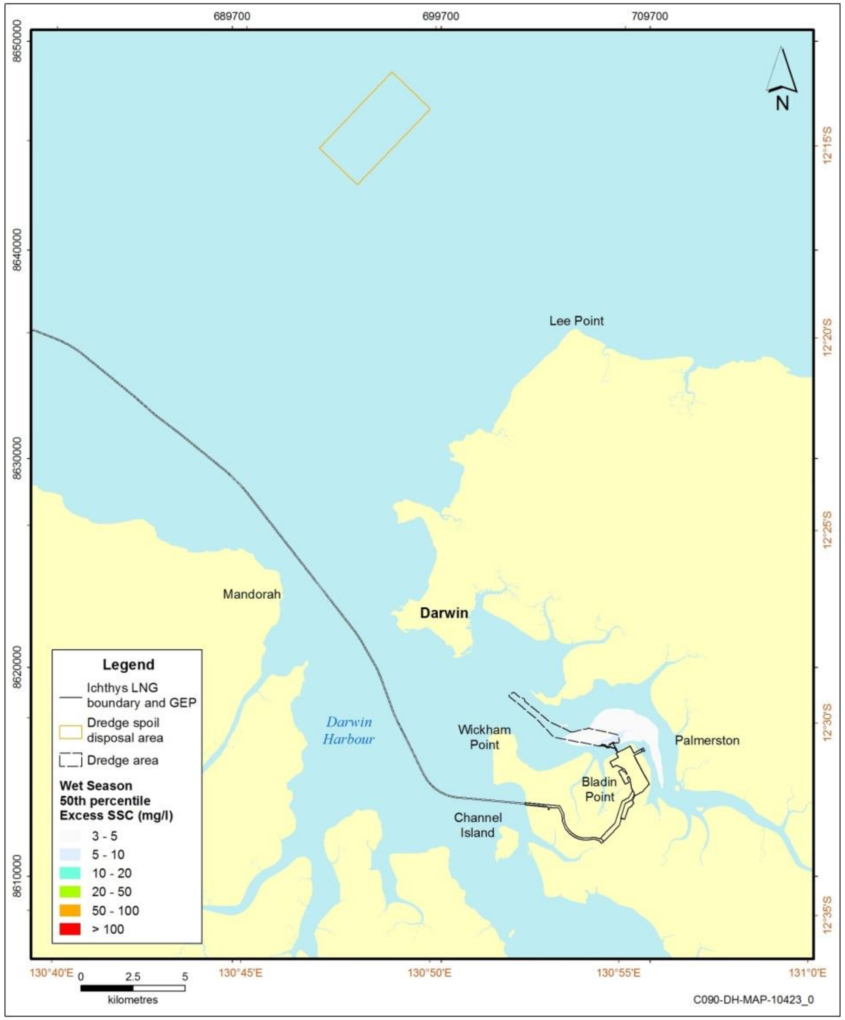


Figure 6-4: Worst-case credible scenario model results representing the 50th percentile excess SSC (mg/L) for the highest intensity phase (SN2; 15 to 29 days) in both representative dry season conditions (left) and representative wet season conditions (right)

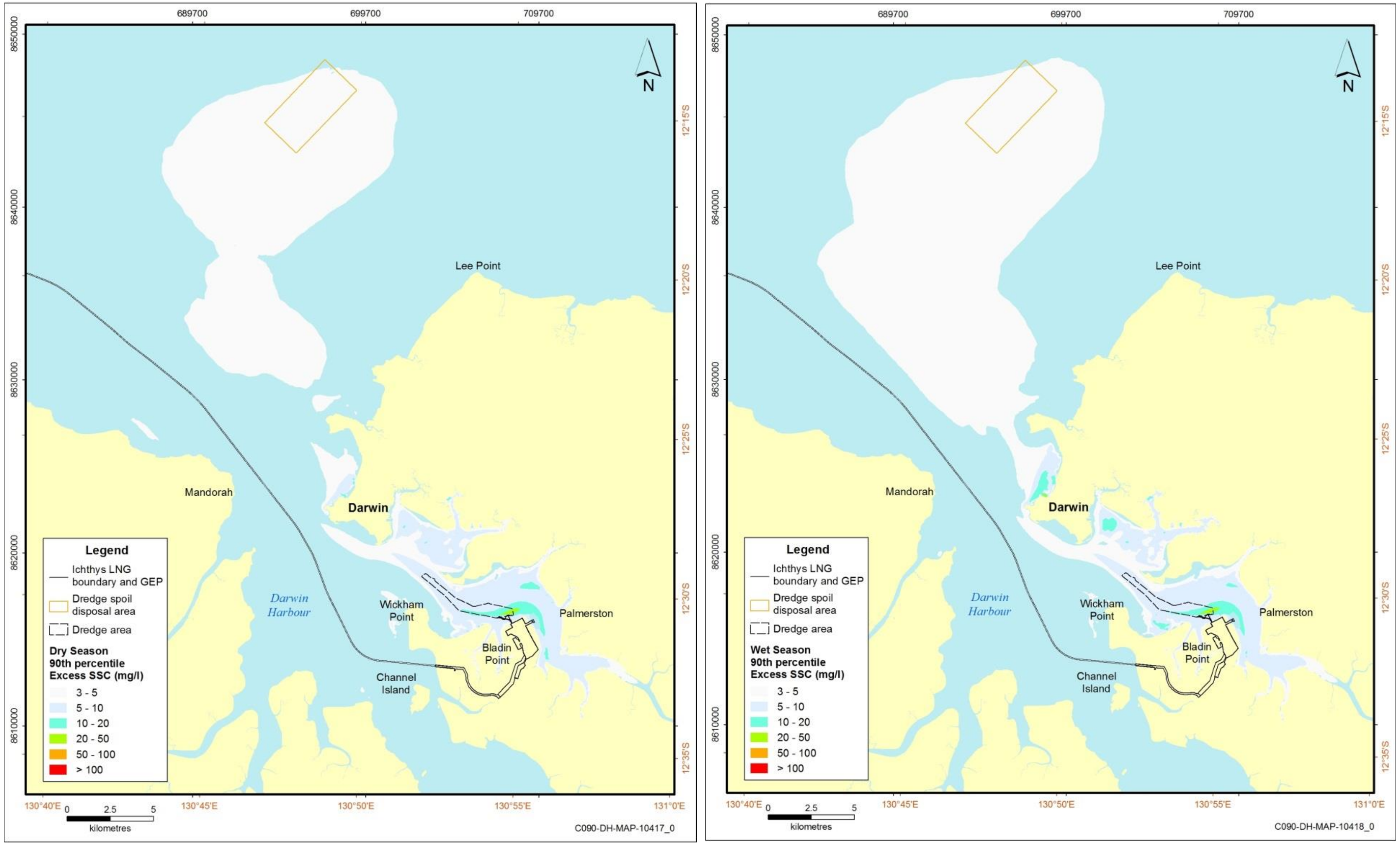
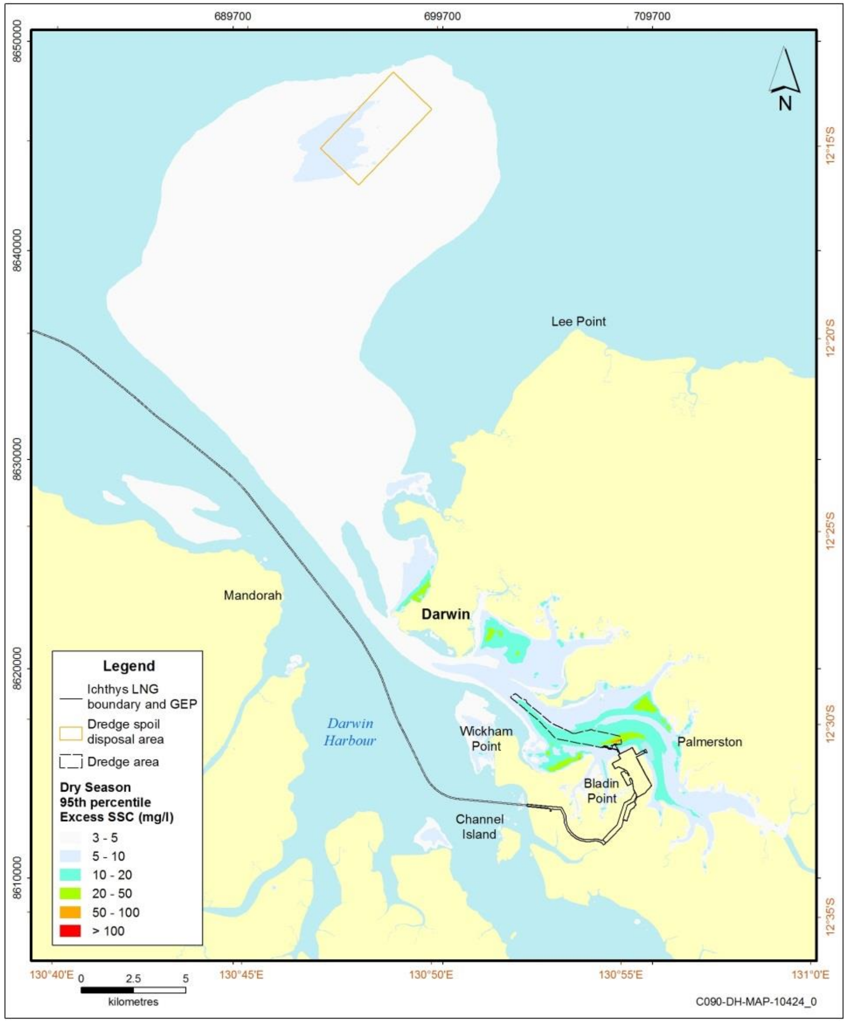


Figure 6-5: Worst-case credible scenario model results representing the 90th percentile excess SSC (mg/L) for the highest intensity phase (SN2; 15 to 29 days) in both representative dry season conditions (left) and representative wet season conditions (right)



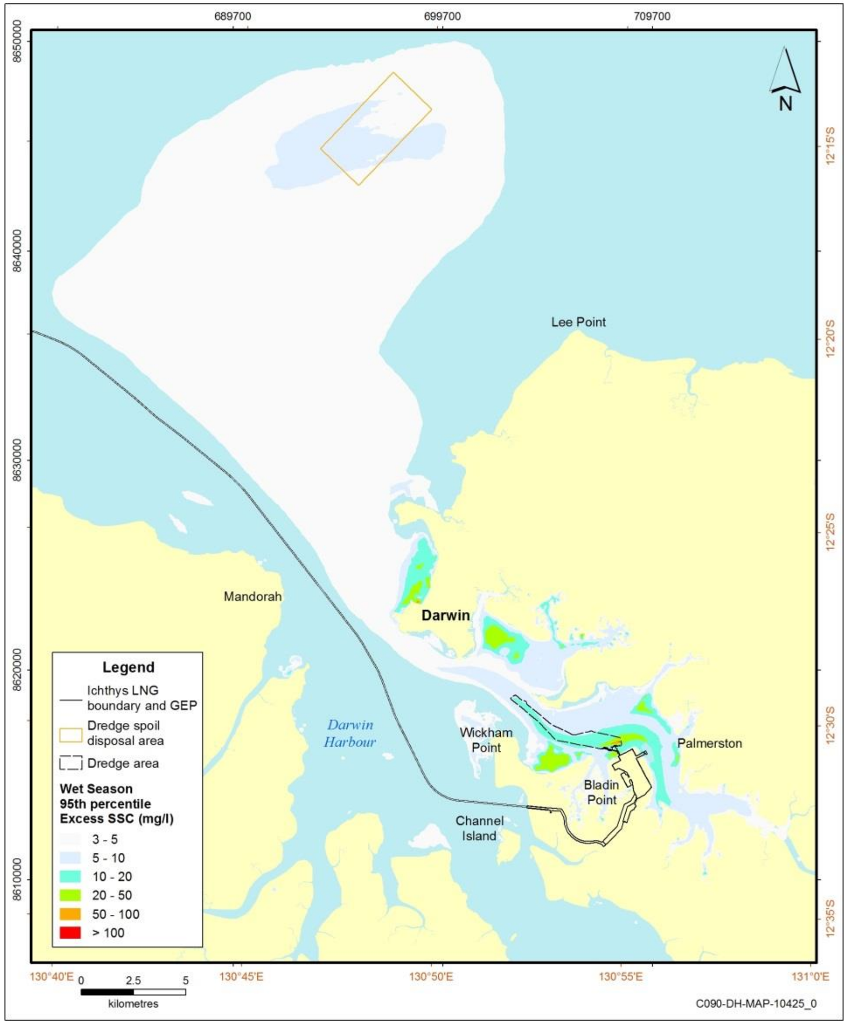


Figure 6-6: Worst-case credible scenario model results representing the 95th percentile excess SSC (mg/L) for the highest intensity phase (SN2; 15 to 29 days) in both representative dry season conditions (left) and representative wet season conditions (right)

6.5.2 Sediment deposition maps

For sedimentation, the model calculates the net thickness (in millimetres) of fine sediment deposited on to the seabed associated with the fine material released by the potential dredging activity for the entire duration of the maintenance dredging program. The simulated net thickness of sediment is a function of the estimated density of the material and the transport, deposition and erosion processes simulated by the model.

Figure 6-7 shows the sedimentation pattern at the end of the simulation, for both wet and dry season, respectively. Note that this represents the calculated layer thickness of excess sediment deposition (dredging-induced) at the end of the model run. Based on a review of these sedimentation net thickness (mm) figures, the following observations can be made:

- There is little or no difference between wet and dry season model simulations, with the thickest layer of excess sedimentation simulated to occur within the south eastern portion of the dredge area, where the majority of dredging is likely to occur. The simulated thickness of excess sedimentation within this portion of the dredge area is 100 to 200 mm. This is likely to be due to the rate of accumulation of fine material from overflow exceeding the transport capacity of the flow, and hence will likely be removed during clean-up dredging using limited or no overflow.
- The nearshore location (outside the dredge area) simulated to receive the most excess sedimentation is in the subtidal/intertidal area shore-side of the jetty infrastructure, with isolated patches of up to 50 mm.
- In both the wet and dry season simulations, excess sedimentation is not predicted to occur at levels greater than 18 mm within any of the intertidal mangrove assemblages, nor greater than 5 mm within the Beagle Gulf.

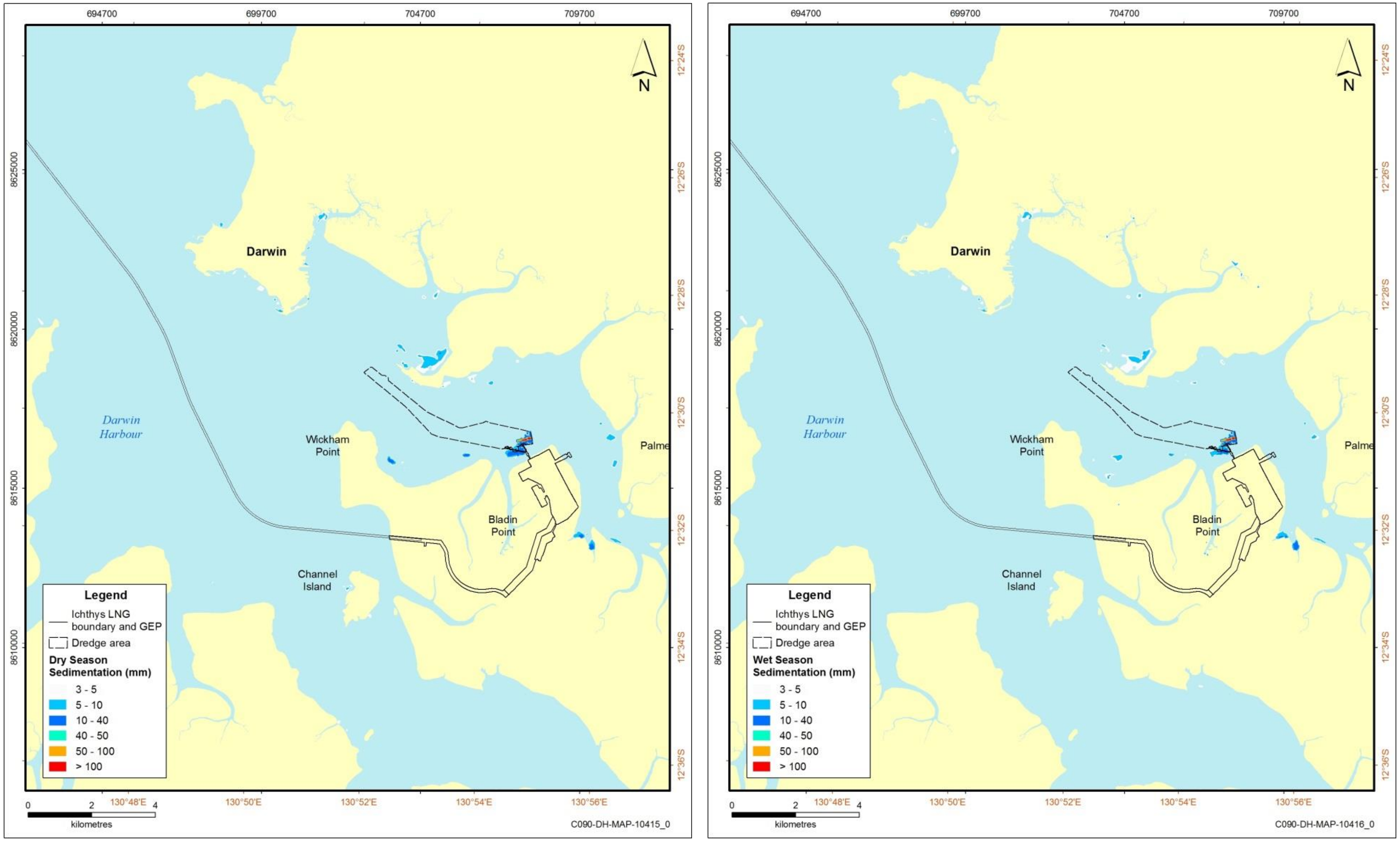


Figure 6-7: Worst-case credible scenario modelled excess (dredging-induced, above background) sediment deposition (mm) at the end of modelling simulation for representative dry season conditions (left) and representative wet season conditions (right)

6.6 Tolerance limits for habitats

To interpret the modelling outputs described in Section 6.5 and calculate areas of potential impact from dredging-induced excess SSC and sedimentation, tolerance limits were established for various sensitive receptors including mangrove, seagrass and hard coral habitats. Tolerance limits were derived in two different ways as per the method developed and applied for the Final EIS (INPEX 2010, 2011) and the capital dredging program (INPEX 2013).

Tolerance limits for SSC were derived from site-specific water quality monitoring, arguing that resident flora and fauna are adapted to local conditions but will be stressed if exposed to conditions that regularly exceed background concentrations. Tolerance limits for sedimentation were derived from habitat-specific dose-response experiments and field observations reported in the scientific literature.

The tolerance limits used in the analysis for this Maintenance DSDMP are presented in Table 6-3, in context of those used during the capital dredging program. Refinement of these tolerance limits (based on new information, data and literature) is described in Section 6.6.1 and 6.6.2.

Table 6-3: Tolerance limits for excess SSC and sedimentation

Habitat	Location	Season	Capital dredging DSDMP (Rev 4)		Current analysis	
			SSC (mg/L)[1]	Sedimentation (mm)	SSC (mg/L)[1]	Sedimentation (mm)
Mangrove	Anywhere	all	N/A	50	N/A	50
Coral	East Arm	dry	10.5	15	11.9	15
		wet	25.2		23.8	
	Middle Arm	dry	17.3	15	12.4	15
		wet	32.6		27.0	
	Mid Harbour	dry	7.9	15	10.7	15
		wet	50.6		28.4	
	Offshore	dry	10.5	15	17.9	15
		wet	25.2		64.2	
Seagrass	Anywhere	dry	12.8	40	13.3	40
		wet	51.7		60.6	

[1] Note turbidity (measured in NTU), has been converted to SSC (measured in mg/L) for practicality in the analysis based on a 1:1 relationship as was found during the capital dredging program (Cardno 2013a)

6.6.1 SSC tolerance limits

For this Maintenance DSDMP, the method to calculate the SSC tolerance limits have been consistently applied and refined over time as a direct result of the expanding water quality dataset. Tolerance limits for SSC were derived from site-specific turbidity data, which has been converted to SSC based on the 1:1 relationship established during the capital dredging program (Cardno 2013a).

The original SSC tolerance limits for the Final EIS (INPEX 2010, 2011) were derived from a one year (2010 to 2011) baseline turbidity dataset collected for the EIS Supplement (INPEX 2011). These data were collected from four monitoring sites inside Darwin Harbour, i.e. East Arm (South Shell Island and Northeast Wickham Point), Middle Arm (Channel Island) and Mid Harbour (Weed Reef). No data were collected at offshore locations and as such, the offshore tolerance limits for coral and seagrass were conservatively estimated from the lowest inner harbour values.

Prior to the commencement of capital dredging program, the SSC tolerance limits were updated to reflect seasonal variability. Season-specific tolerance limits were established

for the dry season (May to October) and the wet season (November to April) (INPEX 2013).

Following completion of the first half of the capital dredging program, seagrass-specific tolerance limits were derived as monitoring results indicated no discernible evidence that suspended sediment generated by the dredging activities had reached the seagrass monitoring sites. As such, seasonal SSC tolerance limits for seagrass were calculated using turbidity data collected from August 2012 to October 2013 (inclusive) from the full suite of data collected at the seagrass monitoring locations (combined).

For this Maintenance DSDMP, the SSC tolerance limits were further refined for coral and seagrass in consideration of the comprehensive water quality dataset collected as part of the NEMP (2012 to 2015) and baseline data (2010 to 2011) collected for the EIS Supplement (INPEX 2011). For conservatism turbidity data collected at South Shell Island and Northeast Wickham Point (in proximity to the dredge area) during the capital dredging activities was removed from the analysis, in addition to any turbidity data collected at sites further afield that was influenced by suspended sediment from dredging. This was irrespective of whether or not a corresponding impact to the receiving sensitive receptor was measured.

Following review of literature recently published as a part of the WAMSI Dredging Science Node the appropriateness of this aforementioned approach to deriving SSC tolerance limits was reassessed. Based on the findings presented in Jones et al. (2016), the approach adopted is considered sound as the SSC tolerance limits are based on a comprehensive site-specific turbidity dataset from the Darwin region, where the water quality characteristics are now well known.

Further, as Jones et al. (2016) argue in their review, experimental conditions used in past manipulative laboratory studies often vastly differed in many regards to the water quality conditions measured in situ during numerous Western Australian capital dredging programs, placing doubts with regards to their usefulness for appropriate management of dredging activities (Jones et al. 2016). Consequently, this introduces limitations and potential confounding effects when developing thresholds based on past experimental studies, which in some cases include complexities (e.g. inter-connected cause-effect pathways) that make generalisations and comparative interpretations difficult (Jones et al. 2016).

6.6.2 Sedimentation tolerance limits

For this Maintenance DSDMP, the same conservative sedimentation tolerance limits as used in the latter half of the capital dredging program were adopted.

The sedimentation tolerance limits originally established from literature for the Final EIS (INPEX 2010, 2011) were retained for the capital dredging program, with the exception of the tolerance limit for seagrass. This tolerance limit was revised following the completion of the first half of capital dredging, as the original value (15 mm) was based on the lowest values reported in literature for the most sensitive seagrass species, *Cymodocea rotundata* (Vermaat et al. 1997). Following completion of the first half of the program, seagrass monitoring had identified *Halodule uninervis* and *Halophila decipiens* as the dominant species in the Darwin region (Cardno 2012). Therefore, based on literature (Cabaçao et al. 2008; Duarte et al. 1997; Ooi et al. 2011; Vermaat et al. 1997), the sedimentation tolerance limit for seagrasses was revised to 40 mm and subsequently approved for the remainder of the capital dredging and for all future analyses.

For sedimentation, the model calculates the thickness (in millimetres) of sediment deposited on to the seabed over the entire duration of the dredging program (a net result of deposition, resuspension and erosion, all of which are incorporated in the sediment transport model). Most of the literature values for sediment tolerances; however, are

based on sudden burial experiments or events. As such, the effects of gradual deposition are implicitly equated to those of sudden burial events.

Following a review of recently published WAMSI Dredging Science Node outcomes, the appropriateness of using values derived from manipulative studies reported in literature to derive sedimentation tolerance limits was reassessed. Jones et al. (2016) observed that the application rates for sediment deposition as applied in most past manipulative studies (on corals) have been unrealistically high, often far beyond the range of relevance to dredging operations. Additionally, in contrast to water quality monitoring, techniques to monitor subtidal sedimentation in situ have many challenges. Jones et al. (2016) state *"there are currently no suitable techniques for measuring low mg per cm^2 deposition events with sufficient resolution to be effective as a monitoring tool for dredging programmes".*

Given that no dredging-attributable lethal impacts to sensitive receptors were recorded during the capital dredging program, and in the absence of a more suitable alternative, the approach to derive sedimentation tolerance limits based on literature is considered to remain adequate, albeit conservative. Therefore, no changes are proposed to the sedimentation tolerance limits for this Maintenance DSDMP. It is also noted that the tolerance limit values were extensively discussed with and endorsed by the Ichthys Project Dredging Expert Panel for the capital dredging program.

6.7 Habitat impact assessment analysis

Direct impacts from maintenance dredging include the removal of substrate within the dredge area and smothering of substrate at the DSDA during disposal, in addition to a 20 m buffer extending outwards from each of these areas. These areas constitute the Zone of High Impact (ZoHI), where the predicted impacts are expected to be severe and often irreversible (WA EPA 2011). It should be noted that the substrate within and directly adjacent to both the dredge area and the DSDA is classified as soft-bottom benthos, which is well represented and widely distributed both in Darwin Harbour and regionally (Section 4.2.5) and as such not considered a sensitive receptor of concern (INPEX 2010, 2011).

Sensitive receptor communities are predicted to be indirectly impacted where their respective ecological tolerance limits for SSC (Table 6-3) are exceeded for 10% of the time or where the simulated sedimentation depth exceeds their respective sedimentation tolerance limits (Table 6-3) at the end of the simulation. Relative to the respective habitat types, these areas constitute the Zone of Moderate Impact (ZoMI). Within the ZoMI, damage/mortality of sensitive receptor communities may occur as a result of the indirect effects from elevated SSC and sedimentation. While impacts within this zone are predicted to occur, the disturbed areas are considered to have good potential for recovery (post-cessation of dredging activities) and it is expected that within the ZoMI there will be no long-term modification of the benthic habitats and thus no long-term effects on sensitive receptor communities (WA EPA 2011).

Sensitive receptor communities are predicted to be indirectly influenced where their respective ecological tolerance limits for SSC (Table 6-3) are exceeded for 5% of the time or where the simulated sedimentation depth exceeds 3 mm, irrespective of habitat type, at the end of the simulation. Relative to the respective habitat type, this area constitutes the Zone of Influence (ZoI). Within the ZoI the sensitive receptor communities may, at some time experience detectable elevations in SSC and sedimentation (beyond expected background levels). However, the intensity, duration and frequency of these changes are such that no sublethal stress or mortality of benthic communities is expected to occur within the ZoI (WA EPA 2011).

Simulated areas of (indirect) impact or influence for each habitat type were calculated by determining areas where the ZoMI and ZoI (determined for each habitat type) coincided

with the mapped presence of that habitat. The simulated effects should be viewed as risk-based assessment outcomes showing the habitats and their respective locations that are the most sensitive and most likely to be affected by suspended sediment (and associated sedimentation) released during a maintenance dredging campaign. A dedicated water quality monitoring program (Section 8) has been designed to monitor the actual turbidity at each of the sensitive receptor sites.

6.8 Habitat impact assessment outcomes

Interrogation of the modelling results for the highest intensity phase (SN2) suggests that the worst-case credible maintenance dredging scenario (Section 6.1) will have no impacts on high-confidence or inferred seagrass or mangrove communities. While only a minor area (0.8 ha; Table 6-4) of potential coral habitat is simulated to be impacted if conducted during the dry season, when the ecological tolerance limits of corals are assumed to be lower than in the wet season (Section 6.6).

The "simulated impact" was based on exceedance of SSC tolerance limits for coral habitat during a single spring-neap cycle (14 days). This is considered conservative as analysis based on longer phases (i.e. 2 x spring-neap period or the entire dredging period) resulted in smaller areas of simulated impacts of only 0.2 ha of coral, if a maintenance dredging campaign was to be conducted in the dry season. Moreover, several studies indicate that corals have the ability to tolerate poor light conditions for considerable periods of time (>14 days) by surviving on energy reserves and heterotrophic feeding mode (Erftemeijer et al. 2012; Jones et al. 2016).

Table 6-4: Simulated areas of impact based on highest intensity period (SN2; days 15 to 29) of the worst-case credible scenario

Sensitive receptor habitat	Dry Season	Wet Season
Mangrove	0 ha	0 ha
Coral	0.8 ha	0 ha
Seagrass	0 ha	0 ha

The coral simulated to be impacted is located directly upstream from the main dredge area, in proximity to the Module Offloading Facility (as illustrated in Figure 6-8 (left)) and is classified as Mixed Community; Reef habitat[15]. In contrast to the capital dredging program, there are no predicted impacts to areas of high confidence Hard Coral; Reef habitat such as South Shell Island and Northeast Wickham Point, which are downstream and in proximity to the western portion of the dredge area.

Mixed Community; Reef habitat in the Darwin region comprises 8,231 ha, of which 8% is classified high confidence and the remainder is classified as inferred. Based on biota classification definitions, coral represents 15% of this habitat and as such, 1,235 ha of coral could be assumed. Coupled with high confidence Hard Coral; Reef habitat, the total coral habitat for the Darwin region is considered to be 1,457 ha. Based on these calculations, simulated effects to 0.8 ha of coral represent only 0.05% of potential coral habitat in the Darwin region.

In order to assess the significance of affecting the small portion of Mixed Community; Reef habitat upstream from the dredge area, the coral community composition has been

[15] Based on the outcomes of habitat mapping and classification undertaken for the Final EIS (INPEX 2010; 2011), Mixed Community; Reef habitat consists of macroalgae (8%), hard coral (15%), filter-feeder (29%) and <10% macrobiota (47%). Note these percentages do not refer directly to percent cover but rather are an allocated attribute based on biota classification definitions.

inferred using the Northeast Wickham Point monitoring results. This is likely to be comparable given the similar depth profile and its location within East Arm. As described in Section 4.2.2 of the Maintenance DSDMP, the hard coral composition at Northeast Wickham Point is 2.4% made up primarily species of the Faviidae, Pectiniidae and Poritidae families. Given these families are well represented at other Hard Coral; Reef sites in Darwin Harbour, it is unlikely that the small portion of coral potentially affected in this area would be ecologically significant.

Further, in consideration of the monitoring results collected during the capital dredging program, it is unlikely that this modelled impact of a maintenance dredging campaign would eventuate. This is because no dredging-attributable coral mortality was recorded at monitoring sites in proximity to the dredge area during the capital dredging program (which was an order of magnitude larger in terms of duration and volume), where 100% loss was predicted (Cardno 2015c).

The results of the modelling showed that no high-confidence or inferred seagrass habitat is predicted to be impacted (Figure 6-9). However, a small area of high-confidence seagrass habitat within Fannie Bay is simulated to be influenced by excess SCC if a maintenance dredging campaign were to be conducted during the dry season, when the ecological tolerance limits of seagrasses are assumed to be lower (Section 6.6). As a contingency, the Fannie Bay water quality site north of this area is proposed to be monitored as a part of the water quality monitoring program described in Section 8, to verify model predictions and ensure that management actions can be implemented to keep turbidity at this site within levels that will prevent impacts from occurring.

Similar to seagrass, no areas of mangrove habitat are predicted to be impacted; however, there are isolated patches of mangrove habitat simulated to be influenced (Figure 6-10). Given these areas are predicted to receive only <18 mm of deposition (which is markedly less than the 50 mm tolerance limit) and considering that no excess sedimentation was recorded during the capital dredging program at levels predicted by the modelling, nor at heights that would cause impact, the risk to mangroves from the proposed maintenance dredging program is considered low.

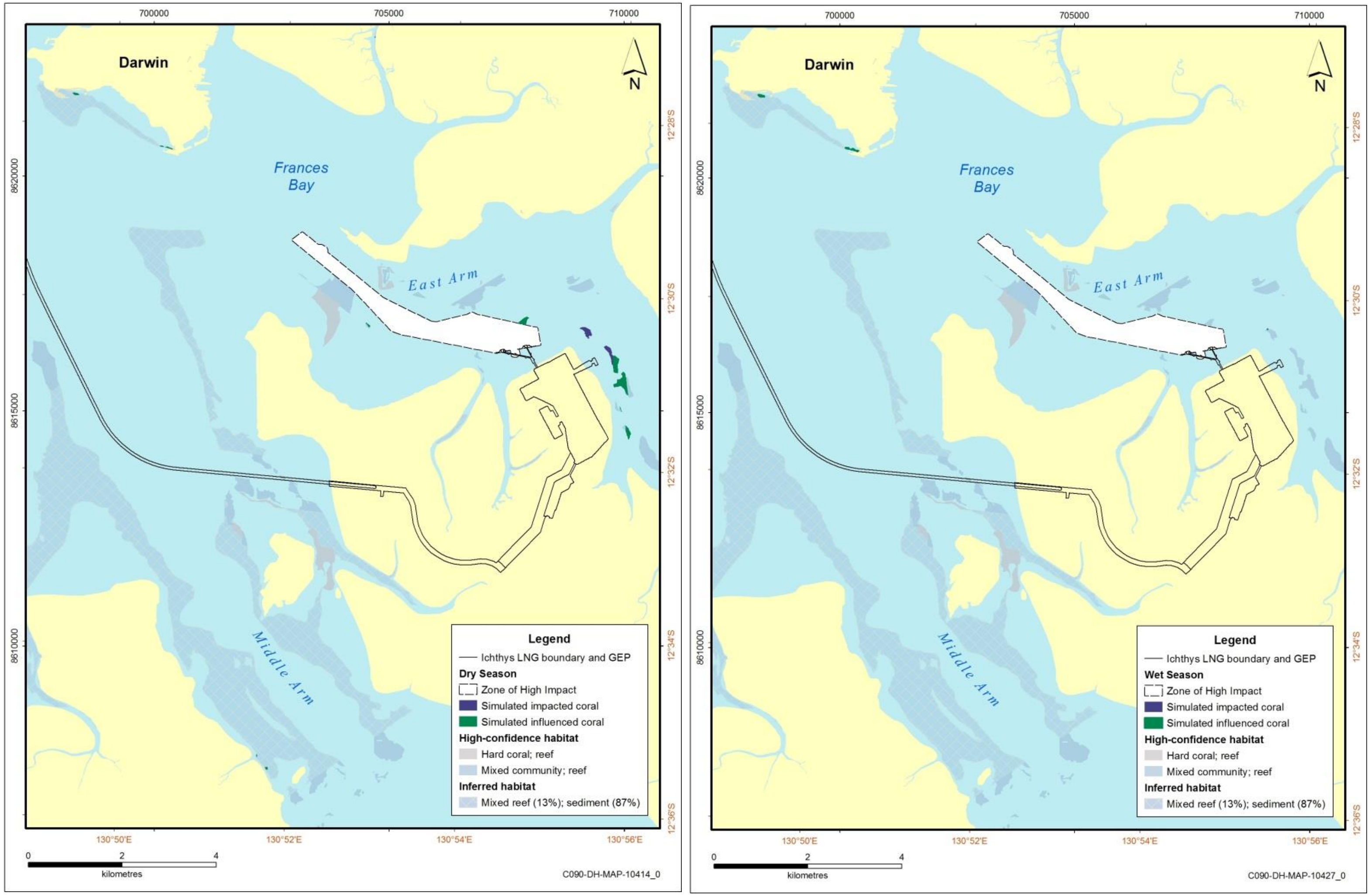
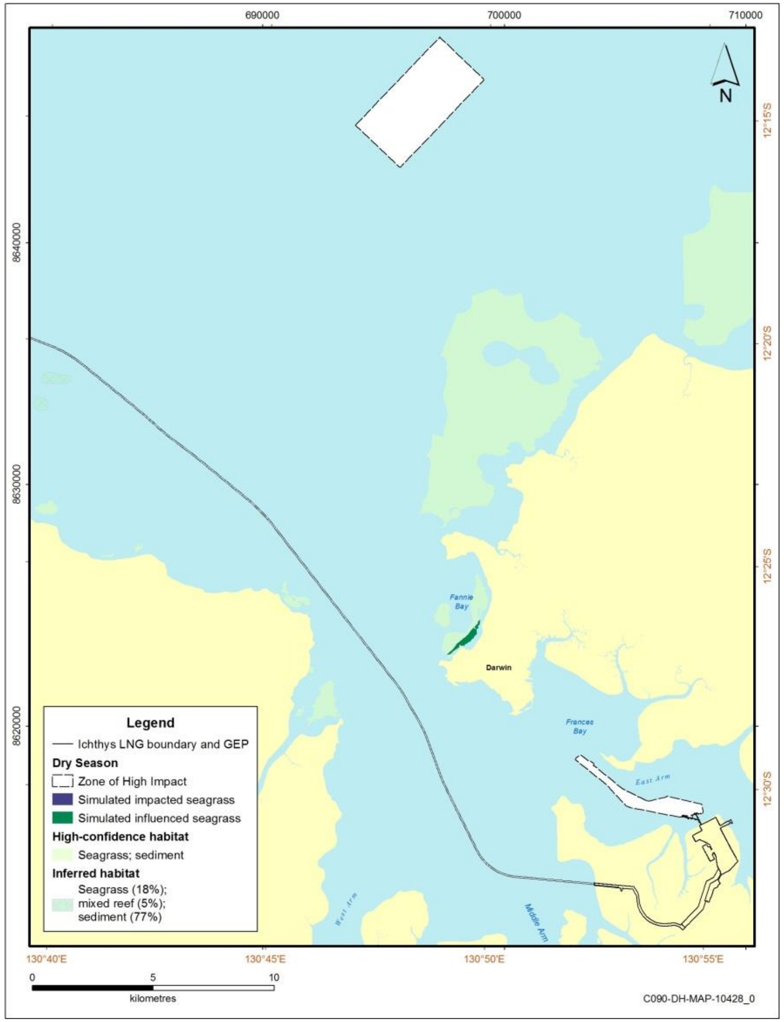


Figure 6-8: Areas of coral habitat simulated to be impacted and influenced by excess SSC and sedimentation based on highest intensity period (SN2; 15 to 29 days) during the dry season (left) and wet season (right)



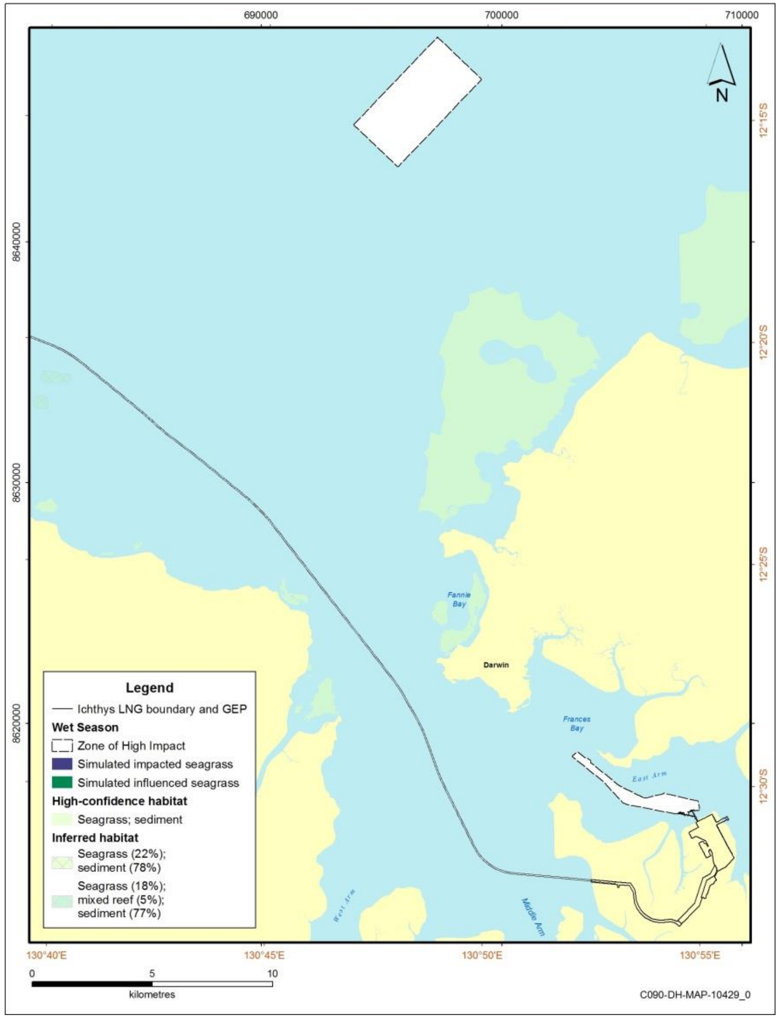
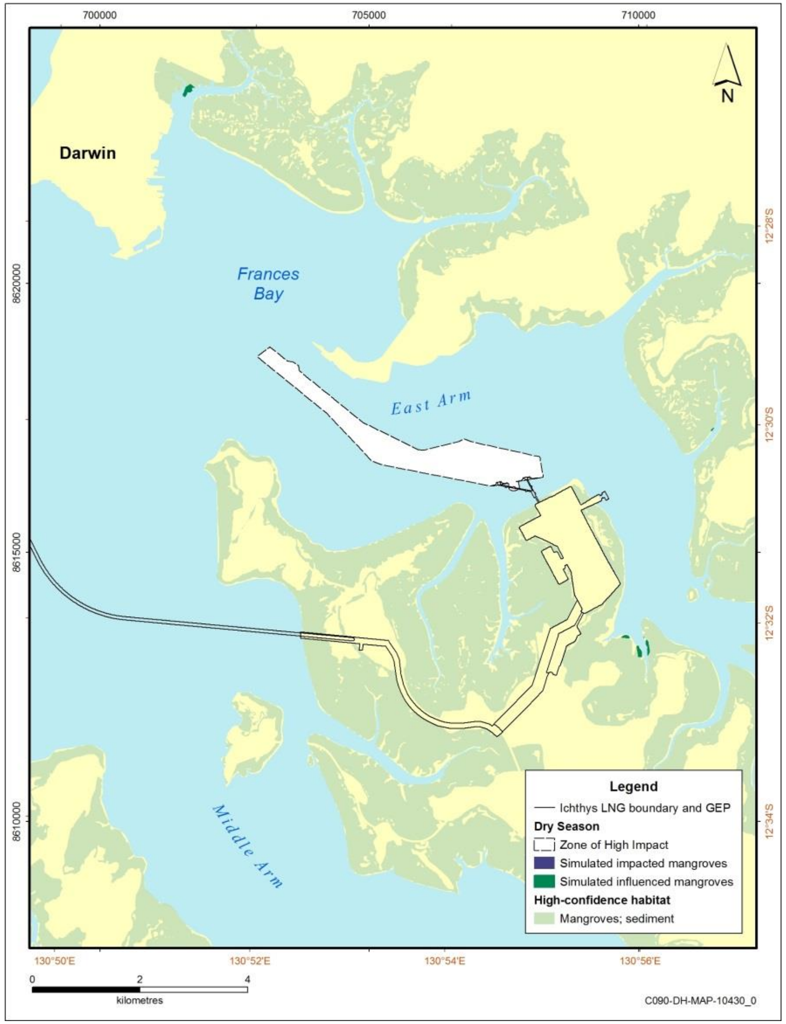


Figure 6-9: Areas of seagrass habitat impacted and influenced by excess SSC and sedimentation based on highest intensity period (SN2; 15 to 29 days) during the dry season (left) and wet season (right)



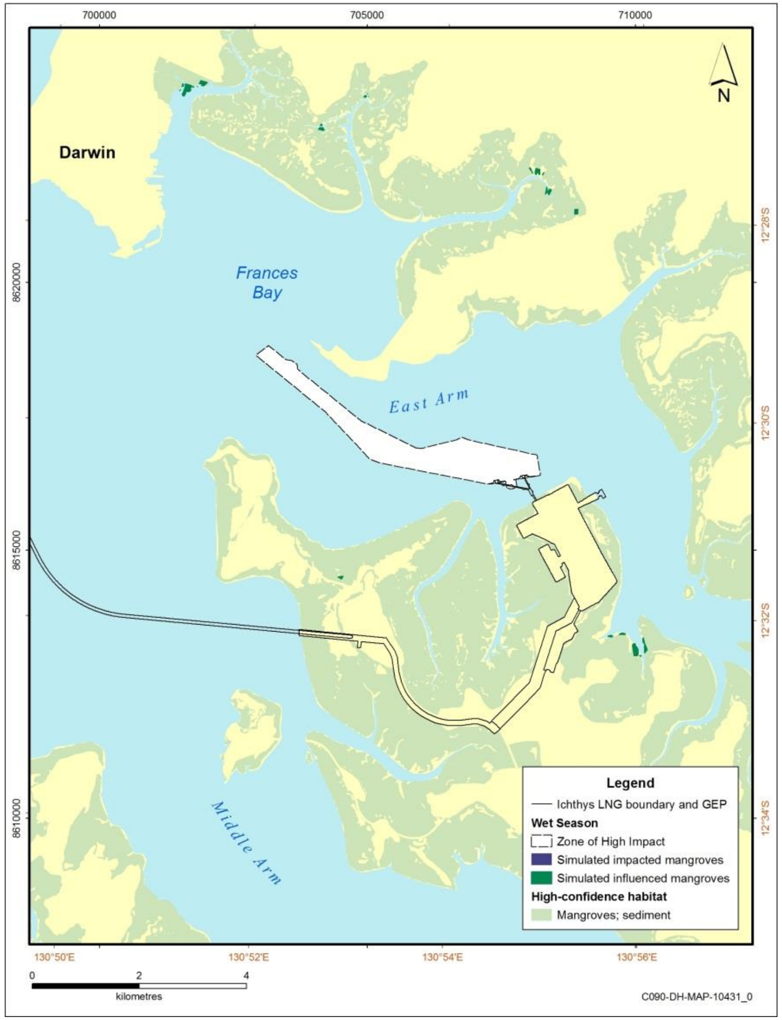


Figure 6-10: Areas of mangrove habitat impacted and influenced by excess sedimentation based on highest intensity period (SN2; 15 to 29 days) during the dry season (left) and wet season (right)

7 Environmental management

The following sections describe the environmental management frameworks (EMFs) that will be implemented to manage specific aspects and activities associated with maintenance dredging, in order to minimise/mitigate the risk to sensitive receptors and protected marine megafauna.

The EMFs have been divided into two specific groups:

- management of sediment-related effects (Section 7.1)
- management of other dredging-related impacts (Section 7.2)

Environmental objectives, targets and indicators have been developed for each EMF in order to demonstrate the effectiveness of controls in minimising impacts. Further, the EMFs have been developed using a standard template to ensure information is presented in a uniform and consistent manner (Table 7-1 and Table 7-2).

Table 7-1: Environmental objectives, targets and indicators template

Objective/s	Target/s	Indicator/s
The overarching environmental goal/s to be achieved.	The performance criteria that must be met in order to achieve the overarching objective/s.	The factor to be measured to assess whether the target/s have been achieved.

Table 7-2: Environmental management framework template

Item	Content
Element	Aspect that requires management.
Management actions	All tasks to be undertaken to meet the objective/s. For example, install turtle deflection chains on TSHD draghead, comply with Darwin Port vessel speed restrictions etc.
Monitoring	Activities that will be performed to monitor the success of meeting the objective/s and target/s or management actions.
Applicable period	Active period of management framework or relevant management plan.

7.1 Management of sediment-related effects

Maintenance dredging and spoil disposal activities have the potential to impact sensitive receptors through elevated suspended sediment (decreasing benthic light) and excessive sedimentation, which can reduce photosynthesis and lead to smothering respectively (Section 5.3.1). This section describes the adaptive management process (Figure 7-1) that will be followed to manage these potential sediment-related effects to sensitive receptors to agreed levels, as described in Section 6.8.

Adaptive management was selected as a management practice (MP M5) applicable to the maintenance dredging based on PIANC 100 (Netzband et al. 2009). Implementation of adaptive management during the execution of a dredging program involves the use of monitoring results in order to systematically learn and adapt. The objective of adaptive management is to use turbidity data to inform changes to the dredging operations to:

- manage the potential sediment-related effects to sensitive receptors to within agreed levels through implementation of a tiered management response consisting of responsive and contingency management practices

- decrease duration of the activity by increasing production in an environmentally responsible manner thereby minimising associated affects to environmental, social and cultural values.

For this Maintenance DSDMP, adaptive management is premised on maintaining or returning within the "desired" state of the environment, which is defined as the water quality envelope below the Level 1 turbidity triggers, as specified in Section 7.1.1. In the event of a Level 1 or 2 trigger exceedance the first step is to determine whether or not the exceedance is attributable to dredging activities, as described in Section7.1.3.

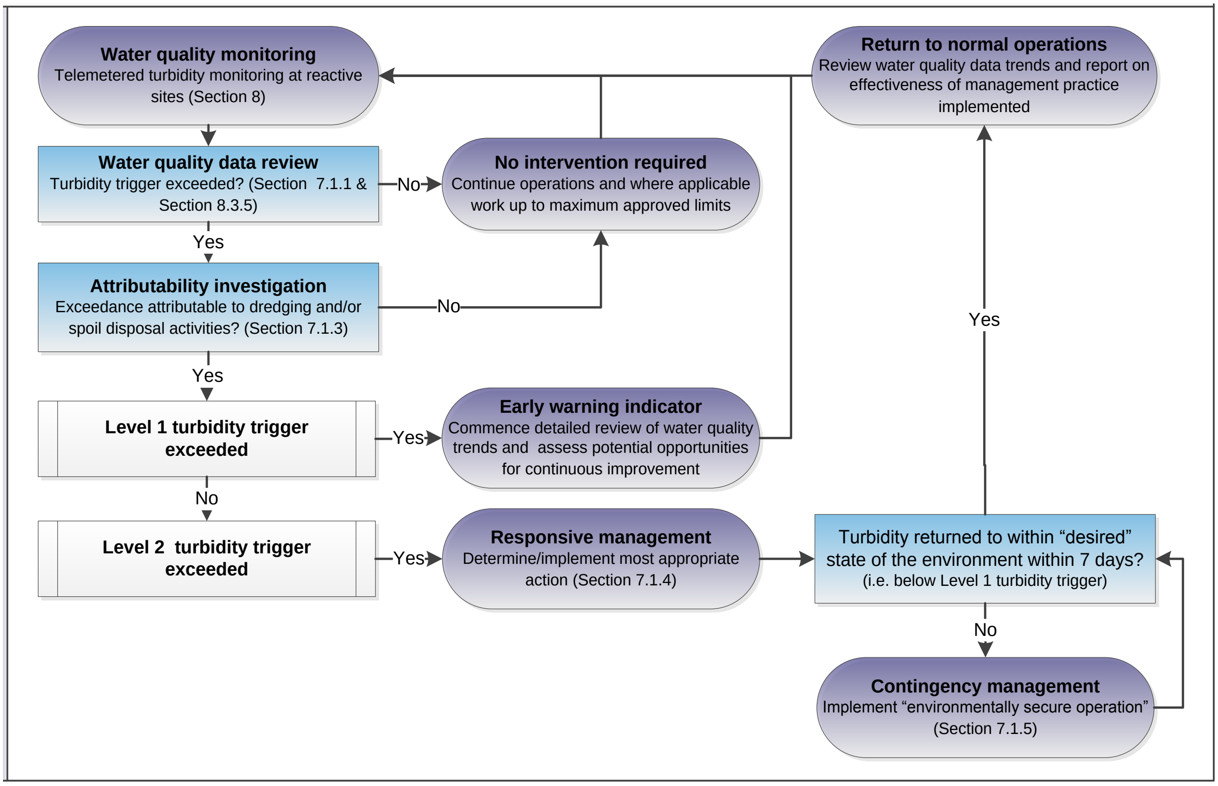


Figure 7-1: Overview of adaptive management process

The use of benthic light (measured as PAR), instead of turbidity, as the management trigger was evaluated for this activity. For the following reasons turbidity was found to remain the most appropriate early warning indicator.

- Light based triggers are in their infancy, while the use of turbidity as an early warning indicator has been tried and tested, and was proven to be an effective way to manage dredging and minimise the potential for impacts on corals and seagrass during the capital dredging program. During the execution, natural and dredging-related exceedances of the Level 1 turbidity triggers were recorded; however there was no recorded mortality to seagrass or coral as a result of Project dredging activities (Cardno 2015d, 2015c). A description of how the triggers have been calculated for this activity is provided in Section 7.1.2.
- Light based triggers are predominantly being recommended for the protection of seagrass habitat, which is not predicted to be impacted based on predictive modelling and associated habitat impact assessment outcomes (see Section 6.8), in addition to experience gathered during the capital dredging program (Section 4.2.3; Cardno 2015d).
- The primary guidance document (Collier et al. 2016) relating to the adoption of light-based management triggers, recommends the development of locally-specific guidelines as these capture inherent site conditions (including tidal exposure).

Results from seagrass monitoring program undertaken during the capital dredging campaign however, suggested that light-based variables (i.e. PAR daily dose) were not the most appropriate metric related to changes in seagrass in the Darwin region (Cardno 2015d). Results indicated that the daily mean turbidity best accounted for changes in seagrass distribution. As such, the use of (site-specific) turbidity as the base metric for the derivation of adaptive management triggers, to protect coral and seagrass, is considered to be appropriate and sound.

7.1.1 Sediment-related effects management framework

The risk-based environmental monitoring and management strategy, including the actions to be implemented are described within the sediment-related impacts management framework (Table 7-3), with the specific turbidity trigger criteria provided in Table 7-4.

The framework is a tiered pressure-response strategy based on turbidity, with escalating management response commensurate with the risk to sensitive receptor communities, namely coral and seagrass. The water quality monitoring program is premised on the use of turbidity as a lead indicator to provide an early warning of water quality deterioration due to dredging activities. This means dredging operations can be proactively managed to prevent or minimise potential ecological effects to within agreed levels, eliminating the need for intensive sensitive receptor monitoring.

The management trigger hierarchy is described below:

1. Level 1 triggers are considered early warning indicators that the water quality conditions are approaching the upper bounds of background conditions naturally experienced by the receptor. In the event of a Level 1 trigger exceedance (attributable to dredging), a detailed review of the water quality trends will be undertaken and potential opportunities for continuous improvement will be assessed.
2. Level 2 triggers represent the upper bound of background conditions naturally experienced by the receptor. In the event of a Level 2 trigger exceedance (attributable to dredging) responsive management of dredging operations must be applied to reduce turbidity to within the desired state of the environment (i.e. below the Level 1 turbidity trigger). Responsive management practice/s can only cease (i.e. return to normal operations) once turbidity returns to below the Level 1 turbidity trigger or once superseded by the implementation of contingency management practice/s.

   In the event that turbidity does not return to within the desired state of the environment within seven days post implementation of responsive management practice/s, then contingency management practice/s must be implemented until such time that turbidity returns to below the Level 1 turbidity trigger. Normal operations can only recommence once turbidity returns to below the Level 1 turbidity trigger.

A description of the reactive monitoring sites, the analysis method and general water quality monitoring information is provided in Section 8.

Table 7-3: Sediment-related effects management framework

Sediment-related effects management framework	
Element	Sediment-related effects
Management actions	• Turbidity data will be reviewed on a daily basis for the purpose of trigger assessment and forecasting of potential future trigger exceedances (Section 8.4.4). • Where turbidity data remains within the desired state of the environment, the Dredging

<table>
<tr><th colspan="2">Sediment-related effects management framework</th></tr>
<tr><td></td><td>Contractor in consultation with INPEX will, where practicable, employ maximum approved operational limits.
• In the event of a trigger exceedance, an attributability investigation will be completed (Section 7.1.2).

In the event of a Level 1 dredging-attributable trigger exceedance:
• INPEX will undertake a detailed review of the water quality data identifying any related trends.
• The Dredging Contractor in consultation with INPEX will assess potential opportunities for continuous improvement.

In the event of a Level 2 dredging-attributable trigger exceedance:
• The Dredging Contractor will in consultation with INPEX:
– select the most appropriate responsive management practice/s (Table 7-5) based on investigation of expected effect
– prepare an implementation plan and procedures, as necessary.
• The Dredging Contractor will seek approval from INPEX with regard to:
– confirmation that implementation of management practice/s is still required
– implementation of selected management practice/s.
• INPEX will inform DENR and DEE of exceedance and actions taken.
• INPEX will review water quality monitoring data to measure the effectiveness of the implemented management practice/s.
• Once turbidity has returned to below Level 1 turbidity trigger, and on approval from INPEX, the Dredging Contractor will return to normal operations (i.e. discontinue responsive management practice/s).
• The Dredging Contractor in consultation with INPEX will prepare a report on the actions taken and effectiveness for further use in the adaptive management processes.

In the event that responsive management practice/s have been implemented; however, turbidity does not return within the desired state of the environment within seven days, the following contingency management will be implemented:
• The Dredging Contractor will in consultation with INPEX:
– go to established operational modes known to reduce impacts below Level 1 triggers (“environmentally secure operation”; Section 7.1.5)
– select most appropriate contingency management practice/s (Table 7-6) based on investigation of the expected effect.
– prepare implementation plan and procedures, as necessary.
• Dredging Contractor will seek approval from INPEX with regard to:
– confirmation that implementation of management practice/s is still required
– implementation of selected management practice/s.
• INPEX to notify DENR and DEE within 24 hours.
• INPEX to demonstrate to DENR and DEE that selected contingency management practices/s are appropriate for mitigation.
• INPEX to review water quality monitoring data to measure the effectiveness of implemented management practice/s.
• Once turbidity has returned to below Level 1 turbidity trigger and on approval from INPEX, the Dredging Contractor will return to normal operations (i.e. discontinue contingency management practice/s).
• Dredging Contractor in consultation with INPEX shall prepare a report on the actions taken and effectiveness for further use in the adaptive management processes.</td></tr>
<tr><td>Monitoring</td><td>• Water quality monitoring (Section 8)
• Audits and health, safety and environment (HSE) inspections (Section 10.6).</td></tr>
<tr><td>Applicable period</td><td>For the duration of dredging and spoil disposal activities.</td></tr>
</table>

Table 7-4: Level 1 and 2 turbidity management trigger criteria for sediment-related effects

Monitoring site	Season	Level 1 trigger (daily average) >intensity value & >duration		Level 2 trigger (daily average) >intensity value & >duration	
		Intensity (95th%ile)	Duration (consecutive days)	Intensity (99th%ile)	Duration (consecutive days)
South Shell Island	Wet season	27 NTU	4 days	35 NTU	1 day
	Dry season	13 NTU	5 days	21 NTU	5 days
Northeast Wickham Point	Wet season	30 NTU	7 days	48 NTU	3 days
	Dry season	14 NTU	3 days	17 NTU	2 days
Fannie Bay*	Dry season	13 NTU	7 days	24 NTU	5 days

*Only applicable where volumes to be dredged are more than 0.25 Mm^3 (refer to Section 8 for more information)

7.1.2 Development of reactive management triggers

Dredge management is typically based on the monitoring of key environmental pressures (i.e. changes in water quality) that are capable of causing adverse biological effects (Jones et al. 2015b). There were no recorded declines in coral and seagrass health attributed to dredging during the capital dredging program. As such ecologically relevant triggers, based on a conclusive link between dredging-induced changes in water quality and sensitive receptors within the Darwin region, could not be derived. As such, the established (conservative) method to setting management triggers based on turbidity adopted for the capital dredging program has been employed, as described below.

The method used to calculate the turbidity triggers is based on the underlying principles described by McArthur et al (2002), which promotes using local data within which to maintain water quality. The approach also recognises that sediment-related effects to sensitive receptors are not only caused by the level of turbidity (i.e. intensity), but more importantly the duration of exposure, in context of natural ranges (McArthur et al. 2002; Jones et al. 2015b). The frequency that background conditions are exceeded is also considered an important aspect by McArthur et al. (2002), while Jones et al. (2015b) further suggests that management triggers should be developed for both acute and chronic events. Due to the relatively short duration of a maintenance dredging campaign (in context of dredge volume), only acute triggers as they relate to intensity and duration were considered relevant to this Maintenance DSDMP.

Learnings from the capital dredging program found significant temporal and spatial variability in turbidity between monitoring sites (Cardno 2015a). As such, no single turbidity value is representative of all sites within and outside of the Harbour. From an ecological perspective, it is also likely that each site has its own characteristics, and elevations in turbidity at one site may be more significant for local receptors than the same turbidity level at another site.

Site-specific management triggers for reactive monitoring sites (Section 8), South Shell Island, Northeast Wickham Point and Fannie Bay have been derived from turbidity data at these respective sites, collected from January 2010 to January 2011 and August 2012 to January 2015. For sites in proximity to the dredge area (i.e. South Shell Island and Northeast Wickham Point), data collected during the capital dredging period, including the reported lag periods following the cessation of dredging (Cardno 2015a), were removed from the analysis, even though no dredging attributable coral mortality was recorded (Cardno 2015c). The entire dataset (i.e. baseline, dredging and post-dredging)

from Fannie Bay monitoring site was used as no dredging attributable elevations in turbidity were reported.

Level 1 and Level 2 turbidity triggers were derived from the recorded daily average turbidity and consist of an intensity value and allowable duration, which both need to be exceeded for a trigger exceedance to occur. For Level 1, the intensity value is represented by the 95th percentile of the daily average turbidity data recorded. For the duration trigger, the dataset was reviewed to determine the number of consecutive days the intensity value was exceeded, which are collectively known as individual events. The 95th percentile was then calculated for the number of individual events, providing an allowable number of consecutive days that the intensity value can be exceeded.

The Level 2 intensity and duration values were derived following the same method, with the exception that the intensity values are represented by the 99th percentile of the daily average turbidity data recorded. For the duration trigger, the dataset was reviewed to determine the number of consecutive days the intensity value (i.e. 99th percentile) was exceeded (i.e. individual events). The 95th percentile was then calculated for the number of individual events, providing an allowable number of consecutive days that the intensity value can be exceeded.

Given the Maintenance DSDMP allows for multiple maintenance dredging campaigns over a nominal five year period, the trigger levels will be reviewed by INPEX on an as needs basis to ensure they remain representative. Noting that a review of the management triggers does not necessitate a revision of the values presented.

7.1.3 Attributability investigation

When a trigger is exceeded (Section 8.4.4), the initial response is to investigate the cause of the exceedance and whether or not it is can be attributed to dredging and/or spoil disposal activities.

The first step is to determine whether or not the data are reliable. If the trigger is a false trigger resulting from data quality issues (e.g. fouling on the sensor), then no action is required. However, to reduce the potential for future false triggers, an investigation into possible improvements in data collection and quality assurance will be undertaken through continuous improvement.

Where the data are considered reliable, the next step in the attributability assessment is to investigate multiple lines of evidence to determine the cause of the exceedance as per ANZECC/ARCMANZ (2000) recommendations. Information considered in the investigation may include:

- recent weather and oceanographic conditions (e.g. tidal phase, wind speed and direction, significant wave height, rainfall and river discharge data)
- site specific water quality data from reactive and informative sites (e.g. turbidity, temperature, light, etc.)
- regional water quality data (e.g. remote sensing imagery)
- sediment characteristics (e.g. particle size distribution)
- location of dredging and spoil disposal activities relative to the monitoring site recording the exceedance (e.g. are sentinel sites recording a deterioration in water quality?).
- nature of recent dredging activities in relation to the onset of the exceedance.

The multiple lines of evidence assessment may reference published scientific literature (where applicable) and utilise tools developed and validated during the capital dredging program. These include:

- hydrodynamic model outputs including the predicted current speeds and direction

- sediment transport model predictions of excess SSC in relation to the nature of recent dredging activities
- empirical turbidity model[16], which predicts daily average background turbidity at water quality monitoring sites based on tide and can explain approximately 80% of the data.

In the event that an exceedance is found to be attributable to dredging activities, the appropriate actions will be identified and initiated. It should be acknowledged, however, that a dredging attributable exceedance does not necessarily result in ecological impact. This is particularly the case for Level 1 exceedances, which are early warning indicators to highlight that turbidity levels are approaching the upper bounds of that naturally experienced. For a Level 2 exceedance, the identification and execution of appropriate responsive or contingency management practices respectively, will consider many factors as described in the following sections.

7.1.4 Responsive management

Responsive management practices will be implemented when a dredging-attributable Level 2 exceedance has occurred. Responsive management practice/s can only cease (i.e. return to normal operations) once turbidity returns to below the Level 1 turbidity trigger or once superseded by the implementation of contingency management practice/s. Table 7-5 summarises the range of options that are considered practical to modify the mass of sediment released during dredging activities.

Not all options will have similar effect in all circumstances and locations, therefore any option implemented will require evaluation and subsequent modification where appropriate. The applicability of all management actions will be interpreted, validated and justified by the Dredging Contractor, and the response approved by INPEX prior to implementation.

Table 7-5: Responsive management practices as adapted from the PIANC 100 Report (Netzband et al. 2009)

Nr	Description	Affects
Dredging options		
RM-D-1	Change location of dredging and/or trailing length	Location of the losses of fines
RM-D-2	Alter dredging direction	Location of the losses of fines
RM-D-3	Adjust overflow time of TSHD	Duration of the losses of fines
RM-D-4	Adjust overflow height	Magnitude of the losses of fines
RM-D-5	Adjust jet water flow velocity	Magnitude of the losses of fines
RM-D-6	Adjust suction flow velocity	Magnitude of the losses of fines
RM-D-7	Adjust TSHD trailing speed	Magnitude of the losses of fines
RM-D-8	Optimise sailing route of TSHD (propeller wash)	Location of the losses of fines
Spoil disposal options		

[16] As originally described in the Water Quality and Subtidal Sedimentation Monitoring Program Baseline Report [L384-AW-REP-10004_1], and updated to include bed shear stress (as appropriate). The empirical model is subject to continuous improvement.

Nr	Description	Affects
RM-S-1	Optimise disposal location within DSDA	Location of the losses of fines
RM-S-2	Adjust timing of disposals in relation to tides	Timing of the losses of fines

7.1.5 Contingency management

Contingency management practices will be applied in the event that turbidity does not return to within the desired state of the environment within seven days following the implementation of responsive management practice/s. In this circumstance, contingency management practices must be implemented until such time that water quality returns to below the Level 1 turbidity trigger. Normal operations can only recommence once turbidity returns to below the Level 1 turbidity trigger. Table 7-6 summarises the range of contingency management options that are considered practical to reduce the mass of sediment released during dredging activities.

The application of contingency management practices means that the dredging process is restarted based upon new management constraints. In the interim while agreement is being sought for suitable contingency management practice/s, dredging will be conducted in an "environmentally secure operation" that markedly reduces the loss of fines by relocating dredges, reducing production rates, restricting overflow or by the temporary suspension of dredging activities.

Contingency management practices will be notified to stakeholders (DENR/DEE) prior to implementation by INPEX. The applicability of all contingency management practices will be interpreted, validated and justified by the Dredging Contractor and approved by INPEX prior to notification to DENR and DEE.

Table 7-6: Contingency management practices as adapted from the PIANC 100 Report (Netzband et al. 2009)

Nr	Description	Affects
Dredging options		
CM-D-1	Tidal operations	Timing of the losses of fines
CM-D-2	Night/day time operations	Timing of the losses of fines
CM-D-3	Limit production	Magnitude of the losses of fines
CM-D-4	Suspend dredging operations	Timing of the losses of fines
Spoil disposal options		
CM-S-1	Optimise placement of coarser over finer material	Magnitude of secondary source

7.2 Management of other dredging aspects

The following sections describe the EMFs in place to manage dredging-related potential impacts other than those relating to sediment. These include management of dredge materials, introduced marine pests, protected marine megafauna, heritage and sacred sites, waste and hydrocarbons and chemicals. Those aspects that were assessed as ALARP or not credible, as described in Section 5, are excluded.

7.2.1 Introduced marine pests management framework

Introduced marine pests are marine biota that are translocated into waters outside their natural geographical distribution range and subsequently settle, survive and threaten the environment, human health and/or economic values.

The import of dredge and auxiliary vessels from overseas locations has the potential to introduce marine pests into Darwin Harbour as a result of the following:

- discharge of high-risk ballast water[17]
- presence of biofouling on external wet areas and in internal seawater systems.

Management actions have been identified and will be implemented to minimise the potential for marine pests to be introduced into Darwin Harbour as a result of importing dredge and auxiliary vessels from overseas locations. These management approaches were also adopted during the capital dredging program, during which no incursions of marine pests associated with the import of Project vessels were identified.

The objectives, targets and indicators for management of introduced marine pests are described in Table 7-7. The management actions to be implemented to assist in achieving these are described within the introduced marine pest management framework in Table 7-8.

Table 7-7: Introduced marine pest objectives, targets and indicators

Objective(s)	Target(s)	Indicators
Minimise the risk of introducing marine pests into Darwin Harbour and at the DSDA	All ballast water discharges are managed in accordance with the *Biosecurity Act 2015* and the Australian Ballast Water Management Requirements, Version 7 (DAWR 2017)	• Vessel ballast water management records • Vessel audits
	All vessels mobilised from outside Australia will complete a vessel biofouling risk assessment and/or implement mitigation measures commensurate with the level of risk prior to the commencement of activity	• Vessel pre-mobilisation audits • Vessel biofouling risk assessment or inspection report • Vessel biofouling log book

Table 7-8: Introduced marine pest management framework

Introduced marine pest management framework	
Element	Introduced marine pests
Management actions	• The Dredging Contractor will implement the requirements of the biofouling management process outlined in Figure 7-2 for all vessels mobilised from outside Australia. • The Dredging Contractor will ensure the processes described in Section: Introduced marine pests—vessel biofouling risk assessment, are implemented. These include, but not limited to, the following: – All dredge vessels mobilised from outside Australia will complete a biofouling vessel risk assessment and/or implement mitigation measures commensurate with the level of risk. – Biofouling risk assessments will be undertaken by a suitably qualified biofouling inspector. – A report of the outcomes of the biofouling risk assessment or inspection and records

[17] As defined by the Australian Ballast Water Management Requirements, Version 7 (DAWR 2017)

Introduced marine pest management framework	
	of any implemented mitigation measures will be maintained. • The Dredging Contractor will maintain a biofouling record book in accordance with the International Maritime Organization biofouling guidelines[18]. • The Dredging Contractor will ensure all dredge vessels have an antifouling coating applied that is in accordance with the *Protection of the Sea (Harmful Antifouling Systems) Act 2006* (Cwlth). • The Dredging Contractor will comply with the requirements of the *Biosecurity Act 2015* and the Australian Ballast Water Management Requirements, Version 7 (DAWR 2017). • The Dredging Contractor will maintain a ballast water management records on board the dredge vessel in accordance with the IMO Ballast Water Management Convention[19] (IMO 2009).
Monitoring	Pre-mobilisation audits will be used to assess compliance (Section 10.6).
Applicable period	Mobilisation of the dredge vessels and for the duration of dredging and spoil disposal activities.

[18] International Maritime Organization. 2012. *Guidelines for the control and management of ships' biofouling to minimize the transfer of invasive aquatic species*. International Maritime Organization, London, United Kingdom.

[19] International Maritime Organization. 2009. Ballast Water Management Convention and the guidelines for its implementation. International Maritime Organization, London, United Kingdom.

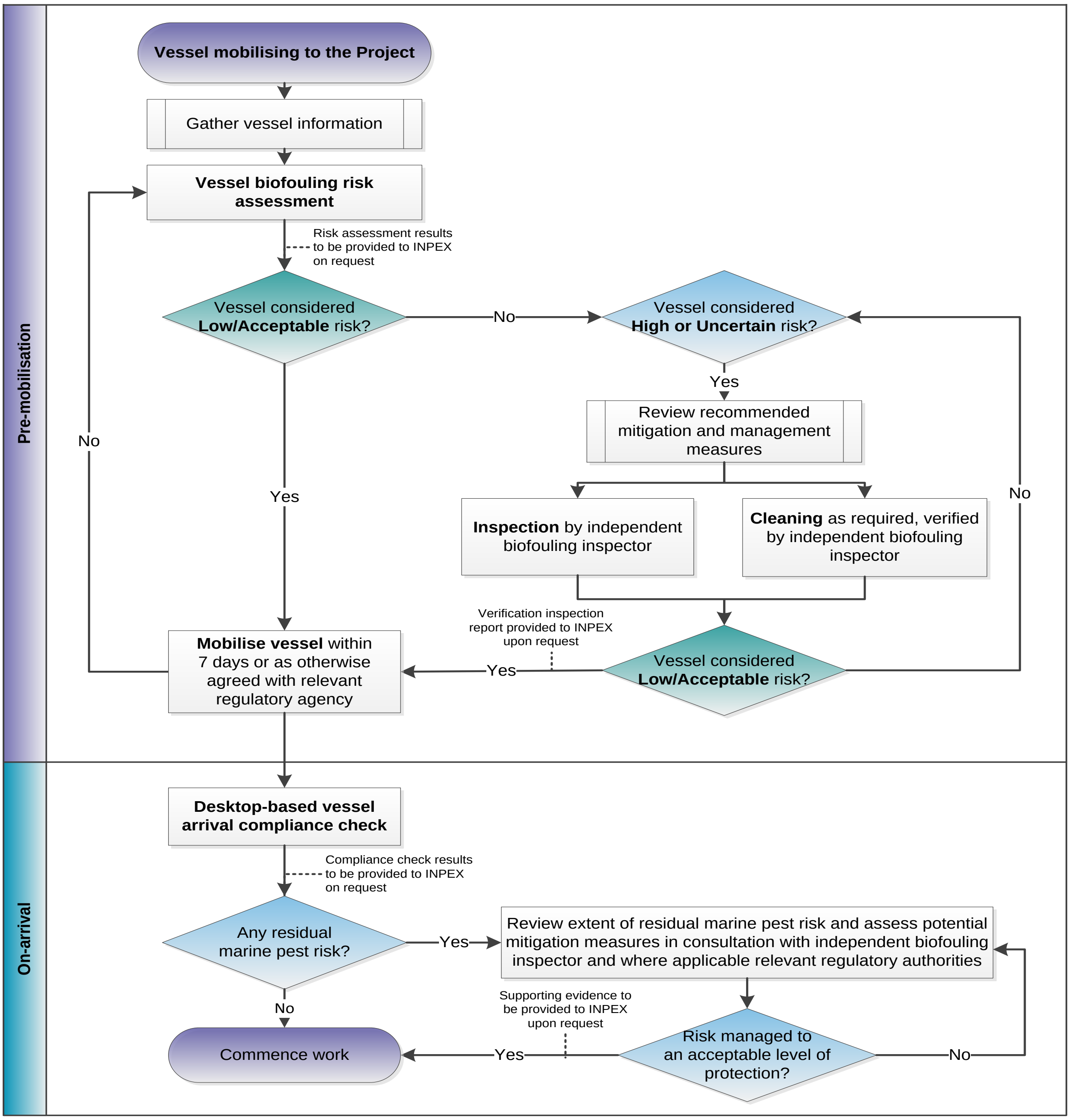


Figure 7-2: Biofouling management for dredge vessels mobilising from outside Australia

Introduced marine pests—vessel biofouling risk assessment

A biofouling risk assessment is a desktop based evaluation to determine the likelihood, and hence theoretical risk of a vessel acting as a vector for the transfer of marine pests into Australian territorial seas. It does not attempt to identify whether or not a vessel is actually carrying a pest species, but rather ranks vessels on a relative scale of High, Uncertain or Low/Acceptable risk, to isolate which vessels may require further detailed investigation and/or management actions to reduce potential risk.

An independent biofouling inspector[20] will be engaged by the Dredging Contractor to undertake the following tasks where applicable.

[20] Independent biofouling inspectors are suitably qualified personnel, as determined by Western Australian Department of Fisheries, experienced with biofouling and the associated marine pest risks.

- Complete biofouling risk assessments for vessels mobilising from overseas locations and in particular, any complex voyages where multiple risk factors need to be considered (e.g. multiple stopovers, complex structures, etc.).
- Where the risk assessment concludes a High or Uncertain risk, conduct inspections to determine the presence/absence of marine pests of concern and hence the actual risk of the vessel acting as a vector for marine pest translocation. Where required provide recommended mitigation measures, that once implemented are likely to reduce the biofouling risk to Low/Acceptable level.
- Supervise any remedial actions (e.g. cleaning) if marine pests are observed and where required, verify (e.g. by inspection) that the recommended mitigation measures have been executed as required to ensure the residual biosecurity risk is Low/Acceptable.

The independent biofouling inspector should provide a written report to the Dredging Contractor that can be forwarded to INPEX upon request. The inspection report should be presented as a stand-alone report, and include all of the information in the risk assessment report, in addition to specific information as relevant to the inspection phase (i.e. survey method, cleaning method, etc.). Representative photographs should be provided for relevant features such as niche areas, fouling or areas of damage or absent anti-fouling coating as evidence.

The biofouling risk assessment and any associated mitigation measures are to be undertaken prior to mobilisation of the dredge vessel from an overseas location.

7.2.2 Dredge materials management framework

Mismanagement of dredge materials such as inadvertently undertaking dredging outside the existing dredge area or disposal of dredged material outside of the DSDA has the potential to impact on:

- sensitive receptor habitats through removal or smothering
- shipping navigation.

Management actions have been identified and will be implemented to minimise the potential for dredging and disposal activities to occur outside designated areas.

The objectives, targets and indicators for management of dredged materials are described in Table 7-9. The management actions to be implemented to assist in achieving these are described within the dredge material management framework in Table 7-10.

Table 7-9: Dredge materials objectives, targets and indicators

Objective(s)	Target(s)	Indicator(s)
Avoid disturbance to habitats outside of the maintenance dredging area	• No dredging to occur outside of the boundaries of the dredge area	• Hydrographic surveys • Dredge log files
Minimise, as far as practicable, the magnitude and spatial distribution of suspended sediment plumes through dredge methods	• Overflow time not to exceed 60 min • Overflow height not to exceed 0.5 m	• Dredge log files
Manage the spoil disposal activities at the DSDA to minimise potential environmental impacts to adjacent areas	• All dredge spoil to be disposed of within the boundaries of the DSDA	• Maintain records of disposal locations within the DSDA • Hydrographic surveys • Dredge log files
Avoid disturbance of navigation and shipping activities in East Arm and	• Communications to be maintained with Harbour	• Records of notifications

Objective(s)	Target(s)	Indicator(s)
at the DSDA	Master to minimise disruptions to shipping activities	
	• Dredge spoil height not to exceed the maximum deposition heights agreed with the Department of Transport (NT)	• Hydrographic surveys

Table 7-10: Dredge materials management framework

Dredge materials management framework	
Element	Dredging, transport and disposal of dredged material.
Management actions	• The Dredging Contractor will establish clear communication with the Darwin Port concerning: – safety zones around the dredges and/or the dredge areas – dredging operations, locations, schedule and any associated amendments – shipping traffic schedules (Project-related and other traffic in Darwin Harbour) – communication with other marine traffic ("Notices to Mariners", radio contact, etc.). • The Dredge Vessel Master will establish that the position of the dredge vessel is within the dredge area using Differential Global Positioning System (DGPS) prior to commencement of dredging. • The Dredge Vessel Master will establish that the position of the dredge vessel is within the DSDA prior to disposal using DGPS. • The Dredging Vessel Master will ensure the height of disposed dredged material does not exceed the maximum deposition heights agreed with the Department of Transport (NT). • The Dredge Vessel Master will adhere to vessel speeds below 3 knots during spoil disposal operations. • The Dredge Vessel Master will comply with Darwin Port vessel speed restrictions when operating in Darwin Harbour. • Specified crew member(s) will complete opportunistic qualitative visual observations of the extent of the dredging-related surface sediment plume (if present), during daylight hours. • The Seabed Leveller Vessel Master will establish that the position of the vessel is within the dredge area using DGPS prior to commencement of seabed levelling activities.
Monitoring	• The Dredging Contractor will as a minimum undertake a hydrographic survey of dredge area and DSDA prior to the commencement of dredging, and following the cessation of dredging activities. • The hydrographic survey of the dredge area will include a 200 m buffer and will be performed to Class A criteria. • The hydrographic survey of the DSDA will be of the area used, including a 500 m buffer and will be performed to Class B criteria. • Audits and HSE inspections (Section 10.6).
Applicable period	For the duration of dredging and spoil disposal activities.

7.2.3 Protected marine megafauna management frameworks

As described in Section 4.3, there are a number of protected marine megafauna, which inhabit or occasionally frequent the waters surrounding Darwin Harbour.

Dredge and auxiliary vessels movements and maintenance dredging and spoil disposal activities pose a potential risk to these species through vessel interaction (collision and

impact), accidental entrainment in TSHD dredge equipment, as well as through the effects of increased turbidity and sedimentation on foraging areas (habitat).

The sediment-related effects described above are managed under the EMF presented in Section 7.1, with impacts resulting from vessel interactions and entrainment managed under EMFs described in the following sections. In context of the EMFs, protected marine megafauna includes whales, dolphins, dugongs, marine turtles and sawfish.

Protected marine megafauna—whale, dolphin, dugong and turtle interaction (vessel collision)

Interaction with sailing dredge vessels poses a potential risk to protected marine megafauna, specifically whale, dolphin, dugong and turtle species. Management actions have been identified and will be implemented to minimise the potential for injury or mortality of protected marine megafauna as a result of interactions with sailing dredge vessels. These management approaches were also adopted during the capital dredging program, during which there were no incidences of Project-related vessel collisions with protected marine megafauna.

The objectives, targets and indicators for management of dredge vessel interactions with protected marine megafauna are described in Table 7-11. The management actions to be implemented to assist in achieving these are described within the protected marine species—dredge vessel interactions management framework in Table 7-12.

Table 7-11: Protected marine megafauna—whale, dolphin, dugong and turtle interaction objectives, targets and indicators

Objective(s)	Target(s)	Indicator(s)
Avoid or minimise the risk of injury to or mortality of protected marine megafauna	Compliance with observation and exclusion zones during dredging and dredge disposal activities	• Records of sightings of live, injured or deceased protected marine megafauna
	No incidents of vessel strikes during transit of dredge and support vessels	• Incident reporting
Establish and maintain awareness of the importance of avoiding interaction with protected marine megafauna	All relevant dredge vessel masters will be trained in protected marine megafauna interaction procedures	• Number of trained vessel masters on interaction procedures
	As a minimum, one crew member trained as a Marine Megafauna Observer (MMO) to be on duty during daylight operations above deck with good visibility	• Number of crew members trained as MMOs • Records of on-duty MMOs
	100% of dredge and support vessel personnel to complete a HSEQ induction, which includes information on protected marine megafauna and their management	• Percentage of personnel completing a HSEQ site induction

Table 7-12: Protected marine megafauna—whale, dolphin, dugong and turtle interaction management framework

Protected marine megafauna: whale, dolphin, dugong and turtle interaction management framework	
Element	Dredge and support vessel interaction with whales, dolphins, dugongs and turtle species
Management	• All dredge and support vessel personnel will complete a Contractor HSEQ induction,

Protected marine megafauna: whale, dolphin, dugong and turtle interaction management framework	
actions	which will include information on protected marine megafauna management. • Dredge Vessel Masters and specified crew members will be trained as MMOs and the marine megafauna vessel interaction procedures. • When vessels are transiting to or from the DSDA or dredge area, the dredge and support vessel masters will comply with the approach distances outlined in the *Australian National Guidelines for Whale and Dolphin Watching 2005* (DEH 2005), as far as reasonably practicable. The approach distances for dolphins will also be applied for dugongs (refer to Figure 7-3). • The Dredge Vessel Master and MMOs will implement the marine megafauna management procedure described in Figure 7-4, when undertaking dredging within the dredge area or disposal activities within the DSDA. • During dredging and spoil disposal activities the following observation and exclusion zones for protected marine megafauna will be implemented and monitored by a MMO: – whales: observation zone 300 m; exclusion zone 100 m – dolphins: observation zone 150 m; exclusion zone 50 m – dugongs: observation zone 150 m; exclusion zone 50 m – turtles: observation zone 100 m; exclusion zone 50 m. • During daylight hours, the MMO will undertake a visual assessment of marine megafauna observation or exclusion zones (as applicable) prior to and during dredging and spoil disposal activities. • In the event that the MMO is unable to confirm the departure of marine megafauna from observation or exclusion zones due to failing light, then the MMO will utilise vessel searchlights and/or hand held spotlights to confirm the departure from zones. • The MMO will maintain a lookout for stranded, injured or deceased marine megafauna during dredging and spoil disposal activities. • The MMO and dredge and support vessel masters will report sightings of deceased or injured marine megafauna to Marine WildWatch (NT). • The Dredge Vessel Master will ensure the vessels operates at "no wash speed" when marine megafauna are approaching the observation zone. • The Dredge Vessel Master will adhere to vessel speeds below 3 knots during disposal operation. • Dredge and support vessel masters will comply with Darwin Port vessel speed restrictions when operating in Darwin Harbour. • Dredge and support vessel masters will not intentionally approach marine megafauna for the purpose of casual viewing and no marine megafauna will be fed and/or touched by crew members.
Monitoring	• Marine fauna observations. • Audits and HSE inspections (Section 10.6).
Applicable period	For the duration of dredging and spoil disposal activities.

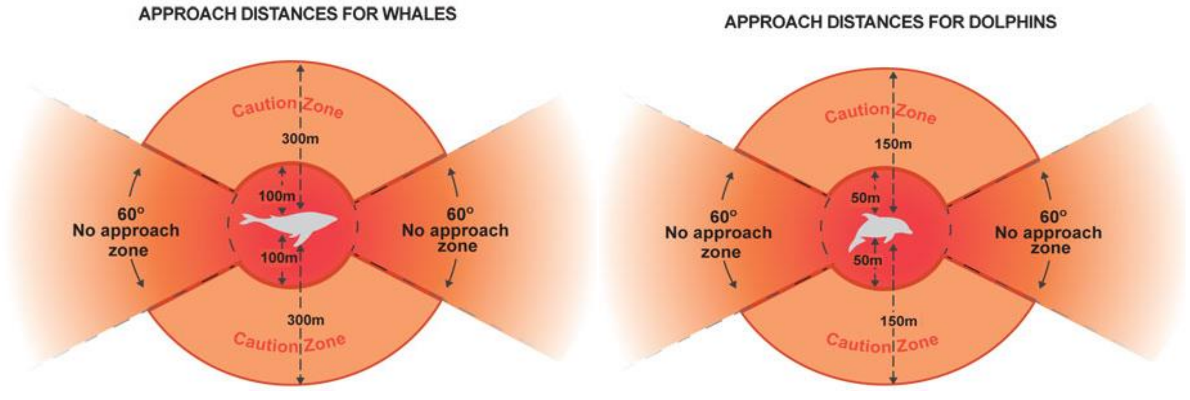


Figure 7-3: Vessel approach distances applicable for whales, dolphins and dugongs

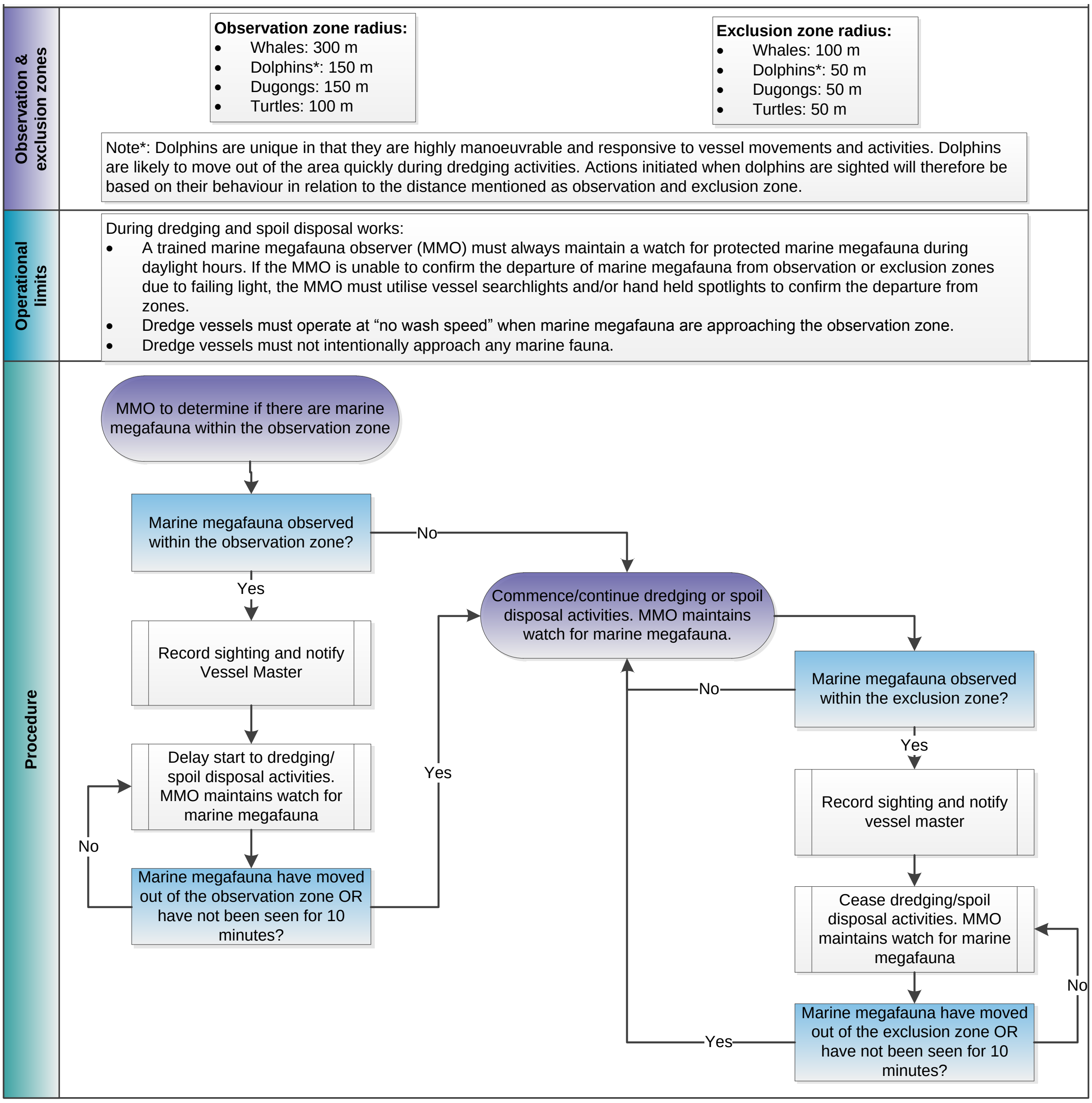


Figure 7-4: Protected marine megafauna—management of whale, dolphin, dugong and turtle interactions during dredging and spoil disposal activities

Protected marine megafauna—marine turtles and sawfish entrainment

There is the potential for marine turtles or sawfish to become entrained during the operation of the TSHD draghead. Management actions have been identified and will be implemented to minimise the potential for injury to or mortality of marine turtles and sawfish as a result entrainment. These management approaches were also adopted during the capital dredging program, during which there were no incidences of entrainment of turtle or sawfish through the TSHD draghead.

The objectives, targets and indicators for management of entrainment of marine turtles and sawfish are described in Table 7-13. The management actions to be implemented to assist in achieving these are described within the protected marine megafauna—marine turtle and sawfish entrainment management framework in Table 7-14.

Table 7-13: Protected marine megafauna—marine turtle and sawfish entrainment objectives, targets and indicators

Objective(s)	Target(s)	Indicator(s)
Minimise the risk of entrainment of turtles and sawfish during dredging and spoil disposal activities	No incidents of entrained turtle and sawfish	• Incident reporting of entrained turtle and sawfish
Establish and maintain awareness of the importance of avoiding interaction with protected marine megafauna.	100% of dredging personnel to complete a HSEQ induction, including protected marine megafauna awareness of interaction procedures	• Percentage of personnel completing a HSEQ site induction

Table 7-14: Protected marine megafauna—marine turtle and sawfish entrainment management framework

Protected marine megafauna: marine turtle and sawfish entrainment management framework	
Element	Entrainment of protected marine turtles and sawfish in dredge equipment
Management actions	• All Dredge Vessel Personnel will complete a Contractor HSEQ induction, which will include information on protected marine megafauna management. • The Dredging Contractor will ensure turtle protection chains are installed on draghead/s of the dredge vessel. • Dredge Vessel Masters and specified crew members will be trained as MMOs and the whale, dolphin, dugong and marine turtle interaction procedure. • The Dredge Vessel Master and MMOs will implement the marine megafauna management procedure described in Figure 7-4 during dredging and dredge disposal activities. • The Dredge Vessel Master or delegate will ensure that TSHD pumps are only started when the draghead is as close as practicable to the seabed. The operation of the TSHD pumps will cease as soon as possible after the completion of dredging (refer to TSHD pump procedure shown in Figure 7-5). • The Dredging Contractor will ensure screens are installed and maintained on the overflow to assist in the identification of any marine turtle or sawfish entrainment. • The Dredge Work Supervisor will ensure overflow screens are inspected after every loading cycle to determine the presence of any entrained turtles or sawfish. • The Dredge Work Supervisor will immediately contact Marine WildWatch (NT) in the event of discovery of an entrained turtle or sawfish. • Dredge personnel will not touch or handle live, injured or deceased marine megafauna unless directed to do so by Marine WildWatch (NT) and on advice from the INPEX Client Representative.
Monitoring	• Marine fauna observations. • Audits and HSE inspections (Section 10.6).
Applicable period	For the duration of dredging activities.

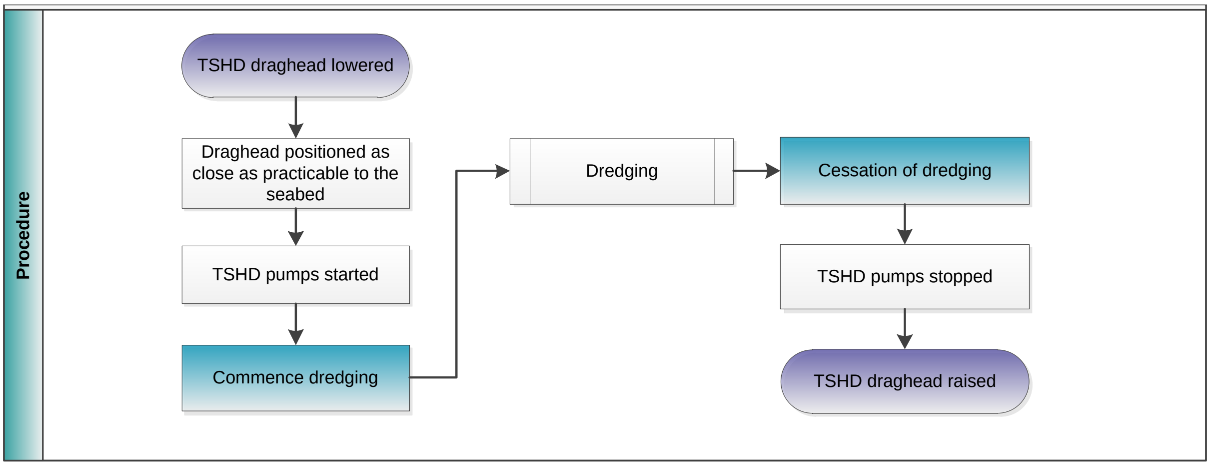


Figure 7-5: TSHD pump operation procedure

7.2.4 Heritage and sacred site management framework

As described in Section 4.5, there are a number of Aboriginal sacred sites and non-Aboriginal heritage sites located in Darwin Harbour within the vicinity of the nearshore maintenance dredging area and on route to the DSDA.

Movement or anchoring of dredge and support vessels over or on heritage or sacred sites has the potential to result in accident disturbance or damage to sites. Management actions have been identified and will be implemented to minimise the potential for accidental disturbance or damage to heritage and sacred sites.

The objectives, targets and indicators for sacred site and heritage management are shown in Table 7-15. The management actions implemented to assist in achieving these targets described within the heritage and sacred site management framework shown in Table 7-16.

Table 7-15: Heritage and sacred site objectives, targets and indicators

Objective(s)	Target(s)	Indicator(s)
Comply with the requirements of heritage wreck site protection zones (both INPEX and regulatory) and conditions stipulated within relevant AAPA authority certificates	No breaches of the requirements of heritage wreck site protection zones or restricted work areas identified within relevant AAPA authority certificates	• Review vessel track plots against heritage wreck site protection zones and AAPA restricted work areas • Incident reporting
Establish and maintain personnel awareness of the importance of Aboriginal and non-Aboriginal cultural values of Darwin Harbour and their management	100% of dredge and support vessel personnel to complete a HSEQ induction, which includes information on the values of sacred sites and heritage sites, and their management	• Percentage of personnel completing an HSEQ site induction

Table 7-16: Heritage and sacred site management framework

Heritage and sacred site management framework	
Element	Damage or disturbance to heritage sites or Aboriginal sacred sites.
Management actions	• All dredge and support vessel personnel will complete a Contractor HSEQ induction, which will include information on heritage and sacred site management. • Dredge and support vessel masters will comply with the requirements of INPEX's heritage management plans. • INPEX will ensure copies of AAPA authority certificates (C2011/166, C2012/138 and

Heritage and sacred site management framework	
	C2014/007) and sacred site data files (GPS coordinates) are provided to the dredging contractor and support vessel (including monitoring consultant) for inclusion in appropriate vessel navigation systems. If these systems are not available or compatible on a vessel, these are to be maintained on portable hand held devices on board the vessel. • Dredge and support vessel masters will comply with the requirements of all relevant AAPA authority certificates. • INPEX will establish Project no anchor or exclusion zones around heritage wreck sites (refer to Appendix C). Dredge and Monitoring Vessel Masters will comply with the requirements of all heritage wreck site protection zones. • INPEX will provide heritage wreck site protection zone data files (GPS coordinates) to the Dredging Contractor and support vessel (including monitoring consultant) for inclusion in vessel navigation systems. If these systems are not available on a vessel, these are to be maintained on portable hand held devices on board the vessel. • For heritage wreck sites located directly adjacent to dredging activities, the Dredge Vessel Master will ensure buffer distances are established around heritage protection zones within on board vessel navigation systems. This will include an early warning alarm that is activated upon entry into the buffer zone and a secondary alarm upon entry into the heritage protection zone. • If works are required within a sacred site or heritage protection zone (other than those allowed for) the Dredging Contractor must notify INPEX whom will consult with the relevant regulators with regard to the approvals require. No works can commence until regulatory approval is granted. • The Dredge Work Supervisor will immediately report the discovery of a potential heritage object to the Dredge Vessel Master and INPEX Client Representative, and implement the procedure outlined in Section: Heritage—Discovery of previously unidentified objects. • The INPEX Client Representative will notify the Northern Territory Department of Tourism and Culture—Heritage Branch (Heritage Branch) upon discovery of potential heritage object. • The INPEX Client Representative will maintain records of all potential heritage objects within a chance finds register.
Monitoring	• Dredge, support and monitoring vessel track plots will be monitored against heritage protection zones and AAPA restricted work areas during maintenance dredging and monitoring activities. • Audits and HSE inspections (Section 10.6).
Applicable period	For the duration of the maintenance dredging campaign and monitoring activities.

Heritage—Discovery of previously unidentified objects

As described in Section 4.5.2, INPEX undertook an extensive heritage survey and removal/relocation program within the proposed dredge area prior to the commencement of the capital dredging program. Whilst it is highly unlikely, given the extent of this program, it is possible that previously unidentified heritage objects may be discovered during the course of maintenance dredging.

The procedure to be implemented in the event that an object is recovered from the dredge head, hose, pump, chute, or found floating at the rear of the dredge vessel is shown in Figure 7-6.

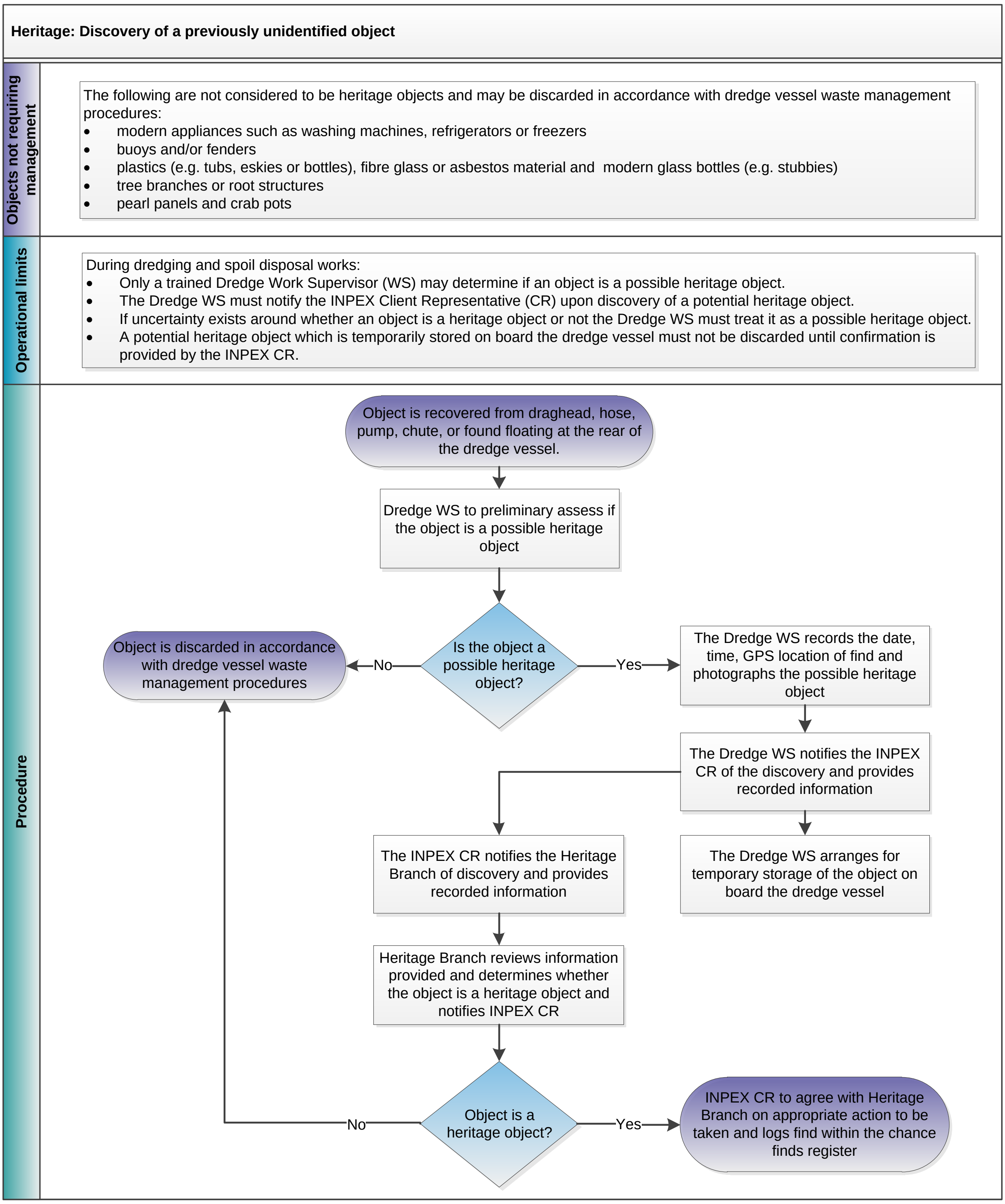


Figure 7-6: Heritage—Discovery of previously unidentified object

7.2.5 Waste and liquid discharges management framework

During the dredging and spoil disposal activities, waste and liquid discharges will be generated as result of routine vessel activities. Mismanagement of waste and liquid discharges has the potential to result in injury to or mortality of marine fauna as a result of ingestion or entanglement, or pollution to the marine environment. Management actions have been identified and will be implemented to minimise the potential impacts resulting from mismanagement of waste and liquid discharges during maintenance dredging and spoil disposal activities.

The objectives, targets and indicators for management of dredge vessel waste and liquid discharges are described in Table 7-17. The management actions to be implemented to assist in achieving these are described within the waste and liquid discharge management framework in Table 7-18.

Table 7-17: Waste and liquid discharges objectives, targets and indicators

Objective(s)	**Target(s)**	**Indicator(s)**
Prevent environmental impacts from waste and liquid discharges generated during maintenance dredging operations	All solid (except recyclables) and hydrocarbon wastes disposed of onshore at approved facilities. This excludes food scraps.	• Audit of waste management processes • Incident reporting
	All vessel discharges (with exception of sewage) will be managed in accordance with the *Marine Pollution Act* (NT) and the intent of MARPOL 73/78	• Audit of waste and liquid discharges management processes • Incident reporting
	Discharge of sewage will be managed in accordance with the intent of MARPOL 73/78	• Audit of waste and liquid discharges management processes • Incident reporting
	Correct separation of hazardous and non-hazardous waste streams	• Audit of waste management processes
	No environmental incidents resulting from mismanagement of waste or liquid discharges	• Incident reporting
Establish and maintain awareness of the importance of good waste management and liquid discharge practices	100% of dredge vessel personnel to complete a HSEQ induction, which includes information on waste and liquid discharges management practices	• Percentage of personnel completing an HSEQ site induction

Table 7-18: Waste and liquid discharges management framework

Waste and liquid discharges management framework	
Element	Generation of waste and liquid discharges on dredge vessels
Management actions	• All Dredge Vessel Personnel will complete a Contractor HSEQ induction, which will include information on waste management and liquid discharge practices. • INPEX and the Dredging Contractor will ensure waste minimisation will be included in procurement and contracting processes. • The Dredging Contractor will ensure responsible waste management will be accomplished through the application of practices outlined in the waste management hierarchy—from source reduction, reuse, recycling, recovery and treatment to responsible disposal. • The Dredging Contractor will ensure a sufficient number of waste receptacles are provided for on the dredge vessel to allow for appropriate waste segregation. Waste

Waste and liquid discharges management framework	
	receptacles will be fit for purpose, covered and seafastened (where applicable). • The Dredging Contractor will ensure that only approved and licensed waste contractors are engaged for the transport and disposal of vessel waste. • The Dredging Contractor will ensure the dredge vessel (where applicable) has a current International Sewage Pollution Prevention Certificate or similar issued by the Country or State of registration. • The Dredging Contractor will ensure the dredge vessel (where applicable) has a current International Oil Pollution Prevention Certificate or similar issued by the Country or State of registration. • The Dredge Vessel Master will ensure chemicals and hazardous waste stored on board the dredge vessel are segregated from other waste types. These will be clearly labelled, stored, transported and disposed of in accordance with relevant material safety data sheets and regulatory requirements. • The Dredge Vessel Master will ensure that oily water discharges from vessel bilge systems are managed and recorded, in accordance with the Marine Pollution Act (NT) and subordinate regulations, and the intent of MARPOL 73/78, Annex I. • The Dredge Vessel Master will ensure food scraps are managed in accordance with the Marine Pollution Act (NT) and subordinate regulations, and the intent of MARPOL 73/78, Annex V. Specifically, the following will apply: – Food scraps which have been comminuted/ground to a particle size <25 mm will only be discharged while the vessel is en route and ≥3 nm from the nearest land (refer to Figure 7-7). – Food scraps, which have not been comminuted or ground will only be discharged while the vessel is en route and ≥12 nm from the nearest land. • The Dredge Vessel Master will ensure sewage discharges are managed in accordance with the intent of MARPOL 73/78, Annex IV and in accordance with the following: – Treated sewage will only be discharged while the vessel is en route and is ≥3 nm from the nearest land (refer to Figure 7-7). – All untreated sewage will be discharged to an approved licenced onshore premises for treatment. • The Dredge Vessel Master will ensure that wastes, • The Dredge Vessel Master will maintain vessel garbage logs and waste receipts (including sewage receipts) on board in accordance with MARPOL 73/78. • The Dredge Vessel Master will maintain records of listed wastes in accordance with the *Waste Management and Pollution Control Act* (NT). • All Dredge Vessel Personnel will implement general "good housekeeping" practices on board the dredge vessel to ensure there is no accumulation of waste materials and wastes are appropriately stored.
Monitoring	Audits and HSE inspections will be used to assess compliance (Section 10.6).
Applicable period	For the duration of dredging and spoil disposal activities.

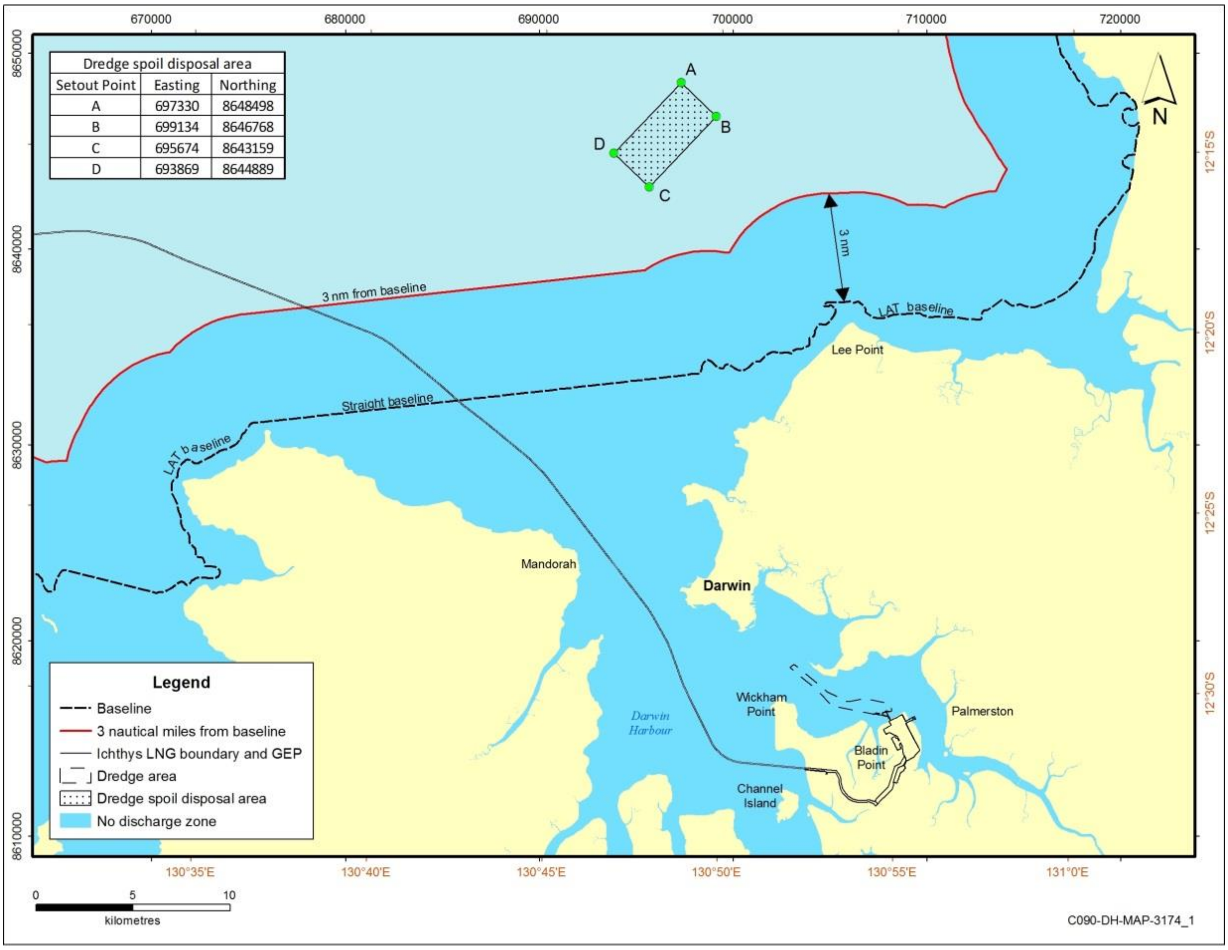


Figure 7-7: 3 nm from NT coastline

7.2.6 Hydrocarbon and chemical management and spill response framework

During the dredging and spoil disposal activities, mismanagement of chemicals and hydrocarbons has the potential to result in pollution to the marine environment. Further, a spill resulting from a vessel refuelling incident may result in exposure of moderate areas of nearshore waters to oil or localised impacts to mangroves and intertidal communities. Management actions have been identified and will be implemented to minimise the potential impacts resulting from mismanagement of hydrocarbons and chemicals, and spill events during maintenance dredging and spoil disposal activities.

The objectives, targets and indicators for management of hydrocarbons and chemicals, and response to spill events are described in Table 7-19. The management actions to be implemented to assist in achieving these are described within the hydrocarbon and chemical management framework in Table 7-20.

Table 7-19: Hydrocarbon and chemical management and spill response objectives, targets and indicators

Objective(s)	Target(s)	Indicator(s)
Minimise the potential environmental impact from the use, transport and storage of hydrocarbons and chemicals	All chemicals used in the activity are subject to an assessment of suitability in accordance with INPEX requirements.	• Records of chemical assessment and approval for use
	No incidents resulting in an environmental impact during the delivery, transport and storage of	• Incident reporting

Objective(s)	Target(s)	Indicator(s)
	hydrocarbons and chemicals	
	Compliance with MARPOL 73/78 Annex I requirements (as applicable to vessel class and size)	• Pre-start audit of spill preparedness including vessel SOPEP
Establish and maintain awareness of the importance of good hydrocarbon and chemical management and response practices	All dredge and support vessel personnel to complete a HSEQ induction, which includes information on hydrocarbon and chemical management and spill response practices	• Percentage of personnel completing an HSEQ site induction

Table 7-20: Hydrocarbon and chemicals management and spill response framework

Hydrocarbon and chemicals management and spill response framework	
Element	Hydrocarbon and chemicals management and spill response
Management actions	• All dredge and support vessel personnel will complete a Contractor HSEQ induction, which will include information on hydrocarbon and chemical management and spill response practices. • The Dredging Contractor will develop an HSEQ management plan (or similar) which will describe oil spill preparedness and response and interfaces with INPEX oil spill emergency response plans. This will be vetted and approved by INPEX prior to commencement of a maintenance dredging campaign. • The Dredge Vessel Master will maintain and implement vessel specific Shipboard Oil Pollution Emergency Plan (SOPEP) in accordance with MARPOL 73/78. • The Dredging Contractor will consider the potential for ecotoxicity in the selection process for hydrocarbons and chemicals. • The Dredging Contractor will submit a list of chemicals for approval in accordance with INPEX requirements. • The Dredging Contractor will ensure the dredge vessel (where applicable) has a current International Oil Pollution Prevention Certificate or similar issued by the Country or State of registration. • The Dredge Vessel Master will ensure material safety data sheets (MSDSs) are available for all hydrocarbon or chemical product stored on board the dredge vessel. • The Dredge Vessel Master will ensure appropriate storage and handling of oils, grease and chemicals in accordance with AS 1940-2004. • The Dredge Vessel Master will ensure hydrocarbon and chemicals stored on deck are bunded. The net capacity of any bund will be at least 110% of the total volume of the largest storage vessel. • Relevant Dredge Vessel Personnel will inspect hazardous materials and hydrocarbon storage areas regularly. • The Dredging Contractor will use a licensed supplier for fuel transfer and transport operations. • The Dredging Contractor will ensure dry-break, breakaway couplings or similar technology are installed and used during refuelling operations. • The Dredging Contractor will develop and implement a bunkering/refuelling procedure. • Relevant Dredge Vessel Personnel will be adequately trained in the bunkering/refuelling procedure. • The Dredge Vessel Master will ensure refuelling of the dredge vessel within Darwin Harbour is undertaken in accordance with National, Northern Territory and Darwin Port requirements. • The Dredge Vessel Master will ensure radio contact is maintained between the dredge vessel and the fuel supply vessels, when refuelling activities are being undertaken. • Relevant Dredge Vessel Personnel will visually monitor hoses, couplings and the sea surface prior to and during refuelling operations. • The Dredge Vessel Master will monitor fuel storage tank levels to identify possible leakages promptly. • The Dredging Contractor will ensure vessels are equipped with sufficient low-pressure

Hydrocarbon and chemicals management and spill response framework	
	alarms and shutdown systems to minimise loss of hydrocarbons to the marine environment in the event of a burst hydraulic hose. • The Dredging Contractor will ensure that any plant and equipment used will be fit for purpose, well maintained, and operated by appropriately trained and competent personnel. • The Dredging Contractor to maintain and regularly inspect hydraulic oil systems, hoses and couplings to minimise the potential for spills. • The Dredging Contractor is responsible for oil spill preparedness and response activities relating to vessel risks, with support made available from the INPEX Emergency Response Team and Darwin Incident Management Team as required. • The Dredging Contractor will ensure personnel on board the dredge vessel are trained in spill preparedness and response measures. • The Dredging Contractor will ensure sufficient and appropriate first strike spill response materials are available on board the dredge vessel, and located in close proximity to hydrocarbon and chemical storage and operational areas. This will include provision of oil absorptive and/or containment booms on board the dredge and support vessels. • The Dredging Contractor will ensure all on board spills are captured, mopped, contained and sent onshore for appropriate disposal. No spill related (oily) waste products will be discharged to open waters. • The Dredging Contractor will undertake spill drills in accordance with the dredge vessel SOPEP and MARPOL 73/78 requirements.
Monitoring	None applicable. Audits and HSE inspections will be used to assess compliance (Section 10.6).
Applicable period	For the duration of dredging and spoil disposal activities.

8 Water quality monitoring

Water quality monitoring is proposed in proximity to maintenance dredging operations and further afield adjacent to key sensitive receptor sites (i.e. coral and seagrass). The water quality monitoring program focuses on near real-time measurements of turbidity, which is the primary indirect stressor elevated during dredging activities. Turbidity will be used as a lead indicator to proactively manage maintenance dredging operations, which based on the outcomes of the capital dredging program, eliminates the need for intensive sensitive receptor monitoring.

The details of the monitoring program are described in the following sections.

8.1 Objectives

The key objectives of the water quality monitoring program are to:

- provide an early warning that turbidity is approaching the upper bounds of background conditions naturally experienced by the receptor
- inform the management of dredging operations to reduce the potential for impacts to sensitive receptors due to dredging attributable deterioration in water quality to within agreed levels
- proactively manage dredging operations to decrease duration of the activity through increasing production, in an environmentally responsible manner.

8.2 Development of risk-based water quality monitoring program

The water quality monitoring program consists of four individual Water Quality Monitoring Plans (A, B, C and D) with escalating monitoring requirements commensurate with the potential risk to sensitive receptors. The decision criterion is premised on the dredge volume and season.

The risk to sensitive receptors is directly influenced by the dredge volume as it relates to the mass of fines released, the magnitude of suspended sediment plume and the duration of the activity (i.e. duration of exposure). The risk to sensitive receptors also varies between seasons i.e. the wet season typically experiences naturally elevated turbidity associated with episodic weather events, while the dry season is typically more benign.

A maintenance dredging volume of 0.25 Mm^3 was chosen as the decision point, as sediment transport modelling results from both wet and dry season were available to inform monitoring site selection based on simulated risk to sensitive receptor habitat. For each Plan, the modelling phases used are as follows:

- Plan A and B (0 to 0.25 Mm^3): informed by the first phase of the modelling outputs (days 0 to 14.5; SN1), which assume dredging of approximately 0.25 Mm^3 of "recently deposited sediments" (Section 6.1). The results of which suggest the same overall trends but at a much lower intensity and extent.
- Plan C and D (0.25 Mm^3 to 0.75 Mm^3): informed by results from highest intensity period (days 14.5 to 29; SN2) for the worst-case credible scenario (0.75 Mm^3) described in detail in Section 6.5 and 6.8.

Figure 8-1 illustrates the decision process as it relates to individual Water Quality Monitoring Plans A, B, C and D.

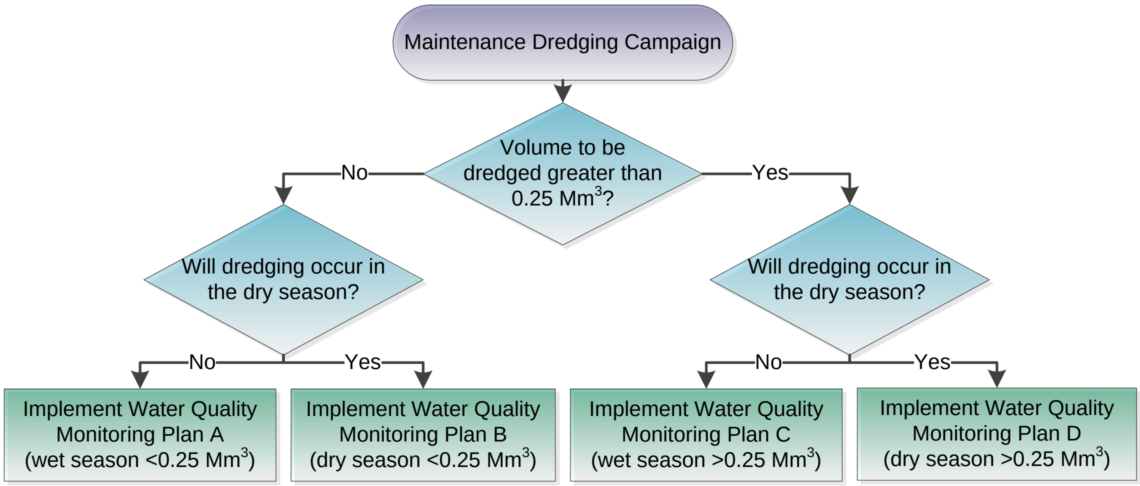


Figure 8-1: Water quality monitoring program decision tree

8.3 Monitoring sites

Proposed monitoring sites and their functions (reactive vs. informative) for all Water Quality Monitoring Plans are illustrated in Figure 8-2 and detailed in Table 8-1.

Reactive monitoring sites are located in proximity to dredging operations and/or are predicted to be influenced by elevated SSC from dredging. Reactive monitoring sites include turbidity triggers that if exceeded, and are attributable to dredging, initiate data review and/or responsive and contingency management practice/s to manage impacts within the limits of acceptable loss. Informative monitoring sites are designed to provide contextual information to inform the assessment of water quality trends and more specifically provide information to support attributability assessments. Note all proposed sites were monitored during the capital dredging program, with extensive data available to aid interpretation.

A summary of monitoring site selection rationale is provided below:

- Plan A (<0.25 Mm^3; Wet Season): based on modelling outputs no sensitive receptor monitoring sites are predicted to be impacted or influenced (as defined in Section 6.6) by excess SSC or sedimentation. For the purpose of adaptive management, coral sites in proximity to dredging (Northeast Wickham Point and South Shell Island) are proposed to be reactive sites to verify the modelling results and allow for adaptation of dredging operations if necessary. Further, as these sites are located downstream of the dredging activities they will act as sentinels for sites further afield. An informative site (Spoil Ground) is also included to contextualise turbidity in the vicinity of the DSDA.
- Plan B (<0.25 Mm^3; Dry Season): same as Plan A with the addition of an informative seagrass site (Fannie Bay) to verify this site is not affected. Note, this site is not predicted to be influenced by excess SSC or sedimentation; however, it has been included as contingency given that model outputs for the same season with increased volume (i.e. Plan D - dry season >250,000 m^3) indicate parts of Fannie Bay may be influenced.
- Plan C (>0.25 Mm^3; Wet Season): same as Plan B with the addition of an informative coral site (Weed Reef) further afield. Note, this site is not predicted to be influenced by excess SSC or sedimentation; however, it has been included as contingency. This is because, with increasing volume, the spatial extent of the plume is predicted to extend further downstream along the naturally deep channel along the eastern side of the mid-harbour area during spring tides.

- Plan D (>0.25 Mm^3; Dry Season): same as Plan C except seagrass site, Fannie Bay becomes a reactive site as modelling suggests that the southern portion of Fannie Bay may be influenced by dredging related excess SSC under this scenario. As such, management triggers have been developed to verify that the turbidity level at this site do not reach levels at which impact is likely to occur.

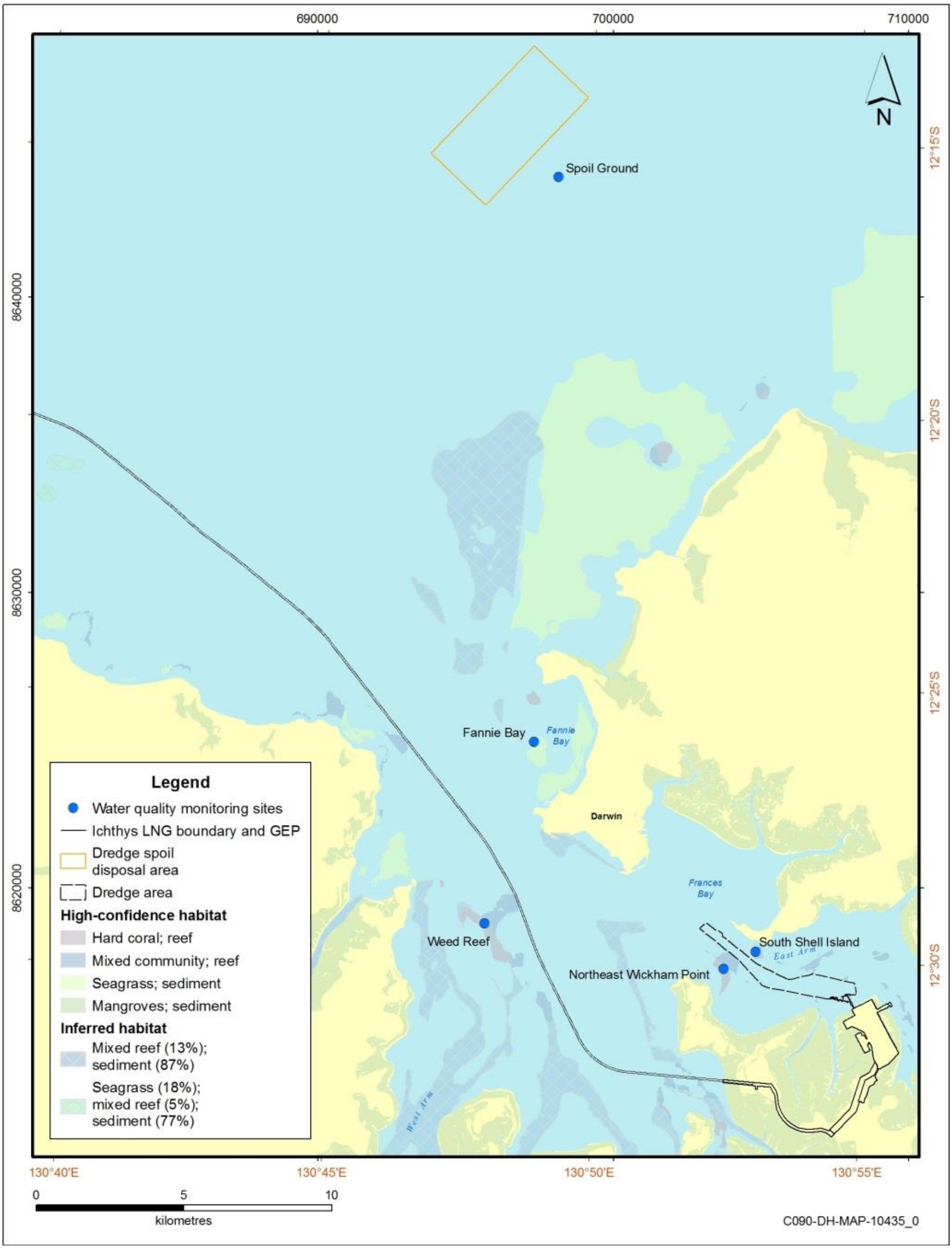


Figure 8-2: Indicative monitoring sites for the Water Quality Monitoring Plans

Table 8-1: Decision tree water quality locations. 'R' = reactive, 'I' = informative

Location	Plan A	Plan B	Plan C	Plan D
Northeast Wickham Point	R	R	R	R
South Shell Island	R	R	R	R
Spoil Ground	I	I	I	I
Fannie Bay		I	I	R
Weed Reef			I	I

8.4 Methods

8.4.1 Data collection

The water quality monitoring program developed for this Maintenance DSDMP is based on the findings from the capital dredging program, as applicable to the reduced scale and nature of the activity.

The water quality monitoring program will be executed by a qualified sampler. Water quality data will be collected at approximately 30 min intervals through the use of in situ water quality data logging instruments. The turbidity instrument will be telemetered with data uploaded daily to an online database for trigger assessment (Section 8.4.4).

For all Water Quality Plans, loggers will be deployed for a minimum of 14 days (i.e. one-spring neap cycle) prior to dredging to ensure reliable operability. For Plan A and Plan B, loggers will be retrieved approximately 14 days post dredging (one spring-neap tidal cycle) or earlier where data indicates there has been no influence or water quality has returned to background conditions. For Plan C and Plan D, loggers will be retrieved approximately one month post dredging (2 x spring-neap tidal cycle post-dredging) or earlier where data indicates there has been no influence or water quality has returned to background conditions. Although not expected based on the results of the capital dredging program (Cardno 2015a), if turbidity remains significantly elevated above background conditions, then the period of time for which the logger may remain deployed will be assessed on a case-by-case basis. For all Water Quality Plans servicing will be undertaken on an as needs basis with the aim of reducing data loss.

Fixed instruments, where possible, should be positioned approximately one metre above the seabed as described in the NEMP (Cardno 2014a), so established methods of analysis and interpretative tools (e.g. empirical model) can be utilised. Further, as per the capital dredging program, the in situ water quality data loggers will be deployed adjacent to the sensitive receptor habitat rather than directly on them to prevent damage to the habitat during deployment and retrieval.

Sedimentation monitoring is not proposed as a routine measure based on outcomes from the WAMSI dredging node. Specifically Jones et al. (2016) states that there are currently no suitable techniques, with sufficient resolution, to measure low deposition events that would be effective as a monitoring tool for dredging programs. It is understood, however, that there have been recent technical advances with continuous in-situ monitoring of sediment deposition, which have yet to be published. As such prior to the execution of a maintenance dredging campaign, INPEX will review and consider the available instruments for potential implementation in future programs.

8.4.2 Parameters

The proposed water quality monitoring program for the protection of coral and seagrass focuses on near real-time measurements of turbidity. Photosynthetic active radiation (PAR), salinity, temperature and depth are secondary variables that will also be measured (but not telemetered) to provide context (e.g. influence of meteorological events on water quality). Table 8-2 provides a list of the parameters to be measured.

Turbidity can be elevated by dredging activities and is therefore the key lead indicator and basis of trigger assessment. It also provides an indirect measure of the light climate received by sensitive receptor communities and how this may be altered as a result of dredging and/or spoil disposal activities. Due to the link between turbidity and sedimentation rates, turbidity data may also indirectly provide a relative measure of the level of sedimentation settling on the substrate or biota.

The quality and quantity of light received by sensitive receptors, measured in PAR, is a direct measure of potential impacts to coral and seagrass communities, as a result of altered water quality. This parameter is as an informative measure, which will be combined with turbidity data to determine whether changes in light climate are a consequence dredging or spoil disposal activities or natural conditions.

Salinity is unlikely be significantly altered by dredging activities as was found in the capital dredging program (Cardno 2015a). Conductivity data (as a proxy for salinity), however, may be useful for inference assessments, particularly given the location of the dredge area at the mouth of Elizabeth River.

Water temperature will not be significantly affected by dredging or spoil disposal activities; however, will be recorded at all sites to identify natural thermal anomalies and inform the potential for natural ecological impacts (e.g. bleaching), and used for inference assessments.

Table 8-2: Proposed water quality parameters and units

Parameters	Units
Turbidity	NTU
PAR	$\mu E\ m^{-2}s^{-1}$
Conductivity (as a proxy for salinity)	S/m
Temperature	°C
Depth	m

8.4.3 Quality control and assurance

All water quality instruments will be calibrated and maintained to suppliers/ manufacturers recommendations. It is anticipated that during a maintenance dredging campaign, there is likely to be some loss of data from water quality instruments due to equipment failure or fouling, based on observations from the capital dredging program. As such, a maintenance schedule will be implemented, with all instruments systematically retrieved, downloaded, cleaned and redeployed/replaced (as necessary) to maintain the data quality and ensure a high percentage of data collection.

Turbidity data are critical to the management of dredging and will be used on a daily basis in management trigger assessments. As such, redundancy, in the form of an additional turbidity logger, will be maintained at each reactive site. Further, as described in Section 8.4.1, the turbidity loggers will be telemetered and uploaded to an online database at the end of each day and therefore any malfunctions or instrument

losses/damage will be promptly identified. Once a malfunction or instrument loss/damage is identified, equipment will be repaired or replaced as soon as practicable.

The parameters light, salinity, temperature, and depth are used primarily to assist with the attributability assessment, and therefore data loss is unlikely to present a significant problem provided it is minimised, where practicable, throughout a maintenance dredging campaign.

Once collected, all data will be subject to rigorous quality assurance and quality control (QA/QC) procedures.

8.4.4 Data analysis

The analysis of water quality parameters will meet the requirements set out in the NT EPA *Guideline for Reporting on Environmental Monitoring* (NT EPA 2015). Best practice summary statistics and analysis techniques based on outcomes from the WAMSI dredging node studies will be used, where applicable (e.g. Jones et al. 2015b).

Prior to data analysis, a preliminary check of data integrity will be undertaken and anomalous data removed using an objective function as part of data QA/QC, following best practice guidance.

Following QA/QC, a trigger assessment will be completed. The following key steps will be followed to assess measured turbidity data (NTU) against respective management triggers at each reactive site during the dredging phase.

- The daily average turbidity will be calculated using turbidity data recorded between 0:01 am to midnight at each reactive monitoring site.
- In the event of data loss, if the period of loss is less than 12 hours, then the daily average will be calculated based on the remaining data as one tidal period (i.e. ebb and flood) should have been captured.
- In the event of data loss, where the period of loss is greater than 12 hours, then the daily average may be derived in a number of ways depending on the duration of data loss:
  - Where more than 12 hours but less than 24 hours of data loss occurs:
    - the daily average turbidity will be calculated on the available data provided that the expected maximum turbidity period based on review of previous water trends is captured.
    - where the expected maximum turbidity period is not captured, then where possible a proximate monitoring site will be used as a surrogate.
  - Where more than 24 hours of data loss occurs:
    - where possible a nearby monitoring site will be used as a surrogate until equipment repair/ replacement can occur.
    - note that even if the telemetered system is down, data in most instances will still be maintained on the logging instrument for download and analysis post repair.
- Once the daily average turbidity value is calculated for the reactive site, it is then compared against the intensity value (Table 7-4).
- Where the intensity value is exceeded for more than the allowable number of consecutive days (i.e. duration; Table 7-4) then an exceedance event has occurred.
- If an exceedance trigger event has occurred, INPEX in consultation with the Monitoring Consultant and Dredging Contractor (as appropriate) will complete an attributability assessment (Section 7.1.3).

- A management trigger exceedance will only require action where the attributability assessment indicates that dredging activities have contributed to or caused each daily exceedance of the intensity value.

It should be noted that the empirical model developed during the capital dredging program (Cardno 2015a) may also be used to predict likely (natural) trigger exceedances ahead of time based on forecasted weather and oceanographic conditions, as was completed for the capital dredging program. Where an exceedance of triggers due to natural events (i.e. not attributable to dredging) is forecasted, DENR and DEE will be notified and no further action (i.e. reporting) will occur.

8.5 Remote sensing

To supplement the near real-time water quality systems and provide greater spatial coverage, Moderate Resolution Imaging Spectroradiometer (MODIS) satellite images (250 m pixel resolution) may also be obtained (Kutser et al. 20017; Evans et al. 2012). The images may be used to contextualise site-specific data where it is believed to add value to the analysis of attributability of exceedances and, where required, to assess the spatial distribution of the visible sediment plume (where present; provided that the images are cloud free). Where possible, satellite imagery with a finer pixel resolution (although infrequent passes) may also be utilised (e.g. Sentinel-2 with 10 m pixels).

9 Stakeholder engagement and communications

INPEX believes effective stakeholder engagement is essential in maximising the safety of Company and Project personnel, and the community; and in establishing, building and maintaining community support and trust. INPEX works closely with identified stakeholders to provide integrated, timely and effective information to the community and provide mechanisms for feedback and response.

INPEX's approach to integrated stakeholder engagement is based on five key principles:

- regular personal contact with priority stakeholders
- consistent, timely, coordinated and responsive communication across all stakeholder groups
- upfront communication about Project issues and impacts
- easily accessible information
- ongoing monitoring and improvement.

The successful implementation of this plan will assist to:

- maximise the safety of Darwin Harbour users and minimise the impact of maintenance dredging activities
- deliver clear, timely and integrated messaging to stakeholders on the dredging program's safety and environmental monitoring measures

9.1 Timing

The stakeholder engagement plan and associated targeted activities will be implemented at key stages of the maintenance dredging program. These include:

- from three weeks prior to the commencement of maintenance dredging to ensure effective communication of the timing of works, and the associated safety and environmental measures
- throughout maintenance dredging, to support safety outcomes
- at completion of the maintenance dredging to communicate final results and acknowledge the community's support.

9.2 Stakeholders

INPEX employs a stakeholder mapping exercise to identify relevant stakeholders and ensure they are engaged fairly and to best effect with targeted and responsive engagement activities.

Stakeholders will be categorised by their level of influence on INPEX, the Project and the wider community. The level of impact the maintenance dredging program will have on the identified stakeholders is also assessed.

9.3 Engagement tools

A range of tools will be used to target and engage with stakeholder groups in an appropriate and best practice manner. These tools build on a strongly established base of engagement established over a number of years by INPEX and will be informed by stakeholder needs and requirements.

These engagement tools may include formal briefings for stakeholders, public information forums, advertising and media, fact sheets, boat ramp information boards, INPEX website, INPEX 1800 community feedback line, INPEX enquiries email account and bi-monthly Ichthys Project bulletin.

10 Environmental management implementation strategy

The following sections describe the environmental management implementation strategy as applicable to maintenance dredging and disposal activities.

10.1 INPEX HSEQ-MS

The INPEX HSEQ-MS is part of the INPEX Business Management System, an integrated framework of policies, standards and procedures that describe how business activities at INPEX are governed and managed.

The INPEX Environmental Policy (see Appendix D) sets the direction and minimum expectations for environmental performance, and is implemented through the standards and procedures of the HSEQ-MS.

The HSEQ-MS is based on the principle of a "plan, do, check, act" (PDCA) continual improvement cycle, and has been developed in accordance with the following Australian standards:

- AS/NZS 4801:2001, *Occupational health and safety management systems-Specification with guidance for use*
- AS/NZS ISO 14001:2004, *Environmental management systems-Requirements with guidance for use*.

It provides mandatory rules and processes for the systematic and consistent management of health, safety, environment and quality (HSEQ) risks, demonstration of compliance, and facilitation of continual improvement.

The 13 external elements that influence the HSEQ-MS reflect key aspects of INPEX activities requiring process safety and HSEQ controls (see Figure 10-1). These elements have to be managed and implemented properly in order to achieve the desired HSEQ performance and reflect a PDCA cycle, which is applied to every aspect of the 13 elements.

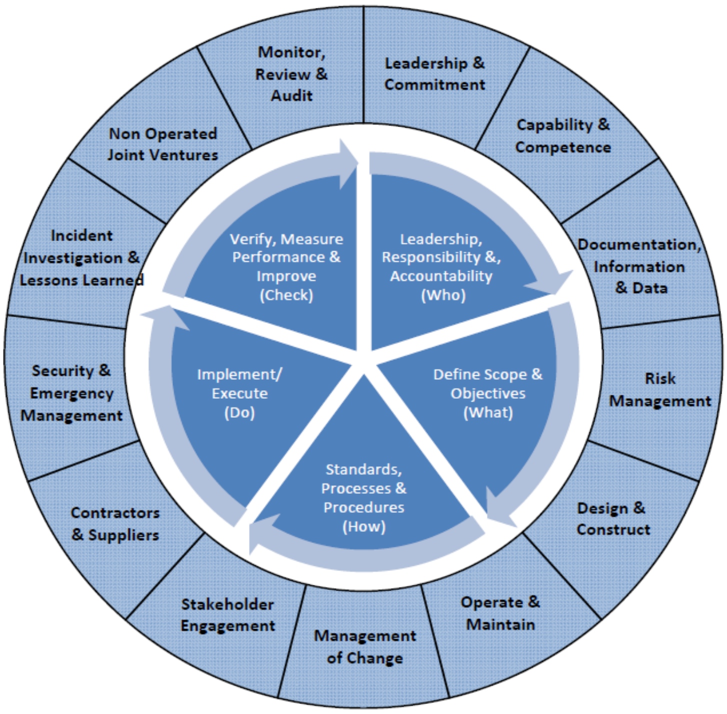


Figure 10-1: INPEX HSEQ-MS

10.2 Dredging contractor HSEQ-MS

The Dredging Contractor will have a HSEQ-MS, which has been developed to align with the INPEX HSEQ-MS.

The Dredging Contractor will develop a HSEQ management plan (or similar) for maintenance dredging and spoil disposal scope of work. The plan is required to be aligned with INPEX HSEQ policies, plans, standards and procedures, in accordance with contract requirements, and will be reviewed and approved by INPEX prior to commencement of maintenance dredging and spoil disposal activities.

The Dredging Contractor's HSEQ management plan (or similar) will, as a minimum:

- address risks associated with the Dredging Contractor's scope of work
- demonstrate how this Maintenance DSDMP will be implemented by the Dredging Contractor
- align with INPEX policies, plans, standards and procedures for HSEQ, in accordance with contract requirements
- address all legal and other requirements applicable to the Dredging Contractor's scope of work.

10.3 Emergency response

INPEX maintains a trained and ready emergency management capability to execute emergency response and crisis management. The Incident Management Teams (IMTs) provide operational management support to a site based emergency and the Crisis Management Team (CMT) provides strategic direction with respect to management of reputational damage and impacts to business continuity.

The INPEX emergency, incident and crisis management system consists of emergency response teams (ERTs) located at its facilities, IMTs in Darwin and Perth respectively, and the CMT located in Perth.

The Dredging Contractor will have adequately trained workplace personnel to form vessel-based ERTs. These will be coordinated by the relevant person in charge (e.g. vessel master) to ensure that there is adequate emergency service cover at all times. The INPEX IMT can be activated to support the Contractor emergency response if required. The point of contact between the vessel ERTs and the INPEX IMT will be via the INPEX Client Representative or delegate.

10.4 Roles and responsibilities

INPEX and the Dredging Contractor will assign suitable resources to oversee the execution of this Maintenance DSDMP. A summary of key environmental roles and responsibilities are described in Table 10-1. Where responsibility is assigned to a role, the task may also be performed by a suitable delegate.

Table 10-1: Summary of key environmental roles and responsibilities

Role	Key responsibilities
INPEX	Responsible for: • obtaining applicable environmental and planning approvals (with exception of the Fisheries Permit) • reviewing the Dredging Contractors HSEQ-MS, and review and approval of associated documents (e.g. HSEQ management plan, induction materials, etc.) • ensuring the Dredging Contractor compliance with the inforce Maintenance DSDMP, and applicable environmental and planning approvals

Role	Key responsibilities
	• executing the proposed monitoring program • undertaking attributability investigations in accordance with Section 7.1.3 • undertaking trigger exceedance reporting in accordance with Section 10.8.1 • undertaking external reporting of environmental incidents/events in accordance with Section 10.8.3.
INPEX Client Representative	Responsible for: • overseeing the Dredging Contractors performance in the field • participating in HSE inspections and audits • participating in HSE incident investigations • reporting discovery of potential heritage finds to the Department of Tourism and Culture.
Dredging Contractor	Responsible for: • obtaining a NT Fisheries permit prior to the commencement of dredging activities. • completing a biofouling risk assessment and implementing mitigation measures commensurate with the level of risk • ensuring that sufficient qualified and trained personnel are on board dredge and support vessels • ensuring the dredge and support vessel personnel are fully aware of their environmental responsibilities as described in the Maintenance DSDMP, relevant HSEQ plans and approvals • ensuring oil spill preparedness and response activities relating to vessel risks and regular drills/exercises are undertaken • ensuring hydrographic surveys are undertaken prior to and following dredging activities • establishing and maintaining clear communication with the Darwin Port • reporting discovery of potential heritage finds to the INPEX client representative.
Dredge/Support Vessel Masters	Responsible for: • complying with all applicable INPEX policies, standards and legislative requirements • complying with the requirements described within the environmental management frameworks of this Maintenance DSDMP • ensuring that identified mitigation/management measures are in place prior to the commencement of works • reporting any non-compliances or incidents which occur on board the vessel during operations to the INPEX Client Representative immediately on becoming aware • ensuring sightings of injured and deceased marine megafauna are reported to Marine WildWatch.
Dredge/Support HSE Advisors	Responsible for: • ensuring compliance with the requirements outlined in this Maintenance DSDMP • participating in HSE inspections and audits • reporting on HSE non-compliances and incidents • participating in HSE incident investigations.
Dredge/Support Vessel Personnel	Responsible for: • participating in HSEQ inductions and training (as applicable to role) • complying with all applicable INPEX policies, standards and legislative requirements • undertaking work activities in accordance with the requirements of this Maintenance DSDMP • exercising a Duty of Care to the environment at all times • reporting on HSE non-compliances and incidents to Dredge/Supply Vessel Master immediately on becoming aware.
Marine Megafauna Observations (MMO)	Responsible for: • monitoring for marine megafauna within the observation and exclusion zones prior

Role	Key responsibilities
	and during dredging activities • maintaining records of marine megafauna observations • ensuring sightings of injured and deceased marine megafauna are reported to Marine WildWatch.

10.5 Inductions and training

The following sections describe the inductions and training requirements for maintenance dredging campaigns.

10.5.1 HSEQ inductions

All personnel (including INPEX representatives, contractors, subcontractors and visitors) are required to complete the Dredging Contractor HSEQ induction prior to the commencement of work activities. Inductions will cover the INPEX and Dredging Contractor HSE requirements, and the relevant commitments contained in this Maintenance DSDMP. This will be reviewed and approved by INPEX, prior to the commencement of a maintenance dredging campaign. The environmental content of these inductions will include the following:

- the environmental and socioeconomic values of Darwin Harbour
- an overview of the potential impacts associated with maintenance dredging activities
- key legislative requirements
- general awareness of management measures for protected marine megafauna, heritage and sacred sites, waste, chemical and hydrocarbons and spills
- reporting of environmental non-compliances and incidents.

Records will be maintained by the Dredging Contractor as evidence of completion of HSEQ inductions.

10.5.2 MMO training

The Dredge Vessel Master and dedicated Dredge Vessel Personnel will undertake MMO training prior to the commencement of maintenance dredging activities. The content of the training will include the following:

- an overview of the potential impacts to protected marine megafauna from operational activities
- an overview of target marine megafauna species
- the role and responsibilities of a MMO
- the management procedures in place to protect targeted marine megafauna
- the observation, recording and reporting requirements.

Records will be maintained by the Dredging Contractor as evidence of the dedicated personnel who have completed the MMO training.

10.6 Inspections and audits

10.6.1 Internal audits

Environmental compliance with this Maintenance DSDMP will monitored through the implementation of audits and inspections described in Table 10-2. The results of all audits and inspections will be communicated to relevant supervisory staff, who will be

responsible for ensuring that any necessary corrective actions are implemented in the timeframe agreed, and for preventing recurrence of any deficiencies observed.

Follow-up audits and/or inspections, if practically necessary, will be carried out to verify the implementation of any required corrective action/s. INPEX and the Dredging Contractor will maintain audit and inspection records including records associated with close-out of issues raised.

Table 10-2: Audits and inspections

Description	Timing	Purpose	Responsible
Dredge vessel pre-mobilisation readiness audit	Prior to mobilisation to site/commencement of dredging activities.	To confirm vessel readiness and assess compliance with applicable requirements described within this Maintenance DSDMP.	INPEX
Post-dredging compliance audit	At the cessation of dredging activities	To confirm dredging activities were undertaken in accordance with requirements described within this Maintenance DSDMP.	INPEX
HSE inspections	Weekly	Compliance monitoring undertaken during a maintenance dredging campaign to ensure activities are being undertaken in accordance with this Maintenance DSDMP.	INPEX and Dredging Contractor (jointly)

10.6.2 External audits

Dredging Contractor environmental management will be audited to evaluate compliance with WDL240 (as amended), the *Water Act*, the WMPC Act and the commitments made in the Maintenance DSDMP. INPEX will engage an auditor to complete the audit during a period when dredging and spoil disposal activities are occurring. The external auditor will be appropriately qualified (i.e. a qualified person in accordance with Section 68 of the WMPC Act).

The proposed scope of the environmental audit will be submitted to the NT EPA for review and approval no later than 20 business days prior to the proposed commencement date of the environmental audit (which will be specified when the proposed scope is submitted). The environmental audit will not commence until written approval is received from the NT EPA; noting that the NT EPA may require INPEX to revise, amend or resubmit the proposed scope.

The environmental audit report will be:

- completed within one calendar months of receipt of approval from the NT EPA unless otherwise agreed
- signed by the qualified person conducting the audit
- provided in full to the NT EPA within five business days of being certified by the qualified person conducting the audit.

In addition, it is recognised that the maintenance dredging activity may be subject to external audits by relevant regulatory agencies, including the NT EPA and DEE. The Dredging Contractor and INPEX will cooperate fully with any regulator-initiated audits.

10.7 Internal reporting

The following sections describe the internal reporting requirements and responsibilities for routine reporting and environmental events and investigations.

10.7.1 Routine reporting

Internal reporting between the Dredging Contractor and INPEX will be undertaken on a weekly basis and will include reporting on maintenance dredging operations and environmental performance. These reports will include, but are not limited to, the following:

- daily dredge logs and dredge/support vessel track plots
- marine megafauna observations
- summary of environmental events (Section 10.7.2)
- inspection/audit outcomes and status of actions/findings
- other matters relating to compliance with approval requirements.

10.7.2 Environmental event reporting and investigation

INPEX refers to environmental incidents, hazards, non-compliances and near misses as environmental events. All environmental events related to maintenance dredging and spoil disposal activities will be reported to INPEX by the Dredging Contractor in accordance with contract requirements. All events will be documented and investigated as appropriate. Any associated preventive or corrective actions will be documented and tracked to close-out by the Dredging Contractor and verified by INPEX.

10.8 External reporting

The external reporting requirements and responsibilities as they pertain to exceedances, incidents and non-compliances and other regulatory reporting are described in the following sections.

10.8.1 Exceedance reporting

As detailed in Section 7.1 and Section 8.4.4, in the event that a Level 1 or 2 trigger has been exceeded during dredging and spoil disposal operations, INPEX shall notify the following stakeholders as soon as practicable, and in any case within 24 hours after becoming aware of the exceedance:

- DENR – pollution@nt.gov.au
- DEE – post.approvals@environment.gov.au

Table 10-3 summarises the relevant notification and reporting timeframes, in business days, for each specific step (i.e. not cumulative business days). Where a natural exceedance of a management trigger has been predicted ahead of time based on forecasted weather and oceanographic conditions, DENR and DEE will be notified in advanced and no further reporting as described in Table 10-3 will occur.

Table 10-3: Reactive monitoring exceedance notification and reporting summary

Communication	Trigger level	Time*	Content
Notification of initial exceedance	Level 1 & 2	24 hours after becoming aware of the exceedance	Notify exceeded trigger
Notification of attributability	Level 1 & 2	5 days	Notify attributability
If attributable to dredging			
Exceedance status report	Level 2	Weekly	Status report including management practice/s implemented and measured

Communication	Trigger level	Time*	Content
			effectiveness (where data is available)
Conclusive lessons learnt report	Levels 2	15 days after exceedance is resolved	Conclusive report on how exceedance was managed, including lessons learnt.

* "days" refers to business days.

10.8.2 Routine monitoring reporting

A comprehensive interpretative water quality report will be prepared and submitted to DENR and DEE, within 60 business days following the cessation of monitoring activities, unless otherwise agreed.

This report will be set out in the format described in the N*ational Water Quality Management Strategy, Australian Guidelines for Water Quality Monitoring and Reporting*, Chapter 7 and include an assessment of the likely impact of release of fine material to sensitive ecological receptors.

10.8.3 Environmental incident and non-compliance reporting

External incident and non-compliance reporting to Administering Agencies or Regulators will be undertaken by either INPEX or the Dredging Contractor. Table 10-4 outlines the external reporting requirements and responsibilities for incident and non-compliance reporting.

In addition to external notifications of environmental incidents outlined in Table 10-4, accidents or incidents, where required, will be reported to the Australian Maritime Safety Authority (AMSA) under the *Occupational Health and Safety (Maritime Industry) Act 1993* or to Northern Territory Worksafe under the *Work Health and Safety (National Uniform Legislation) Act*, within the statutory timeframes, as required by legislation.

Table 10-4: External reporting—incident and non-compliance

Description	Responsible	Regulator	Timeframe
Non-compliances with WDL240	INPEX	DENR	As soon as practicable after (and in any case within 24 hours) first becoming aware of the noncompliance
Incidents reportable under or Section 14 of WMPC Act	INPEX	DENR	As soon as practicable and in any case within 24 hours of first becoming aware of the event occurring
Incident resulting in a significant impact to matters of national environmental significance or habitat for listed species in Darwin Harbour	INPEX	DEE	As soon as practicable and in any case within 24 hours of first becoming aware of the event occurring
Spill to marine waters (POLREP)	Dredge Contractor	Darwin Port (within Darwin Harbour) DIPL (within Northern Territory) DENR	Immediate notification with provision of a POLREP within 24 hours

10.8.4 Other external reporting/notification requirements

Other external reporting to Administering Agencies or Regulators will be required on an ad hoc basis by either INPEX or the Dredging Contractor. Table 10-5 outlines the external reporting requirements and responsibilities for other regulatory reporting.

Table 10-5: External reporting—other

Description	Responsible	Administering Agency/Regulator	Timeframe
Notification of the proposed maintenance dredging and spoil disposal activities including: • the proposed commencement date of dredging • expected duration of dredging • the name and type of dredge vessel undertaking maintenance dredging activities • contact details of the Dredging Contractor • the volume of material to be dredged.	INPEX	DENR and DIPL	At least ten days prior to the commencement of a maintenance dredging campaign
Notification of completion of maintenance dredging and spoil disposal activities	INPEX	DENR	Seven days following the completion of a maintenance dredging campaign
Notification of the proposed maintenance dredging and spoil disposal activities including but not limited to timing, safety zones and communications.	Dredging contractor	Darwin Port and Regional Darwin Harbourmaster DENR DEE	Prior to the commencement of maintenance dredging activities and ongoing.
Final hydrographic survey.	INPEX	DIPL	Upon completion of maintenance dredging and spoil disposal activities.
Stranded, injured or entangled marine megafauna sightings.	Dredging Contractor	NT Marine WildWatch	At the time of observation.
Discovery of a potential heritage object.	INPEX	Department of Tourism and Culture—Heritage Branch	Upon being notified of a discovery of potential heritage object.

10.9 Data and records management

All records will be legible, identifiable and traceable to the activity, product or service involved. Records will be stored and maintained so that they are readily retrievable and protected against damage, deterioration or loss. The following records will be maintained by the Dredging Contractor and provided to INPEX on request:

- vessel ballast management records
- vessel biofouling risk assessment reports and biofouling logbooks
- waste records (e.g. garbage record book, waste receipts)
- marine megafauna observation records including records of injured/deceased animals

- daily dredge logs and dredge/support vessel track plots
- dredged material and disposal records (i.e. times, dates, volumes and location of dumping)
- discovery of potential discovery of heritage objects
- incidents and non-compliance records
- training registers
- inspections and audits records
- emergency drill records.

INPEX will maintain records pertaining to environmental monitoring results and data will be stored in an electronic format. This data will be stored for five years following the completion of maintenance dredging campaigns except where file size and relevancy dictate otherwise.

10.10 Management of change

INPEX's Environmental Policy requires the Project to set, measure and review environmental performance objectives and targets and ensure appropriate management of change processes are followed.

In the event that there is an alteration to dredging activities proposed in this Maintenance DSDMP, or there is a change to how activities or mitigation measures are implemented, the management of change process illustrated in Figure 10-2 will be followed. This will determine whether the works will or may cause, or increase, the potential for environmental harm, such as by any increase of discharges, or increase in impacts to habitat of listed species in Darwin Harbour.

Where a proposed change results in an increase in potential or actual environmental harm, or an increase in risk to listed species in Darwin Harbour, then the change will not be implemented without prior approval from DEE and the relevant Northern Territory Government (NTG) Administering Agency.

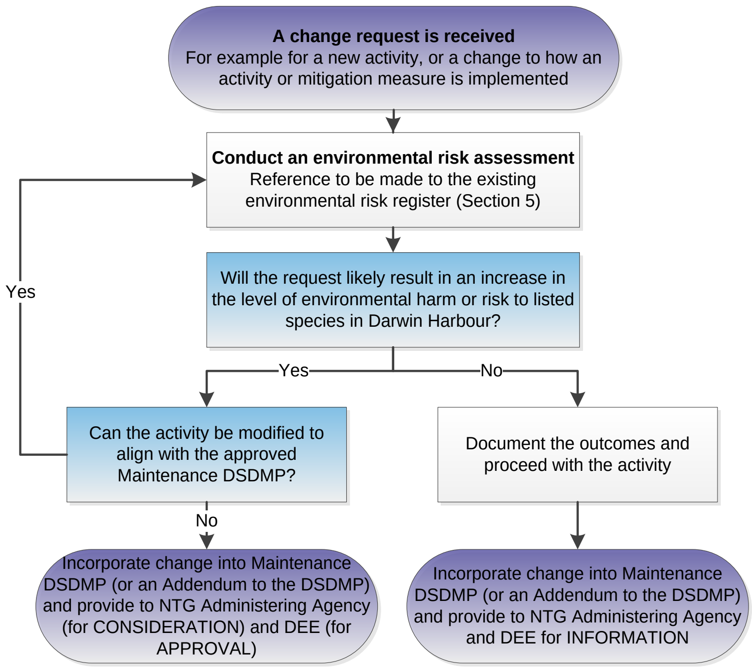


Figure 10-2: Management of change process

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APPENDIX A: MAINTENANCE DREDGING APPROVALS

Conditions of approvals, and demonstration of how these requirements have been met are presented in the following sections.

A.1 Condition 10 Commonwealth approval decision EPBC 2008/4208

Condition 10 Dredging and Spoil Disposal Management Plan		**Section in this Maintenance DSDMP**
The person taking the action must submit for the Minister's approval a Dredging and Spoil Disposal Management Plan (DSDMP) for the protection of inshore dolphins, marine turtles and dugongs occupying Darwin Harbour. The DSDMP must include, but is not limited to, the following:		This Maintenance DSDMP (L060-AH-PLN-60010, Rev 0)
a)	final methodologies for dredging including the method and timing of dredging activities	Section 3
b)	a schedule for dredging activities	Section 3.1
c)	a comparison of dredging methodologies proposed based on potential impacts on dolphins, turtles and dugongs associated with individual methods, including noise and sediment plumes	Section 3.3, 5.3.1, 5.3.2, 6.8 and 7.2.3
d)	justification of the dredging option/s chosen based on best practice at the time	Section 3.3
e)	mitigation measures, including measures for each type of dredge to avoid entrapment of marine turtles	Section 3.3.2, 4 and 7.2.3
f)	methods to prevent, detect and respond to impacts on any number of marine turtles	Section 5.3.1, 7.1, 7.2.3 and 8
g)	measures that allow the alteration of dredging activities and/or implement mitigation methods in an adaptive management framework to ensure the protection of turtles, dugongs and dolphins	Section 7.1 and 7.2.3
h)	the outcomes of hydrodynamic and sediment transport modelling required to predict impacts and finalise the design of the dredging campaign	Section 6.8
i)	contingencies to manage dredging if there is a significant departure from predicted impacts	Section 7.1
j)	an ecological monitoring program, which must exist either in full within the DSDMP, or as a standalone document (see Note 1) that is appropriately referenced in the DSDMP	Section 8 (the ecological monitoring is described in full within the Maintenance DSDMP)
k)	the involvement of an expert panel in the development of the plan and monitoring program required to detect and manage impacts	Section 1.5
l)	reporting and auditing arrangements.	Section 10.6, 10.7 and 10.8
The DSDMP must be submitted at least three months prior to the commencement of dredging. Dredging for which the DSDMP has been prepared must not commence until the DSDMP is approved. The approved DSDMP must be implemented.		Noted

Condition 10 Dredging and Spoil Disposal Management Plan	Section in this Maintenance DSDMP
Note 1: Regarding condition 10(j); if the person taking the action wishes to prepare the ecological monitoring program as a standalone document, then the ecological monitoring program must be approved in writing by the Minister. The approved ecological program must be implemented.	

A.2 Waste discharge licence (WDL240) conditions

Conditions		Section in this Maintenance DSDMP
General		
1.	The licensee must notify the administering agency within 24 hours if there is a change to the licensee or emergency contact details as provided on page one of this licence.	Noted
2.	The licensee must at all times have a 24 hour emergency contact.	Noted
3.	The licensee must notify the administering agency prior to making any operational change that will cause, or is likely to cause, an increase in the potential for environmental harm.	Section 1.6 and 10.10
4.	The licensee must cause a copy of this licence to be available for inspection by any person, in hard copy form on the bridge of the dredge vessel and at the licensee's Darwin corporate office.	Section 2.2
5.	The licensee must provide to the administering agency, within 10 business days of a request, a copy of any document, monitoring data or other information in relation to the activity, in the format requested by the administering agency.	Noted
6.	All notices, reports, documents or other correspondence required to be provided as a condition of this licence, unless otherwise specified as a condition of this licence, must be provided in electronic form by emailing waste@nt.gov.au.	Noted
Maintenance Dredging and Spoil Disposal Management Plan		
7.	The licensee must implement and comply with the INPEX Ichthys Project Maintenance Dredging and Spoil Disposal Management Plan. Document No L060-AH-PLN-60010 (Maintenance DSDMP) which is deemed acceptable provided updates to the DSDMP have been completed as required by administering agency correspondence dated 25 October 2017, reference NTEPA2017/0052-0024.	This Maintenance DSDMP.
8.	The licensee must, for any works not addressed in the accepted Maintenance DSDMP, if those works will or may cause or increase the potential for environmental harm or pollution:	Sections 1.6 and 10.10
8.1	revise the Maintenance DSDMP or prepare an Addendum to the Maintenance DSDMP;	
8.2	have the revised Maintenance DSDMP or Maintenance DSDMP Addendum reviewed and endorsed by a Qualified Professional as having properly identified and mitigated any environmental risk; and	
8.3	submit the revised Maintenance DSDMP or Maintenance DSDMP Addendum at	

Conditions		Section in this Maintenance DSDMP
	least 10 business days prior to implementation of the works with:	
8.3.1.	a tabulated summary of the amendment(s) with document references	
8.3.2.	reasons for the amendment(s);	
8.3.3.	an assessment of environmental risk associated with the amendment(s); and	
8.3.4.	with a copy of the Qualified Professional's endorsement and review to the administering agency.	
9.	Within 10 business days of a typographical revision where the revision has only included document formatting, correction of typographical errors or inclusion of reference to other documents where that revision does not trigger condition 8 must provide the amended document to the administering agency.	Sections 1.6 and 10.10
10.	The licensee must ensure the most current Maintenance DSDMP is available on the licensee's webpage during each maintenance dredging campaign.	Section 2.2
11.	The administering agency may require the licensee to revise or amend and resubmit any amended document.	Noted
12.	The licensee must notify the administering agency within 14 days after completion of monitoring and reporting for the final maintenance dredging campaign, being completion of the licensed activity.	Noted
Environmental Auditing		
13.	The licensee must commission an environmental audit to be undertaken by a qualified person at least once prior to the expiry of the licence, and during a period when dredging and dredge spoil disposal is underway to evaluate compliance with:	Section 10.6.2
13.1.	the conditions of this licence, including the Maintenance DSDMP;	
13.2.	the Water Act; and	
13.3.	the *Waste Management and Pollution Control Act*.	
14.	The licensee must submit the proposed scope for the environmental audit to the administering agency for approval no later than 20 business days prior to the proposed commencement date of the environmental audit. The commencement date for the audit must be specified in the proposed audit scope.	
15.	The licensee must receive written approval for the audit scope from the administering agency before the environmental audit can commence, noting that the administering agency may require the licensee to revise, amend or resubmit the proposed scope.	
16.	The licensee must ensure the environmental audit report is:	
16.1.	completed within one calendar month of receipt of approval from the administering agency unless otherwise agreed;	
16.2.	certified by the qualified auditor conducting the audit; and	
16.3.	provided to the administering agency within five business days of being	

Conditions		Section in this Maintenance DSDMP
	certified and signed by the qualified auditor conducting the audit.	
Consultation and Communication Plan		
17.	The licensee must, for the duration of this licence, implement, maintain and follow a Consultation and Communication Plan which includes a strategy for communicating with persons who are likely to have a real interest in, or be affected by, the activity.	Outlined in Section 9
18.	The licensee must operate and maintain a community feedback number.	Noted
19.	The licensee must display the community feedback number:	Noted
19.1	where the licensee has a website, in a prominent location on the licensee's website;	
19.2.	in the Consultation and Communication Plan; and	
19.3.	in other publicly available documents relating to the activity.	
20.	The licensee must maintain a Complaint Log for all complaints received by the licensee in relation to the activity.	Noted
21.	The licensee must ensure that the Complaint Log includes, for each complaint received by the licensee, the following information:	Noted
21.1.	the person to whom the complaint was made;	
21.2.	the person responsible for managing the complaint;	
21.3.	the date and time the complaint was reported;	
21.4.	the date and time of the event(s) that led to the complaint;	
21.5.	the contact details of the complainant if known, or where no details are provided a note to that effect;	
21.6.	the nature of the complaint;	
21.7.	the nature of event(s) giving rise to the complaint;	
21.8.	prevailing weather conditions at the time relevant to the complaint;	
21.9.	the action taken in relation to the complaint, including any follow-up contact with the complainant; and	
21.10.	if no action was .taken, why no action was taken.	
22.	The licensee must implement, maintain and follow an Emergency Response Plan that addresses procedures for responding to emergencies associated with the activity that may cause environmental harm.	Section 10.3
Early surrender of licence		
23.	Any reports, records or other information required or able to be provided by the licensee under this licence must be submitted to the administering agency prior to the licensee surrendering the licence. If the date on which a report, record or other information is required falls after the date the licensee	Noted

<table>
<tr><th colspan="2">Conditions</th><th>Section in this Maintenance DSDMP</th></tr>
<tr><td></td><td>requests to surrender this licence, the licensee must provide the report, record or information as far as possible using data available to the licensee up to and including the date the request to surrender the licence is made.</td><td></td></tr>
<tr><td colspan="3">Operational</td></tr>
<tr><td>24.</td><td>The licensee must, without limiting any other condition of this licence, in conducting the activity do all things reasonable and practicable to ensure the activity does not adversely affect the Declared Beneficial Uses and Objectives as declared from time to time, including those applying to:
• Darwin Harbour Region; and
• Vernon Islands.</td><td>Sections 7 and 8</td></tr>
<tr><td>25.</td><td>The licensee must ensure all plant and equipment used by the licensee in conducting the activity:</td><td rowspan="4">Sections 7.2.6 and 10.4</td></tr>
<tr><td>25.1.</td><td>is fit for the purpose and use to which it is put;</td></tr>
<tr><td>25.2.</td><td>is maintained; and</td></tr>
<tr><td>25.3.</td><td>Is operated by a person trained to use the plant and equipment.</td></tr>
<tr><td>26.</td><td>The licensee must ensure that discharge of dredge material is not placed outside the dredge spoil disposal area (DSDA) located in Beagle Gulf (NT Portion 7634 (A)) defined by the boundary corner coordinates specified in Table 1 and shown in Appendix A.
Table 1: Authorised Spoil Disposal Area[1]
<table>
<tr><th>Boundary Corner Coordinates</th><th>Latitude</th><th>Longitude</th></tr>
<tr><td>Point 1</td><td>130.81391</td><td>-12.21963</td></tr>
<tr><td>Point 2</td><td>130.83060</td><td>-12.23516</td></tr>
<tr><td>Point 3</td><td>130.79902</td><td>-12.26799</td></tr>
<tr><td>Point 4</td><td>130.78233</td><td>-12.25246</td></tr>
</table>
[1] Comprising an area of approximately 1,250 hectares.</td><td>Section 7.2.2</td></tr>
<tr><td colspan="3">Discharge quality</td></tr>
<tr><td>27.</td><td>The licensee must use visual and/or qualitative observations and maintain records to ensure that all discharges to the DSDA do not:</td><td rowspan="7">Sections 7.1, 7.2.2 and 8</td></tr>
<tr><td>27.1.</td><td>contain any debris, oil, grease, petroleum hydrocarbon sheen, scum, litter or other objectionable matter;</td></tr>
<tr><td>27.2.</td><td>cause or generate odours which would adversely affect the use of surrounding waters;</td></tr>
<tr><td>27.3.</td><td>cause algal blooms in the receiving water;</td></tr>
<tr><td>27.4.</td><td>cause visible change in the behaviour of fish or other aquatic organisms in the receiving water;</td></tr>
<tr><td>27.5.</td><td>cause mortality of fish or other aquatic organisms;</td></tr>
<tr><td>27.6.</td><td>cause adverse impacts on plants.</td></tr>
</table>

Conditions		Section in this Maintenance DSDMP
Monitoring		
28.	The licensee must implement and maintain an environmental monitoring program in accordance with the Maintenance DSDMP to demonstrate that discharges at the DSDA do not cause adverse impact to the receiving environment.	Section 8
29.	The licensee must, for each discharge event at the DSDA, maintain a record of:	Section 10.9
29.1.	the time the discharge commenced and the duration of the discharge;	
29.2.	the discharge volume; and	
29.3.	the location within the DSDA that discharge commenced and ceased for each discharge.	
30.	The licensee must ensure all samples collected in connection with the activity or this licence, are obtained by, or under the supervision of a qualified sampler.	Section 8.4
31.	The licensee must ensure that all water samples and field environmental data are representative of the conditions at the time of sampling and are collected in accordance with recognised Australian Standards and guidelines (e.g. AS/NZS 5667, ANZECC/ARMCANZ).	Section 8.4
Recording and reporting - Notification of commencing a dredging campaign		
32.	The licensee must notify the administering agency at least 10 days prior to commencement of any maintenance dredging activities.	Section 10.8.4
33.	Notification of commencement of maintenance dredging must include:	Section 10.8.4
33.1.	name of dredge vessel and contact details for the dredge contractor;	
33.2.	volume of material to be dredged;	
33.3.	proposed commencement date of dredging;	
33.4.	expected duration of dredging.	
Recording and reporting - Notification of completion of dredging campaign		
34.	The licensee must notify the administering agency within seven days of completing a dredging campaign.	10.8.4
35.	The licensee must provide the administering agency, as soon as practicable, following the completion of each dredging campaign:	Noted
35.1.	certified surveyed bathymetric charts of the dredged area and final configuration of the spoil disposal area; and	
3.5.2.	volume of material dredged from the seafloor within the dredge footprint.	
36.	The licensee must keep records of all non-compliances with this licence. These records must be adequate to enable the licensee to comply with the non-	Noted

Conditions		Section in this Maintenance DSDMP
	compliance notification conditions of this licence.	
37.	The licensee must notify the administering agency of any non-compliance with this licence as soon as practicable after (and in any case within 24 hours) first becoming aware of the noncompliance.	Section 10.8.3
38.	The licensee must include in the notification of non-compliance the following information, as available:	Noted
38.1.	when the non-compliance was detected and by whom;	
38.2.	the date and time of the non-compliance;	
38.3.	the actual and potential causes and contributing factors to the non-compliance;	
38.4.	the risk of environmental harm arising from the non-compliance;	
38.5.	the action(s) that have or will be undertaken to mitigate any environmental harm arising from the non-compliance;	
38.6.	corrective actions that have or will be undertaken to ensure the non-compliance does not reoccur; and	
38.7.	if no action was taken, why no action was taken.	
39.	The licensee must complete and provide to the administering agency an Environmental Monitoring Report in accordance with the Maintenance DSDMP, within 60 business days following completion of the monitoring activities for each dredging campaign.	Section 10.8.2
40.	The licensee must ensure that each Environmental Monitoring Report is prepared in accordance with the DSDMP, in the format described in the National Water Quality Management Strategy, Australian Guidelines for Water Quality Monitoring and Reporting, Chapter 7 and includes:	Section 10.8.2
40.1.	assessment of the likely impact of release of fine material to sensitive ecological receptors; and	
40.2.	for discharges to water, data analysis and interpretation using the National Water Quality Management Strategy, Australian Guidelines for Water Quality Monitoring and Reporting, Chapter 6.	
41.	The licensee must complete an Annual Return and provide it to the administering agency within 60 business days following notification in accordance with condition 34 for completion of each dredging campaign covering the preceding 12 month period.	Noted
42.	The administering agency may require the licensee to revise or amend and resubmit any Annual Return. Where the administering agency requires the Annual Return to be resubmitted the date for resubmission will be specified and will become a condition of this licence.	Noted

A.3 Development Permit (DP17/0336) conditions

Conditions		**Section in this Maintenance DSDMP**
Conditions precedent		
1.	Prior to the commencement of works, an amended Dredge Spoil and Disposal Management Plan (DSDMP) must be submitted to and approved by the consent authority on the advice of the Department of Environment and Natural Resources (DENR) and an endorsed copy will form part of this permit, to the satisfaction of the consent authority.	Section 1.2
2.	Prior to the commencement of any individual dredging campaign, the consent authority and Department of Environment and Natural Resources (DENR) must be notified to provide any campaign specific details including location, timing, vessel type and volume to be dredged, to the satisfaction of the consent authority.	Section 10.8.4
General conditions		
3.	The works carried out under this permit shall be in accordance with the drawing numbered 2017/0162/01 endorsed as forming part of this permit.	Noted
4.	All works relating to this permit are to be undertaken in accordance with the endorsed Dredge Spoil and Disposal Management Plan, upon the advice of Department of Environment and Natural Resources (DENR), to the satisfaction of the consent authority.	Section 1.2
5.	Total dredging activities are not to exceed 1.5Mm3 or 0.75Mm3 in any single campaign, to the satisfaction of the consent authority.	Section 1.2 and 3.1
6.	Dredging works must cease 5 years from the date of issue of this permit, to the satisfaction of the consent authority.	Section 1.2 and 3.1
7.	In each year where dredging is undertaken, an independent third party audit is to be conducted to assess compliance with the Dredge Spoil and Disposal Management Plan (DSDMP) and Section 12 of the Waste Management and Pollution Control Act and provided to the Northern Territory Environmental Protection Authority (NT EPA), to the satisfaction of the consent authority.	Section 10.6.2
8.	The permit holder shall make a copy of this permit and the endorsed Dredge Spoil and Disposal Management Plan (DSDMP) readily available at all times to the person(s) in charge of the dredging and spoil disposal operations and ensure that such persons fully understand all requirements and conditions included in the permit, to the satisfaction of the consent authority.	Section 10.4
9.	Within 1 week of the commencement of works and while dredging works are being undertaken, the permit holder shall make available to the public on a dedicated company website a copy of this permit and the endorsed Dredge Spoil and Disposal Management Plan (DSDMP), to the satisfaction of the consent authority.	Section 2.2

APPENDIX B: DREDGE AREA AND DSDA SUPPLEMENTARY INFORMATION

B.1 Assessment of dredge area sediment dynamics

Hydrographic surveys have been conducted in 2014, 2015 and 2016 to assess the level of accretion and erosion in the dredge area since the completion of the capital dredging program. The first survey was completed at the end of the capital dredging program (June/July 2014) to confirm that the design depth of 13.5 m LAT was achieved. Following this, two additional surveys have been completed in August 2015 and May 2016 to assess any changes to the dredge area (e.g. integrity of batters, accretion/erosion, etc.).

The hydrographic survey data collected in 2014 and 2016 was analysed to assess the rate and location of erosion and deposition within the dredge area. This is indicative of sediment behaviour in the dredge area but may not be representative for all conditions as the two intermediate wet seasons yielded below average rainfall. Analysis of the survey results found that across the dredge area (as a whole) there was net erosion of sediment (~5,500 m^3), with accretion equating to approximately 337,000 m^3 and erosion of approximately 342,500 m^3.

Figure 11-1 shows the difference in sediment heights between the two surveys (2014 and 2016). The distribution of sediment accretion and erosion is not homogenous across the dredge area. Generally, areas of erosion were observed within the southern boundary and locally within the north-east boundary, while the naturally deep areas of the channel towards the west remained relatively unchanged (Figure 11-1).

Sediment accretion was primarily observed in the area adjacent to, and north of the jetty infrastructure with a mean increase of 31 cm (Figure 11-1). Localised accretion ranging from 0.4 m to 1.0 m was also observed at the base and top of the batter in the northern sector (Figure 11-1).

Results from the hydrographic surveys suggest that sediment is shifting over time, with locations of accretion and erosion depending on the prevailing hydrodynamics that drive resuspension, transport and settlement of sediment. The sediment movement observed is not unusual following capital dredging works. Slopes of new channels will always be subject to some degree of erosion as this is where changes in hydraulic conditions are most pronounced. The dredge area remains subject to resuspension and deposition of the fines until they consolidate to levels above the resuspension thresholds.

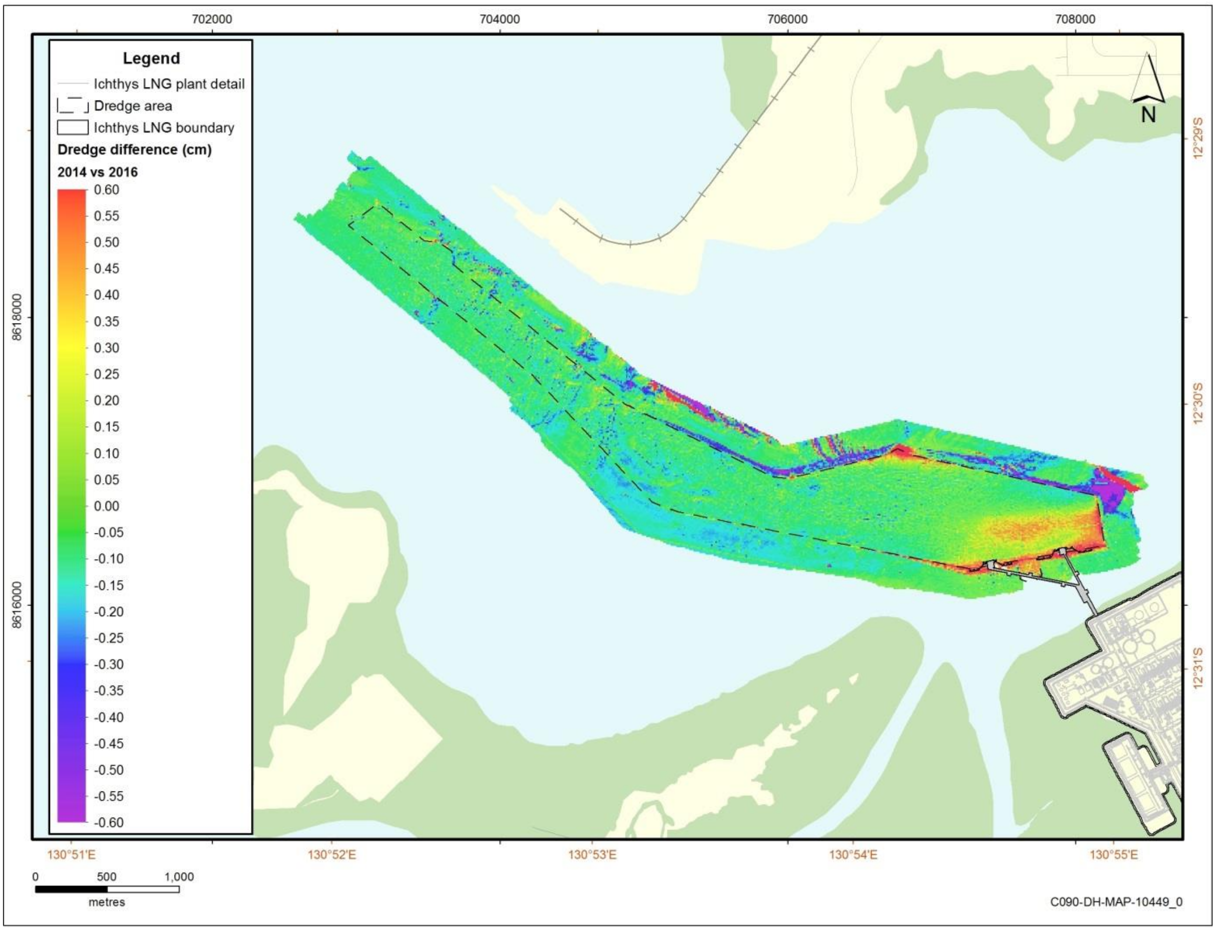

Figure 11-1: Dredge area surface difference maps between 2016 (+ accretion) and 2014 (- erosion) hydrographic surveys.

B.2 DSDA

B.2.1 Assessment of DSDA sediment dynamics

A hydrographic survey of the DSDA was undertaken at the completion of the capital dredging program in 2014 to confirm the final depth and ensure that no navigation hazards existed (e.g. unapproved high spots). In 2015, Geoscience Australia, the Northern Territory Government and the Australian Institute of Marine Science undertook the Outer Darwin Harbour Marine Survey (Siwabessy et al. 2016) using multibeam sonar to map bathymetry. Whilst the methods of this survey are not directly comparable to INPEX's hydrographic survey, they provide a good indication of the stability of the site over time. Results from the 2015 survey show distinct sediment deposits remain within the DSDA, with some individual mounds up to two metres above the surrounding seafloor. It is expected that these mounds will exhibit less definition over time as they dampen (Siwabessy et al. 2016).

Due to local hydrodynamics, a percentage of the fines deposited at the DSDA will mobilise. Assumptions about the loss of fines at the DSDA were included in the sediment transport modelling undertaken for the Final EIS (INPEX 2010, 2011), the capital dredging program (INPEX 2013) and this Maintenance DSDMP (Section 6.4.2). The selection of the DSDA location was informed by modelling outcomes for a number of offshore locations. Details on the site selection assessment are provided in sections 4.4.6 and 7.3.3 of Draft EIS (INPEX 2010) and are summarised here in Appendix B.2.2.

In context of likely sediment movement, currents in vicinity of the DSDA are tidally dominated, with the prevailing current direction from west to west north-west (ebb) through east to east north-east (flood). There is a net drift to the west, which likely arises from a slight inequality in the ebb and flood flows possibly as a result of the coastal constraint to the east (i.e. Gunn Point) (RPS 2012). This prevailing flow intersects with benthic habitat consisting of a mixture of soft-bottom benthos and filter feeder habitat that are well represented regionally.

Results from the subtidal benthos monitoring program during the capital dredging program suggest both the direct and indirect effects of spoil disposal on subtidal benthos are likely to have been relatively localised to sites within the DSDA. Following the completion of spoil disposal, significant recovery in both the abundance and taxon richness of benthic infauna back to baseline levels was recorded within the DSDA (Cardno 2015g). It is also likely that comparable levels of recovery (in terms of subtidal benthos) would have occurred at areas adjacent to the DSDA, which may have experienced similar elevations in suspended sediment and sedimentation (Cardno 2015g).

Environmental monitoring results from the capital dredging program suggest that the location of the DSDA is behaving as predicted from site selection studies. Composite MODIS imagery for wet seasons (November to April) between 2009 and 2012, were compared to the two capital dredging wet seasons (2012/2013 and 2013/2014). A transect between the DSDA and Lee Point was analysed and indicated that the spoil disposal had little effect on surface TSS (and by inference on turbidity) in the area outside of Darwin Harbour during both dredging wet seasons, with only a minor influence (elevation of ~2 mg/L) observed in vicinity of the DSDA (Cardno 2015i). During one of the highest monthly production periods (May 2014), the dispersion of surface TSS from the DSDA extended southwards approximately 10 km towards Lee Point; however, the coastal zone within 3 km appeared to have remained unaffected (Cardno 2015i).

B.2.2 Summary of DSDA site selection

An assessment of spoil disposal options for the capital dredging program was undertaken to inform the Final EIS (INPEX 2010, 2011). Options considered at that time included offshore disposal of acceptable material to a subsea spoil ground, and onshore disposal to settlement ponds either on Bladin Point or on land formally managed by the Darwin Port Corporation (DPC), for land reclamation.

The use of capital dredge material for fill purposes on Bladin Point had been previously ruled out due to insufficient space to accommodate the necessary settlement ponds. Initially it was considered that the existing settlement ponds at East Arm Wharf and the area of a proposed future expansion might provide opportunities for onshore disposal of the capital dredged material. However, INPEX's geotechnical and geophysical investigations prior to the capital dredging program, demonstrated that the dredge source material was fine and therefore unsuitable for infill and construction purposes (INPEX 2010). The sediment characterisation assessment undertaken for the proposed maintenance dredging program (Section 4.1.5) found that silt and fine sands were the overall dominant fractions and therefore the maintenance dredge source material is also considered to be unsuitable for infill and construction purposes.

Onshore disposal was therefore not considered further in the assessment, while offshore disposal for the capital dredged material was further investigated.

Key stakeholders were consulted during the process for determining a suitable offshore disposal location for capital dredged material. These included the (former) Department of Natural Resources, Environment, the Arts and Sport, the (former) Department of Planning and Infrastructure (DPI), the Darwin Port Corporation, the Amateur Fishermen's Association of the Northern Territory (AFANT) and local shipping companies. Key concerns raised during this consultation included the following:

- the possibility of impacts from sediment remobilisation on to Darwin's northern beaches, for example at Fannie Bay, and towards sensitive seagrass beds adjoining these beaches
- the possibility of creating navigation hazards for vessels entering and leaving Darwin Harbour
- the possibility of sediment remobilising back into Darwin Harbour or into the DPC proposed Charles Point Patches navigation channel and thus interfering with safe navigation
- the possibility of sediment remobilisation adversely affecting fishing grounds in the inner Charles Point Patches and Charles Point area as well as disrupting recreational fishing boat movements between these areas and the outer fishing grounds of South Gutter and Fenton Patches
- the possibility of sediment remobilisation adversely affecting recreational fishing activities at a series of artificial reefs off Lee Point.

In addition, the distance to the spoil disposal ground was also taken into consideration with the aim to minimise vessel travel times to avoid extending the overall duration of the capital dredging program in Darwin Harbour.

Nine sites were initially considered (see Figure 11-2), and predictive modelling was used to determine the movement of dredged sediments and turbid plumes from the disposal site in ocean currents.

Site 1 was positioned in a water depth of 12 m in the main tidal channel leading into Darwin Harbour. Plumes of fine sediments generated by spoil disposal at this site were predicted to drift up to 15 km, with low-level deposition at Darwin's northern beaches, Fannie Bay and on the shore adjacent to Darwin's central business district. Site 3 is located in a water depth of 10 m north of Charles Point Patches, where the tidal currents draw plumes of fine sediments towards the Harbour entrance. Relatively high sedimentation rates (>10 mm/h) were also predicted at Charles Point Patches when disposal at this site coincided with ebbing tides.

Site 9 was positioned in the deepest water (at a depth of 15 m), and was considered optimal for spoil disposal as fine sediments drifted north-east and west with the tides without impinging upon Darwin Harbour or inshore habitats. However, while showing good potential for dispersal of dredge spoil in the long term, it was located close to a shipping route for vessels travelling between north eastern Australia and Darwin Harbour.

In order to avoid potentially reducing the under keel clearance for commercial ships using this route, which could affect ship handling and safe navigation, a tenth site was selected. This site was located north-east of Site 9 and >12 km north-west of Lee Point in deeper water. Further, the area was lengthened to align with the main tidal axis. This tenth site was finally selected as the preferred DSDA (see Figure 11-2).

Further details of the assessment process and modelling outcomes are provided in sections 4.4.6 and 7.3.3, and Appendix 14 of the Draft EIS (INPEX 2010).

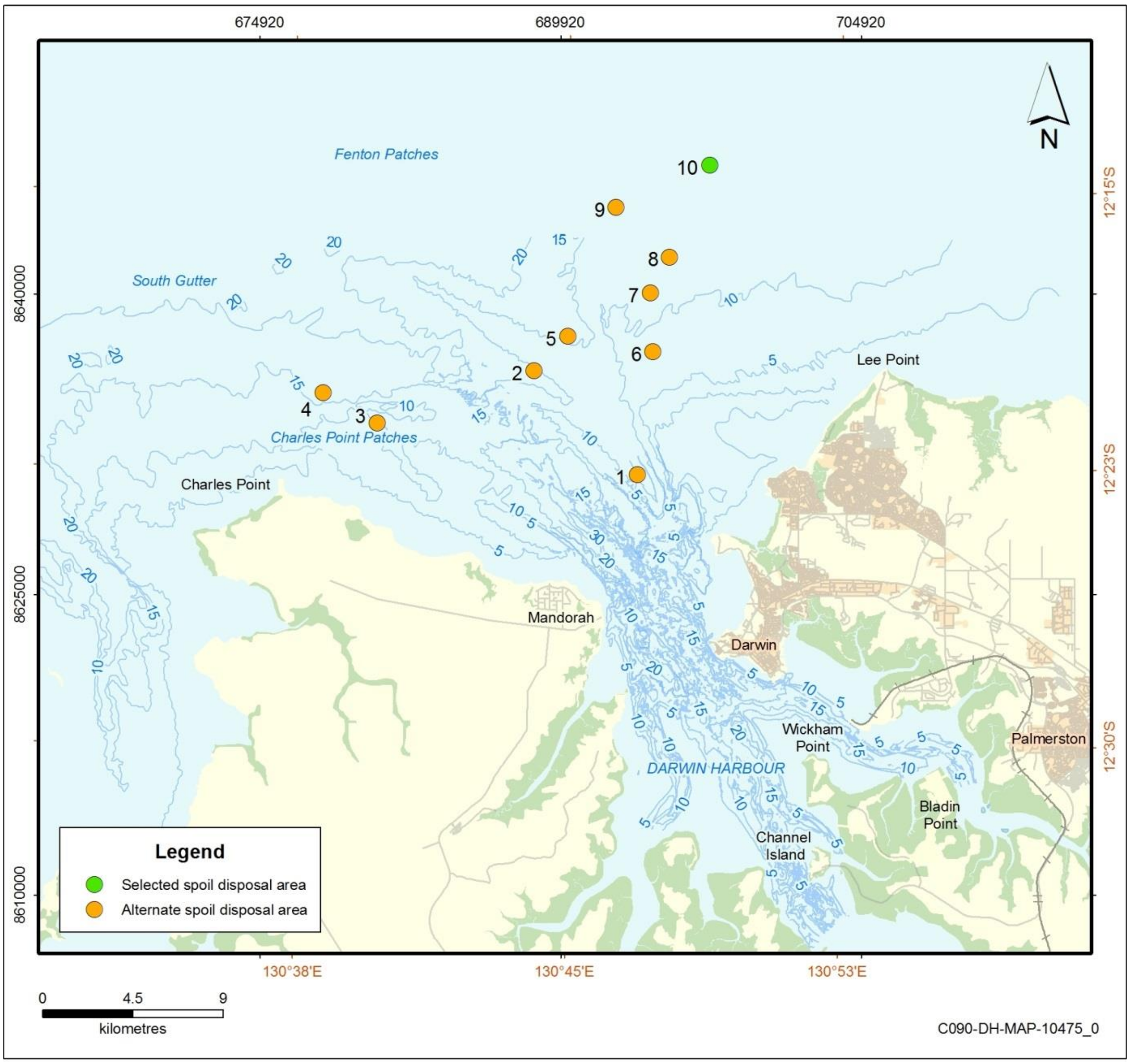

Figure 11-2: Sites outside Darwin Harbour, which were considered for offshore, spoil disposal

APPENDIX C: HERITAGE PROTECTION ZONES

The protection zone types applied to maintenance dredging and monitoring activities, and their requirements are summarised in Table 11-1.

Table 11-1: Protection zone types and requirements

Heritage protection zone type	Heritage protection zone requirements
Project no anchor zone	Project vessels are prohibited from anchoring in this zone but may traverse it.
Project exclusion zone	Project vessels are prohibited from entering, traversing or anchoring within this zone.
Legislated exclusion zone (closed waters)	All vessels Project or other are prohibited from entering, traversing or anchoring within this zone.

Table 11-2 lists all known wreck sites within Darwin Harbour, including their location and where applicable their respective protection zone. Protection zones as they apply specifically to TSHDs are shown in Figure 11-3, with protection zones applicable to all other vessel activities shown in Figure 11-4.

Table 11-2: Heritage wreck sites and protection zones relevant to vessels operating under this Maintenance DSDMP

Wreck name	Wreck type	Current protection status (legislated)	Heritage protection zone type*		Wreck centroid coordinates	Protection zone radius
			TSHDs and tugs	All other vessels		
Booya†	Shipwreck	Protected under the *Heritage Act 2011* (NT) Exclusion zone (closed waters) in force under the *Ports Management Act 2015*(NT)	Legislated exclusion zone		692574 (easting) 8629717 (northing)	150 m
Catalina 6	Sunken aircraft	Protected under the *Heritage Act 2011* (NT) Protected under the *Sunken Military Craft Act* (US) Exclusion zone (closed waters) in force under the *Ports Management Act 2015* (NT)	Legislated exclusion zone + buffer Project exclusion zone (70 m + 30 m)		704869 (easting) 8616771 (northing)	100 m
Catalina 5	Sunken aircraft	Protected under the *Heritage Act 2011* (NT) Protected under the *Sunken Military Craft Act* (US)	Project exclusion zone	Project no anchor zone	706776 (easting) 8616231 (northing)	100 m
Catalina 4	Sunken aircraft	Protected under the *Heritage Act 2011* (NT) Protected under the *Sunken Military Craft Act* (US)	Project exclusion zone	Project no anchor zone	706282 (easting) 8616273 (northing)	100 m
A65-115	Sunken aircraft	Protected under the *Heritage Act 2011* (NT)	Project no anchor zone		695842 (easting) 8625772 (northing)	150 m
British Motorist	Shipwreck	Protected under the *Heritage Act 2011* (NT) Protected under the *Historic Shipwrecks Act 1976* (Cwlth)	Project no anchor zone		699859 (easting) 8619357 (northing)	100 m
Catalina tail section	Sunken aircraft (part of)	None applicable.	Project no anchor zone		705926 (easting) 8616317 (northing)	50 m
Catalina 1	Sunken aircraft	Protected under the *Heritage Act 2011* (NT)	Project no anchor zone		709631 (easting) 8615276 (northing	100 m
Catalina 2	Sunken aircraft	None applicable	Project no anchor zone		706047 (easting) 8617662 (northing)	100 m

Wreck name	Wreck type	Current protection status (legislated)	Heritage protection zone type*	Wreck centroid	Protection
Catalina 3	Sunken aircraft	Protected under the *Heritage Act 2011* (NT)	Project no anchor zone	707419 (easting) 8617799 (northing)	100 m
DPC North	Heritage site	None applicable	Project no anchor zone	704171 (easting) 8616987 (northing)	35 m
DPC South	Heritage site	None applicable	Project no anchor zone	704168 (easting), 8616896 (northing)	35 m
Kelat	Shipwreck	Protected under the *Heritage Act 2011* (NT) Protected under the *Historic Shipwrecks Act 1976* (Cwlth)	Project no anchor zone	704067 (easting) 8617577 (northing)	150 m
Neptuna	Shipwreck	Protected under the *Heritage Act 2011* (NT) Protected under the *Historic Shipwrecks Act 1976* (Cwlth)	Project no anchor zone	700974 (easting) 8620589 (northing)	100 m
SS *Ellengowan*	Shipwreck	Protected under the *Heritage Act 2011* (NT) Protected under the *Historic Shipwrecks Act 1976* (Cwlth)	Project no anchor zone	703015 (easting) 8613248 (northing)	100 m
USS *Mauna Loa*	Shipwreck	Protected under the *Heritage Act 2011* (NT) Protected under the *Historic Shipwrecks Act 1976* (Cwlth) Protected under the *Sunken Military Craft Act* (US)	Project no anchor zone	697714 (easting) 8617804 (northing)	100 m
USS *Meigs*	Shipwreck	Protected under the *Heritage Act 2011* (NT) Protected under the *Historic Shipwrecks Act 1976* (Cwlth) Protected under the *Sunken Military Craft Act* (US)	Project no anchor zone	697615 (easting) 8618844 (northing)	100 m
USS *Peary*	Shipwreck	Protected under the *Heritage Act 2011* (NT) Protected under the *Historic Shipwrecks Act 1976* (Cwlth) Protected under the *Sunken Military Craft Act* (US)	Project no anchor zone	698868 (easting) 8620193 (northing)	100 m

Wreck name	**Wreck type**	**Current protection status (legislated)**	**Heritage protection zone type***	**Wreck centroid**	**Protection**
Zealandia	Shipwreck	Protected under the *Heritage Act 2011* (NT) Protected under the *Historic Shipwrecks Act 1976* (Cwlth)	Project no anchor zone	701128 (easting) 8619520 (northing)	100 m

* Where cell is merged the protection zone stated is applicable to all vessel types

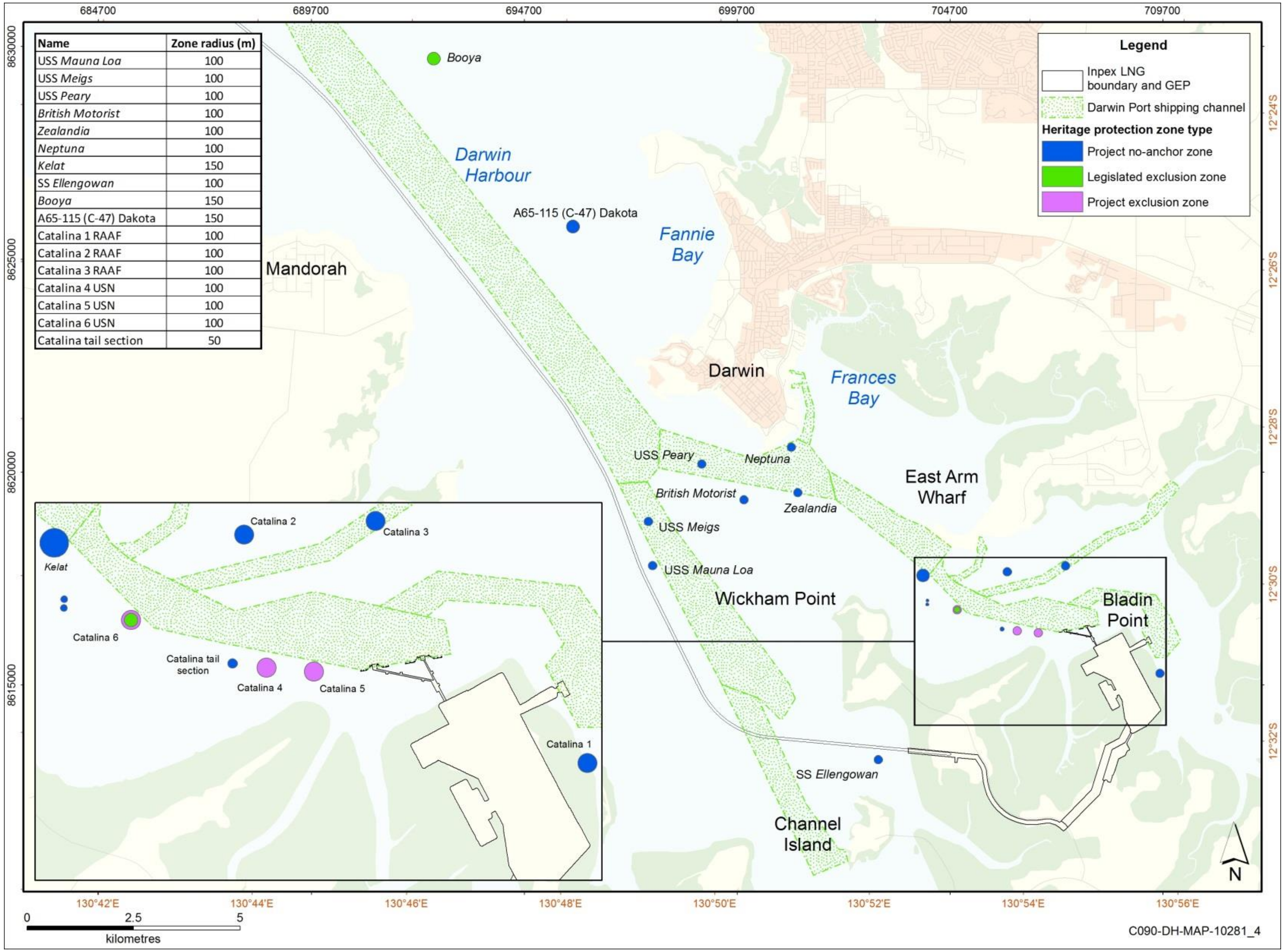

Figure 11-3: Heritage protection zones applicable to dredge vessels

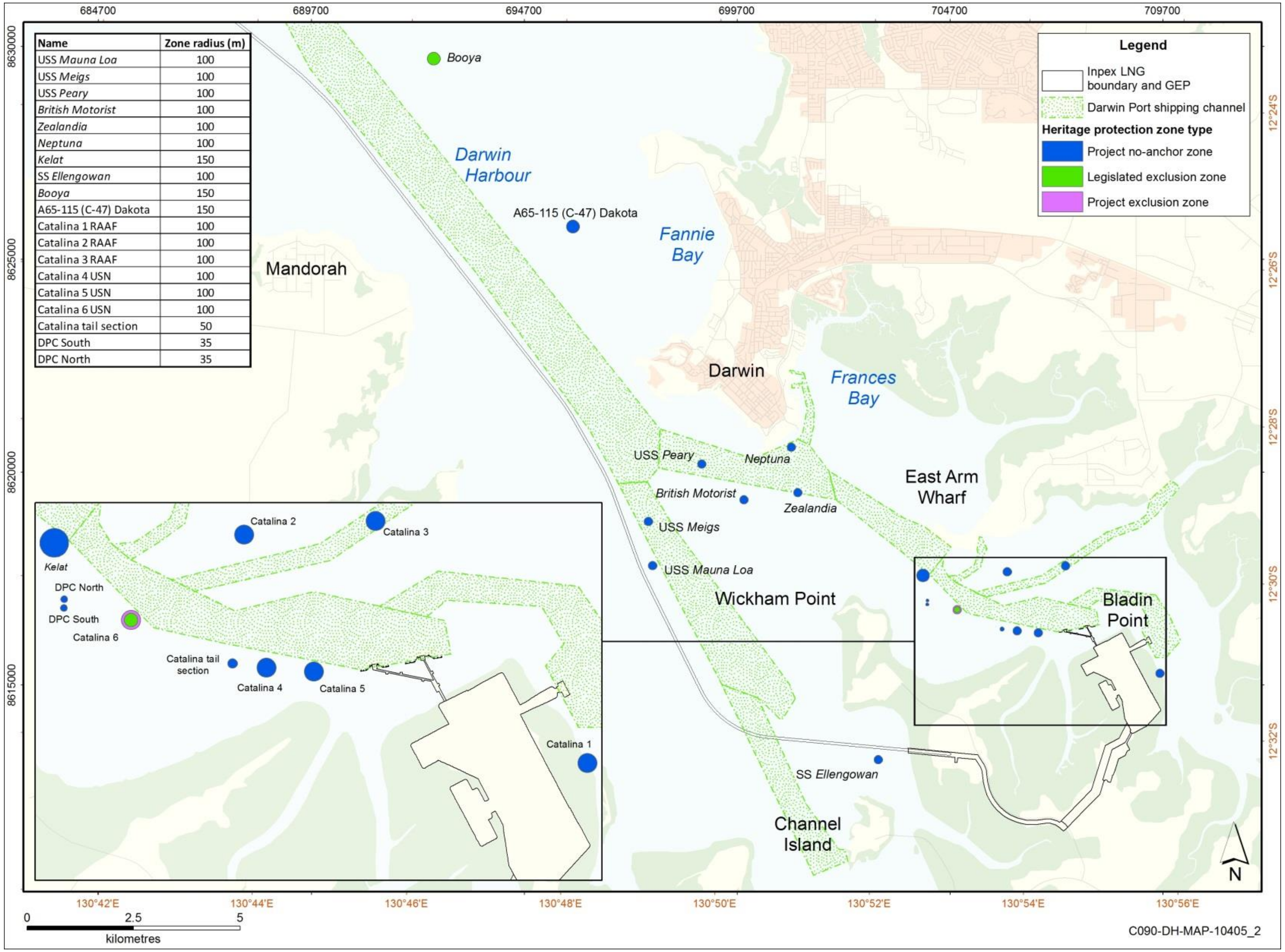

Figure 11-4: Heritage protection zones applicable to all other vessels (other than dredge vessels)

APPENDIX D: INPEX ENVIRONMENTAL POLICY

Environmental Policy

Objective

INPEX is a worldwide oil and gas exploration, development and production company committed to conducting each of its activities in a manner that is environmentally responsible.

Our objective is to develop an environment culture that is recognised as amongst "best in industry" that will exceed the performance expectations of our stakeholders.

We recognise our responsibility to adhere to the principles of sustainable development and we acknowledge that we owe a duty of care to both the natural environment and the communities in which we operate.

Strategy

To accomplish this, INPEX will:

- comply with applicable laws and regulations, environmental obligations and commitments and apply appropriate INPEX standards
- maintain a culture where people are empowered to intervene to prevent environmental harm
- set, measure and review environmental performance objectives and targets and ensure appropriate management of change processes are followed
- ensure our personnel have the necessary awareness, training, knowledge, resources and support, to meet environmental objectives and targets
- identify environmental hazards and risks associated with our business and manage these to levels that are 'as low as reasonably practicable' (ALARP)
- establish, implement, maintain and regularly test control measures associated with major environmental events
- establish, maintain and regularly test emergency management processes and procedures
- communicate openly on environmental issues with internal and external stakeholders
- provide clearly defined environmental performance expectations for our contractors and suppliers, and work collaboratively with them to attain these
- endeavour to prevent pollution and seek continual improvement with respect to emissions, discharges, wastes, energy efficiency and resource consumption
- actively promote the reduction of greenhouse gas emissions across our operations in a safe, technically and commercially viable manner
- drive continual improvement in environmental performance through monitoring, auditing and reviews.

Application

This policy applies to all INPEX-controlled activities in Australia and related project locations. It will be displayed at all company workplaces and on the company's intranet and it will be reviewed regularly.

Seiya Ito
President Director, Australia

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