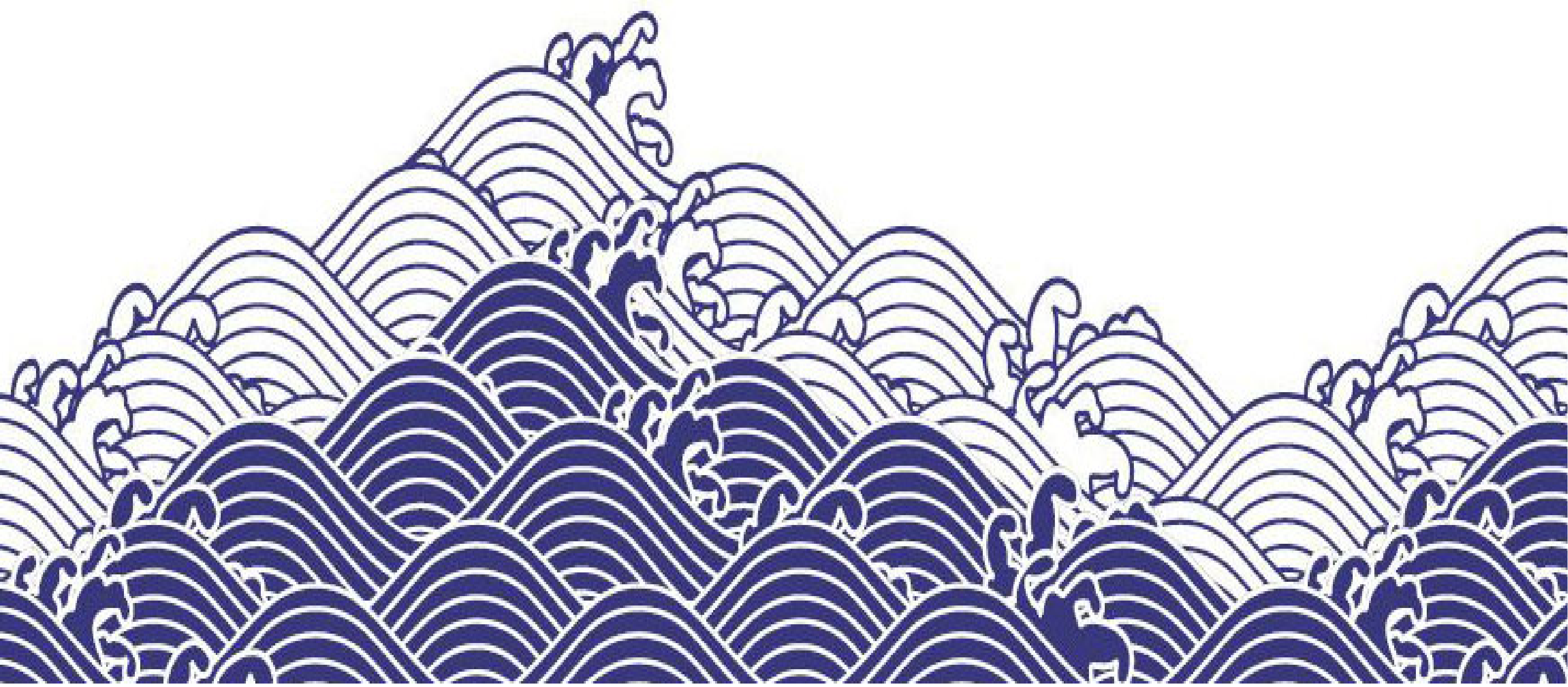
INPEX

Ichthys LNG Maintenance Dredging Program 2023-2027: Referral Report



ACKNOWLEDGEMENT

INPEX is committed to recognising and respecting Aboriginal and Torres Strait Islander peoples whose cultures have existed in Australia for tens of thousands of years.

We wish to pay respects to their Elders – past and present – and acknowledge the important role Aboriginal and Torres Strait Islander peoples continue to play in the development of our business in Australia.

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Terms, abbreviations and acronyms

Term, abbreviation or acronym	Meaning
2D	two-dimensional
3D	three-dimensional
AAPA	Aboriginal Areas Protection Authority (Northern Territory)
AAPowerLink	Australia-Asia PowerLink
ABWM Requirements	Australian Ballast Water Management Requirements. Version 7. (DAWR 2017)
AIMS	Australian Institute of Marine Science
ALARP	as low as reasonably practicable
BHD	backhoe dredge
BIA	biological important area
BTEX	benzene, toluene, ethylbenzene and xylene
CPF	central processing facility
CSD	cutter suction dredge
Cwlth	Commonwealth
DAWE	Department of Agriculture, Water and the Environment
Defence NT	Department of Defence – Northern Territory
DELWAQ	DELFT-3D Water Quality Module
DGPS	Differential Global Positioning System
DIPL-DHIP	Department of Infrastructure, Planning and Logistics – Darwin Harbour Infrastructure Projects
DPC	(the former) Darwin Port Corporation
Draft EIS	Draft Environmental Impact Statement (INPEX 2010)
DSDA	dredge spoil disposal area
EIS Supplement	Supplement to the Draft Environmental Impact Statement (INPEX 2011)

Term, abbreviation or acronym	Meaning
EO	explosive ordinance
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
GPS	global positioning system
Heritage Branch	Department of Territory Families, Housing and Communities—Heritage Branch (Northern Territory)
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
Maintenance DSDMP	Maintenance Dredging and Spoil Disposal Management Plan (INPEX Doc. No. L060-AH-PLN-70003)
Management triggers	Refers to specified criteria that, if exceeded during dredging and found to be attributable to dredging or spoil disposal activities, 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

Term, abbreviation or acronym	Meaning
MHWS	mean high water springs
MLWN	mean low water neaps
MMO	marine megafauna observer
MODIS	Moderate Resolution Imaging Spectroradiometer
MSL	mean sea level
NAGD	National Assessment Guidelines for Dredging (Commonwealth of Australia 2009)
NEMP	Ichthys Project Nearshore Environmental Monitoring Plan (Cardno 2014a)
NT	Northern Territory
NT EPA	Northern Territory Environment Protection Authority
OCP	organochlorine pesticide
OPP	organophosphate pesticides
PAH	polycyclic aromatic hydrocarbon
PAR	photosynthetically active radiation
PCB	polychlorinated biphenyl
PIANC	World Association for Waterborne Transport Infrastructure
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
Santos	Santos Barossa Pty Ltd
SEC	NT EPA Stakeholder Engagement and Consultation: Environmental Impact Assessment Guidance for Proponents (NT EPA 2021)
SN	spring-neap
SOPEP	Shipboard Oil Pollution Emergency Plan
SPL	sound pressure level

Term, abbreviation or acronym	Meaning
SSC	excess suspended sediment concentration
SQGV	sediment quality guideline value
TBT	tributyltin
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
TRH	total recoverable hydrocarbon
TSHD	trailing suction hopper dredge
TSS	total suspended solids
WAMSI	Western Australia Marine Science Institution
WMPC Act	*Waste Management and Pollution Control Act* (Northern Territory)
ZoHI	zone of high impact
ZoI	zone of influence
ZoMI	zone of moderate impact
Units of measurement	**Meaning**
°C	degrees Celsius
%	percent
dB re 1 µPa	sound pressure level
dB re 1µPa @ 1m (RMS)	root-mean-square source level

Term, abbreviation or acronym	Meaning
dB re 1 μPa^2/Hz	sound pressure spectrum level
ha	hectare
Hz	hertz
km	kilometre
km^2	square kilometre
kW	kilowatt
m	metre
m^2	square metre
m^3	cubic metre
m^{s-1}	metre per second
m^3 s^{-1}	cubic metres per second
mg/kg	milligram per kilogram
mg/L	milligram per litre
mm	millimetre
mm/h	millimetre per hour
mm/min	millimetre per minute
Mm^3	million cubic meters
Mt	million tonnes
mol quanta m^{-2} d^{-1}	moles per square metre per day
NTU	nephelometric turbidity unit
PSU	practical salinity unit
s	second
TDS	tonnes of dry solids
tonnes m^{-1} d^{-1}	tonnes per metre per day

Term, abbreviation or acronym	Meaning
µg/kg	microgram per kilogram
µm	micrometre

EXECUTIVE SUMMARY

Project description

INPEX Operations Australia Pty Ltd (INPEX), on behalf of its joint venture partners, operates the Ichthys LNG Project (Project) located offshore Western Australia and onshore at Bladin Point in the Northern Territory. To support the onshore infrastructure at Bladin Point, capital dredging works were carried out within Darwin Harbour's East Arm between 2012 and 2014. To maintain safe operations of the onshore processing plant and associated product carriers, INPEX maintains relevant approvals to undertake maintenance dredging activities, within the existing dredged footprint (herein referred to as the dredge area) in Darwin Harbour over a five-year period.

Natural accretion of sediment has the potential to tidally restrict product carriers. This, and the requirement for periodic maintenance dredging, was assessed in the Ichthys LNG Final Environmental Impact Statement[1]. To date no maintenance dredging activities have been required. However, it is anticipated that at some stage during the next five-years maintenance dredging activities will be required. Approvals associated with the original maintenance dredging activity are due to expire in early 2023. This maintenance dredging referral seeks to obtain relevant maintenance dredging approvals for the next five-year period.

This maintenance dredging referral allows for a maximum of 1.5 Mm^3 of material to be dredged from the dredge area 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 at any time within the five-year period. Dredging is proposed to be undertaken by a single trailing suction hopper dredger (TSHD) with dredged material transported and placed at the previously used 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 (Figure ES-1).

Environmental assessment and management

Assessment of the proposed maintenance dredging activity potential impacts on the Northern Territory Environment Protection Authority (NT EPA) environmental factors identified three of the listed 14 environmental factors may be impacted (Table 0 1). In addition, there is also the potential for cumulative impacts to occur in the event of sequential or concurrent harbour-wide dredging campaigns.

A systematic risk assessment process was adopted for the environmental management of the proposed maintenance dredging activity. This process aligns with INPEX's Environmental Policy, which requires the identification of environmental hazards and risks associated with business activities, and management of these to levels that are 'as low as reasonably practicable' (ALARP). Environmental management frameworks have been developed and proposed to be implemented to manage potential impacts to ALARP; and include a suite of management actions/controls. A summary of proposed management actions/controls applicable to each of the three environmental factors is provided in Table ES-1.

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[1] The Ichthys Gas Field Development Project Draft Environmental Impact Statement (INPEX 2010) and the Ichthys Gas Field Development Project Supplement to the Draft Environmental Impact Statement (INPEX 2011) together make up the "Final EIS". The Ichthys LNG Final EIS noted that maintenance dredging would be required throughout operations to maintain a safe and navigable channel including berthing and loading operations. Modelling indicated a potential frequency of approximately 10 years.

Dredge Spoil Disposal Area

Setout Point	Latitude	Longitude	Northing	Easting
A	-12.220	130.814	8648498	697330
B	-12.235	130.831	8646768	699134
C	-12.268	130.799	8643159	695674
D	-12.252	130.782	8644889	693869

Figure ES-1: Location of the dredge area and DSDA

Table ES-1: Environmental factors potentially impacted by maintenance dredging activities

NT EPA Factor	Environmental values and sensitivities	Potential impact	Key management controls
Marine environmental quality	• quality of the water, sediment and biota • ecosystem health condition	The proposed action has the potential to impact on marine environmental quality as a result of the following: • sediment-related impacts to sensitive receptors (mangroves, coral and seagrass) • routine vessel discharges • mismanagement of waste • unplanned events resulting in loss of containment chemicals or hydrocarbons.	Management of sediment related effects: • water quality monitoring to inform adaptive management of potential sediment-related impacts. • restricting sediment generating activities (i.e. overflow) to avoid environmental windows (e.g. coral spawning). Waste and liquid discharge management: • records, segregation and storage of all chemicals and hazardous wastes in accordance with relevant material safety data sheets and regulatory requirements. • discharges (e.g. bilge water, vessel food scraps, sewage) from vessels will be managed and recorded, in accordance with the Marine Pollution Act 1999 (NT), and the intent of MARPOL 73/78. • hydrocarbon and chemical management. • a Shipboard Oil Pollution Emergency Plan will be maintained in accordance with MARPOL 73/78. • hydrocarbon and chemicals stored on deck will be bunded with net capacity of any bund at least 110% of the total volume of the largest storage vessel. • refuelling within Darwin Harbour is undertaken in accordance with National, Northern Territory and Darwin Port requirements. • sufficient and appropriate first strike spill response materials will be 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.

NT EPA Factor	Environmental values and sensitivities	Potential impact	Key management controls
			• no spill related (oily) waste products will be discharged to open waters.
Marine ecosystems	• conservation of significant marine and coastal fauna and critical habitat such as nesting, breeding or foraging habitat • conservation of significant marine and coastal benthos, flora and vegetation (seagrass meadows, sponge gardens, coral reefs, mangrove communities and salt marshes)	The proposed action, has the potential to impact on marine ecosystems as a result of the following: • introduction of marine pests • interactions (vessel collision) or entrainment of marine megafauna during dredging activities • smothering or removal of habitat beyond the approved maintenance dredging and disposal footprints.	Introduced marine pest management: • all vessels will comply with the requirements of the Biosecurity Act 2015 and the Australian Ballast Water Management Requirements (DAWE 2020). • all vessels mobilised from outside Darwin Harbour will complete a vessel biofouling risk assessment and implement mitigation measures commensurate with the level of risk prior to the commencement of activity. • all vessels will maintain a biofouling record book in accordance with the Guidelines for the Control and Management of Ships' Biofouling to Minimize the transfer of Invasive Aquatic Species (IMO 2012) . Marine megafauna management (vessel collision and entrainment in dredge equipment): • all vessel masters will comply with the approach distances outlined in the Australian National Guidelines for Whale and Dolphin Watching 2017 (Commonwealth of Australia 2017), as far as reasonably practicable. • during dredging and spoil disposal activities (daylight hours) observation and exclusion zones for protected marine megafauna will be implemented and monitored by a marine megafauna observer. • turtle protection chains will be installed on TSHD draghead/s. • TSHD pumps will only start when the draghead is as close as practicable to the seabed and cease as soon as possible after the completion of dredging.

NT EPA Factor	Environmental values and sensitivities	Potential impact	Key management controls
			• screens will be installed and maintained on the overflow to assist in the identification of any marine turtle or sawfish entrainment. Dredge materials management: • the position of the dredge vessel within the dredge area using Differential Global Positioning System (DGPS) will be established prior to commencement of dredging. • the position of the dredge vessel will be established within the DSDA prior to and during disposal using DGPS.
Culture and heritage	• sacred sites • historic heritage and places	The proposed action, specifically the dredge area, is located in close proximity to several Catalina flying-boat wrecks, ship wrecks declared areas and sacred sites.	Heritage and sacred site management: • Aboriginal Area Protection Authority Certificates relevant to maintenance dredging and monitoring activities are obtained. • establishment of maintenance dredging no anchor or exclusion zones around heritage wreck/sunken aircraft sites. • provision of sacred site and heritage wreck/sunken aircraft data files to contractors for inclusion in vessel navigation systems. • for wreck/sunken aircraft which are located directly adjacent to dredging activities, additional buffer zones will be established within on-board dredge vessel navigation systems. These will include an early warning alarm that is activated upon entry into the buffer zone, and a secondary alarm that is activated upon entry into the heritage protection zone.

NT EPA Factor	Environmental values and sensitivities	Potential impact	Key management controls
			development and implementation of a chance find procedure to be followed in the event of discovery of previously unidentified heritage object during dredging activities.

Stakeholder engagement

Stakeholder consultation for the proposed maintenance dredging activity was undertaken to inform the development of the Maintenance Dredge and Spoil Disposal Management Plan and applicable approval documentation (referral and waste discharge licence application). Stakeholder engagement will also be undertaken once a maintenance dredging campaign is determined to be required.

Conclusion

Based on the systematic risk assessment process, the residual risk for the majority of potential impacts associated with the proposed dredging activity are considered low. Only four potential impacts have a residual risk of moderate and are associated with unplanned events (Table ES-2). It is worth noting that none of these potential impacts occurred during the capital dredging project, which was an order of magnitude greater in intensity and duration.

Table ES-2: Summary of potential impacts with residual risk moderate or above

Potential impact	Consequence	Likelihood	Residual risk
Major hydrocarbon spill associated with equipment/ operator failure (e.g. loss of containment during bunkering)	Moderate	Highly unlikely	Moderate
Accidental introduction of marine pests	Significant	Remote	Moderate
Entrainment of marine turtles or sawfish causing injury or mortality	Moderate	Highly unlikely	Moderate
Vessel movements and anchoring – damage to protected heritage wreck/sunken air craft or sacred sites.	Moderate	Highly unlikely	Moderate

1 INTRODUCTION

INPEX Operations Australia Pty Ltd (INPEX), on behalf of its joint venture partners, operates the Ichthys LNG Project (Project) located offshore Western Australia and onshore at Bladin Point in the Northern Territory. Drawing on the hydrocarbon resources of the Ichthys gas and condensate field in the Browse Basin (offshore Western Australia), the Project is expected to produce 9.3 Mt of liquefied natural gas (LNG) and 1.6 Mt of liquefied petroleum gases per annum, along with approximately 100,000 barrels of condensate per day by 2024.

The extraction of natural gas and condensate is carried out via a floating semi-submersible central processing facility (CPF) at the Ichthys Field. This removes water and most of the condensate from the reservoir fluids and the separated condensate is 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 is exported directly from the field at an average rate of up to 85,000 barrels per day.

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

To support the nearshore infrastructure at Bladin Point, capital dredging works were carried out within Darwin Harbour's East Arm. Approximately 16.1 Mm3 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 three backhoe dredges (BHDs) loading six split hopper barges, a cutter suction dredge (CSD) and three trailing suction hopper dredges (TSHD). Split hopper barges and TSHD 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 time, some sediment will naturally accumulate within areas of the existing dredged footprint (herein referred to as the dredge area), having the potential to impact operability of the onshore processing plant, in terms of tidally restricting product carriers. Consequently, periodic maintenance dredging within the dredge area is required.

In 2018 INPEX obtained relevant approvals to undertake maintenance dredging activities, as required, within the existing dredge area over a five-year period (2018-2022). To date no maintenance dredging activities have been required; however, it is anticipated that during the next five-years maintenance dredging will be required.

Approvals associated with the original approved maintenance dredging activity are due for renewal in in early 2023, as such INPEX is in the process of renewing these

1.1 Proponent details

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

The addresses of INPEX offices in Australia are as follows:

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

1.2 Publication statement

This referral and draft Maintenance Dredge and Spoil Disposal Management Plan (Maintenance DSDMP; Appendix A) have been prepared by suitably qualified persons as detailed in Table 1-1.

Table 1-1: Referral preparation and impact assessment

Name	Experience
Josh Corbett	Mr Corbett is a Senior Environmental Advisor – Marine at INPEX with ~15 years of experience developing, implementing and managing environmental monitoring programs, offsets and State/Territory and Commonwealth approvals. Mr Corbett has worked extensively within Darwin Harbour: • implementing the $48M Nearshore Environmental Management Plan for the Projects 16.1 Mm^3 capital dredging campaign, including presentations to an independent dredge expert panel consisting of nine specialists • developing and implementing nearshore monitoring programs for the operations of the onshore processing plant on Bladin Point • manages the $20M Darwin Harbour Integrated Marine Monitoring and Research Program with the Northern Territory Government • is a member of the Darwin Harbour Integrated Monitoring and Research Coordination Committee.
Obelia Akerman	Ms Akerman is a Senior Environmental Approvals Advisor at INPEX with ~15 years of experience of developing, implementing and managing offshore and onshore state/territory and Commonwealth environmental approvals. Ms Akerman has worked on the Project for over a decade and has a comprehensive knowledge of the Northern Territory environmental approvals processes and requirements playing a key role in the majority of the Projects onshore and nearshore approvals to date, including but not limited to: • environmental impact statement • 16.1 Mm^3 capital dredging campaign approvals • onshore construction and operations approvals • GEP (construction, commissioning and operations) approvals • current maintenance dredging approval.

In accordance with Condition 10 (k) of the Ichthys LNG Project approval decision EPBC 2008/4208, independent experts were 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 the Maintenance DSDMP are provided in Table 1-2 with the outcomes of the expert review provided in Appendix B.

Table 1-2: Draft Maintenance Dredge and Spoil Disposal Management Plan expert review

Name	Experience
Dr Paul Erftemeijer (Benthic ecology specialist)	Dr Erftemeijer has 30 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. He was invited member of an Expert Panel to draft a synthesis of the effects of dredging on the Great Barrier Reef. He was commissioned by United Nations Environment Programme to draft 'Guidelines for Seagrass Restoration in the Western Indian Ocean region' and a 'Guidance Manual for Dredging and Reclamation in the Arabian/Persian Gulf region'. He holds an adjunct position as Research Fellow at the University of Western Australia.
Dr Ross Jones (Coral specialist)	Dr Jones has over 30 years of experience in ecotoxicology, water quality issues on coral reefs, in particular sediments on juvenile and adult corals. He currently holds a position as Senior Principal Research Scientist with the Australian Institute of Marine Science (AIMS) and is an Adjunct Associate Professor at the University of Western Australia. Between 2012 and 2019 he was the Western Australian Marine Science Institution Dredging Science Node Leader; which conducted world-class marine research to enhance capacity within Government and the private sector to predict and manage the environmental impacts of dredging. Since 2015 he has also been the AIMS Research Team Lead for tropical ecotoxicology and risk assessment. Further, he has previously served as a member of the Dredging Technical Advice Panel for the Chevron Wheatstone Project and Independent Technical Advisory Committee for the Port of Townsville Chanel Upgrade Project.
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 Ichthys Project Dredge Expert Panel during INPEX's capital dredging program. Mr Pronk's 40 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.

2 PROPOSAL DESCRIPTION

2.1 Maintenance dredging campaigns

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).

This maintenance dredging referral allows 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[2].

2.1.1 Timing of maintenance dredging campaigns

No decision has been made with regard to timing of the first maintenance dredging campaign. However hydrographic surveys, which monitor accretion and erosion of sediment within the dredge area are undertaken annually. The results of these surveys, in addition to other aspects such as, the availability of dredge vessels, planned shutdown periods for maintenance, and the operational schedule of the Project inform the decision for maintenance dredging campaign timing. Environmental windows (e.g. coral spawning) may also be considered when planning a maintenance dredging campaign.

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. As such, contingency has been included to provide flexibility, as the sediment infill rate associated with major natural events has yet to be well established.

During a maintenance dredging campaign, the Dredging Contractor may undertake dredging and spoil disposal activities 24 hours per day, 7 days per week.

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[2] 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 typically ranging from 426,000 m^3 to 766,000 m^3, although following significant flood events volumes can exceed 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 averaged ~363,000 m^3 per annum between 2004 and 2014 (State of Queensland (Department of Transport and Main Roads) 2016).

2.1.2 Rates of accretion and ersosion

Annual accretion for the turning basin (includes jetty pocket, berth area and turning area) adjacent to the Projects onshore facility since 2014 has ranged between -630 m3 and 113,000 m3 (Table 2-1). The erosion reported in 2019 is thought to be associated with scouring of recently deposited sediments by product tankers and associated tugs following start-up (first offtake occurred 30 September 2018) and more than a year of operations[3]. Similarly, offtake frequency increased in 2020 and likely contributed to the lower measured accretion volume in 2020 compared to previous years (Table 2-1). 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 C.

Table 2-1: Reported annual accretion (m^3) within dredge area turning basin

Year	Jetty Pocket	Berth Area	Turning Area	Total
Area (ha)	14.0	32.8	47.6	94.4
2015	21,138	29,294	16,425	66,857
2016	13,262	28,847	18,457	60,566
2017	24,214	39,305	34,333	97,852
2018	24,637	51,429	36,679	112,745
2019	-162	-3,601	3,133	-630
2020	4,750	4,054	6,275	15,079
2021	10,262	5,029	42,216	57,506
Total	**98,100**	**154,356**	**157,519**	**409,975**

2.2 Work locations

The following sections describe the proposed maintenance dredging and spoil disposal work locations, shown in Figure 2-1.

[3] Hydrographic surveys were completed in April 2018 and November 2019

Dredge Spoil Disposal Area				
Setout Point	Latitude	Longitude	Northing	Easting
A	-12.220	130.814	8648498	697330
B	-12.235	130.831	8646768	699134
C	-12.268	130.799	8643159	695674
D	-12.252	130.782	8644889	693869

Figure 2-1: Location of the dredge area and DSDA

2.2.1 Dredge area

The dredge area lies within East Arm, Darwin Harbour, adjacent to the onshore processing plant and East Arm Wharf (Figure 2-1). The dredge area is characterised by soft-bottom benthos, which is well represented regionally.

The dredge area does not encompass any areas of coral, seagrass or mangrove habitat. Further, the dredge area does not overlap any protected areas associated with shipwrecks, sunken aircraft or sacred sites. Further details of the regional environment are provided in Section 3.

Maintenance dredging may be undertaken anywhere within the dredge area as defined in Figure 2-1 provided that the total dredging volume remains within that approved. Maintenance dredging will not extend beyond the boundary (depth and width) of the area[4] 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 2-1. 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.

2.2.2 Dredge spoil disposal area

The DSDA is located to the north of Darwin Harbour, within the Beagle Gulf, approximately 12 km north-west of Lee Point (Figure 2-1). 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 does not encompass any areas of coral, seagrass or mangrove habitat. Further, the DSDA does not overlap any protected areas associated with shipwrecks, aircraft or sacred sites, and is located away from shipping navigational channels and recreational fishing grounds. Further details of the regional environment are provided in Section 3.

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 DSDA used for the capital dredging program. Based on review of the post-capital dredging hydrographic survey of the DSDA in mid-2014 the remaining capacity is calculated to be approximately 7 Mm^3. The DSDA has not been used for spoil disposal since the post-capital dredging hydrographic survey was completed. Further information regarding the original site selection process for the DSDA is provided in Section 2.5.2.

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.

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

2.2.3 Land tenure and planning

The proposed dredge area does not fall under any planning zone; however, it is located entirely within the NT Planning Scheme 2020 "Darwin Harbour[5] Dredging Overlay", which requires planning consent for dredging activities within this overlay.

The DSDA is located outside of the NT Planning Scheme boundaries and Darwin Harbour, in the Beagle Gulf.

The land tenure and relevant NT Portions applicable to the dredge area and DSDA are presented in Table 2-2.

Table 2-2: Land tenure and NT Portion

Work location	Land tenure	NT Portion
Dredge area	Vacant Crown Land	7168
DSDA	Vacant Crown Land	7634 (A) Beagle Gulf

2.2.4 Land use and history

The dredge area is a previously disturbed area, which was dredged during the INPEX capital dredging program. Current uses of the area include commercial shipping (predominantly product tankers associated with the Project) and recreational boating. In addition, fishing and scuba-diving are likely to be undertaken on wreck/sunken aircraft sites located adjacent to the dredge area.

The proposed DSDA was previously used as a spoil disposal area during the Projects capital dredging program. No other spoil disposal activities have been undertaken in the area since completion of the capital program. Uses of the area include commercial shipping and recreational boating.

2.3 Work method and rational

Dredging equipment and method selection for this maintenance referral took into consideration the content provided in the PIANC 100 Report[6] (Netzband et al. 2009) and where relevant, 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.

[5] The NT Planning Scheme 2020 defines Darwin Harbour as being the waters south of a straight line between Charles Point and Gunn Point.

[6] 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.

2.3.1 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. BHD) (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 2.2.1). 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 3.1.5). 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 3-3). 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 2.3.2.
- 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).

2.3.2 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 2-2). 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).[7] 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.

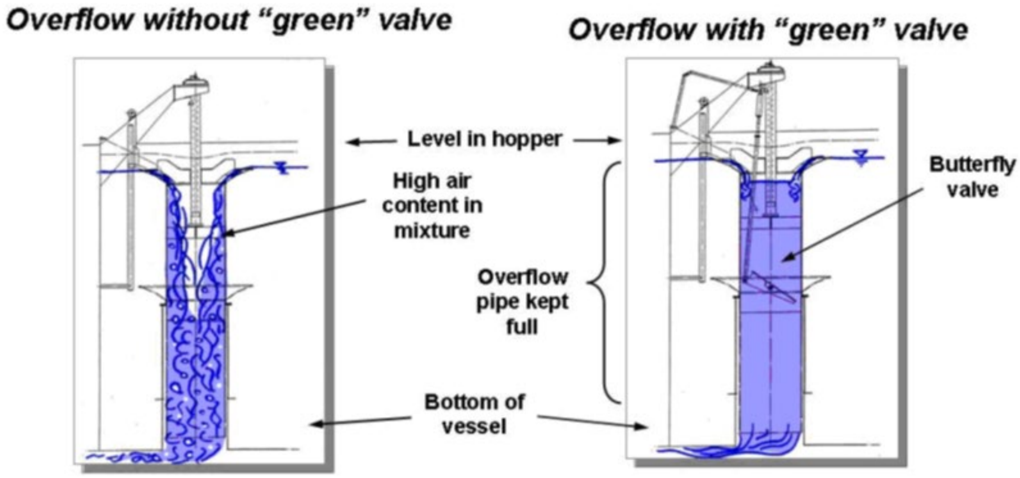

Figure 2-2: Overflow fitted with green valve

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.

[7] 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.

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 3.3.2). 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 6.3). 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 6.3).

2.3.3 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.

2.4 Seabed leveller

Seabed levelling may be required in the dredge area or DSDA, 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 dredging referral, seabed levelling will be used on an as needs basis, this may include but not limited to high spot removal during a maintenance campaign or ad hoc high spot removal to postpone the need for maintenance dredging.

2.5 Site selection and alternatives/options

2.5.1 Dredge area

An assessment of jetty design and the associated dredge area options were undertaken to inform the Ichthys LNG Final EIS[8] (INPEX 2010, 2011). This included a series of complex loading and navigation studies, geotechnical and environmental surveys, and safety risk assessments. The dredge area design avoids maritime heritage sites, maintains the safety buffer necessary to protect the operations of the East Arm Wharf port facilities and the ability to efficiently and safely transit, berth and load product tankers.

The Ichthys LNG Final EIS (INPEX 2010, 2011) also noted that maintenance dredging would be required throughout operations to maintain a safe and navigable channel including berthing and loading operations. Modelling indicated a potential frequency of approximately 10 years, although actual volume and frequency to be dredged would be determined based on annual hydrographic surveys and accessibility (e.g. transit, berthing and loading). As such, maintenance dredging cannot be avoided, it is required in order to maintain:

- safe navigation access for product tankers during transit to and from the Projects product loading jetties
- safe product tanker under-keel clearance when fully loaded and alongside jetty infrastructure.

This is critical for ensuring the continued safe operation of the projects onshore processing plant.

2.5.2 Dredge spoil disposal area

An assessment of spoil disposal options for the capital dredging program was undertaken to inform the Ichthys LNG 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 for land reclamation.

[8] The Ichthys Gas Field Development Project Draft Environmental Impact Statement (INPEX 2010) and the Ichthys Gas Field Development Project Supplement to the Draft Environmental Impact Statement (INPEX 2011) together make up the “Final EIS”.

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 (refer to Section 3.1.5) 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, the former Darwin Port Corporation (DPC), the Amateur Fishermen's Association of the Northern Territory 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 2-3), 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 2-3).

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 Ichthys LNG Draft EIS (INPEX 2010).

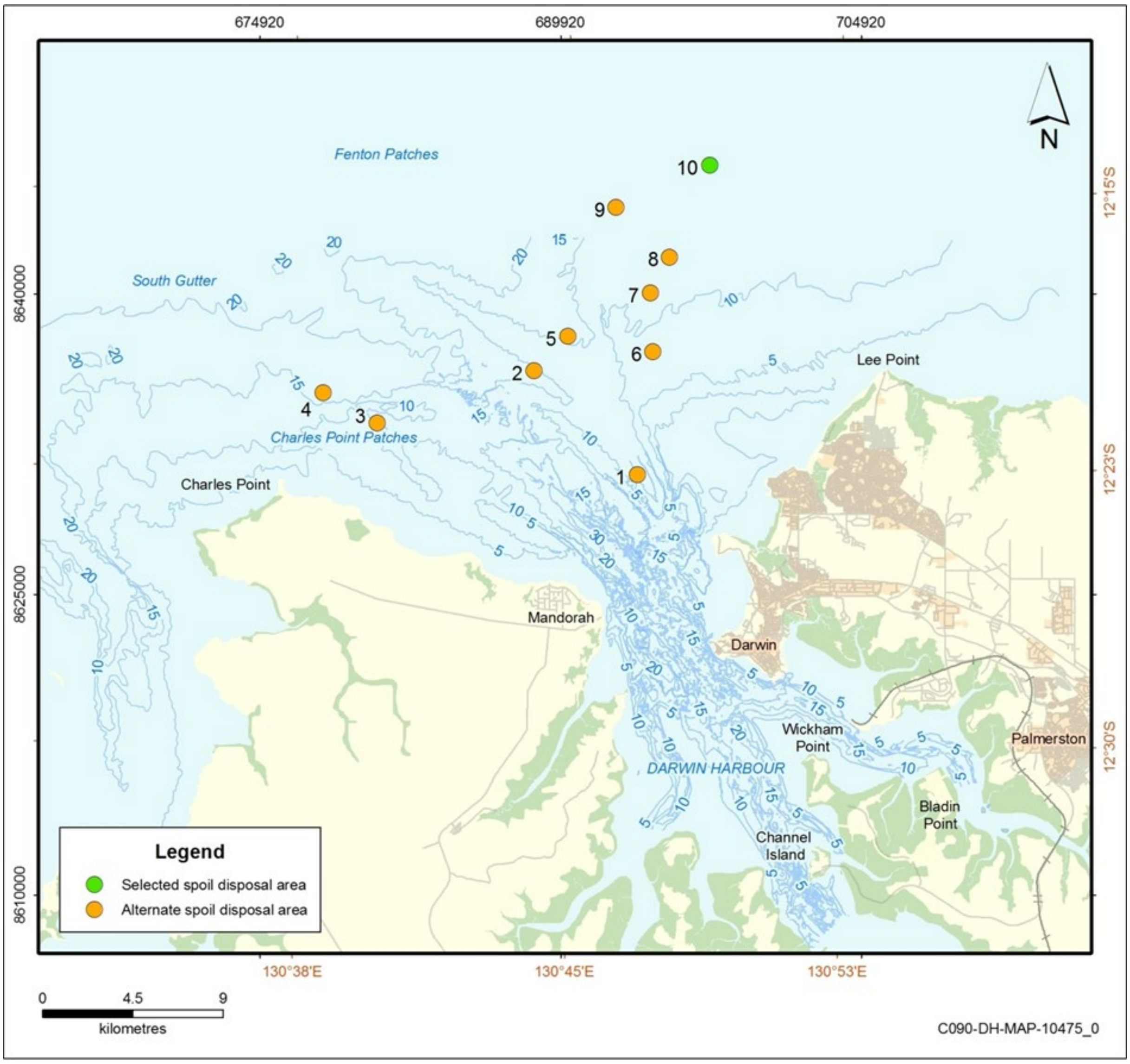

Figure 2-3: Sites outside Darwin Harbour, which were considered for offshore spoil disposal

3 EXISTING ENVIRONMENT

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

3.1 Physical environment

3.1.1 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 31°C maximum (BOM 2021a). The mean annual rainfall for Darwin is 1,723 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 3-1 (BOM 2021a).

Table 3-1: Average monthly rainfall for Darwin (measured as mm)

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Mean	431	369	312	102	21	2	1	5	17	71	142	250
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 2021a, based on data collected over 80 years (1941-2021)

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 3-1 using representative 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. 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 2021b). In 2018 Tropical Cyclone Marcus passed directly over Darwin Harbour as a category 2 cyclone; and was a very small cyclone at this point in time (BOM 2019). A 90 cm storm surge was recorded at the Darwin tidal gauge, although the passage of the cyclone coincided with a low tide, as such the surge did not exceed the highest astronomical tide.

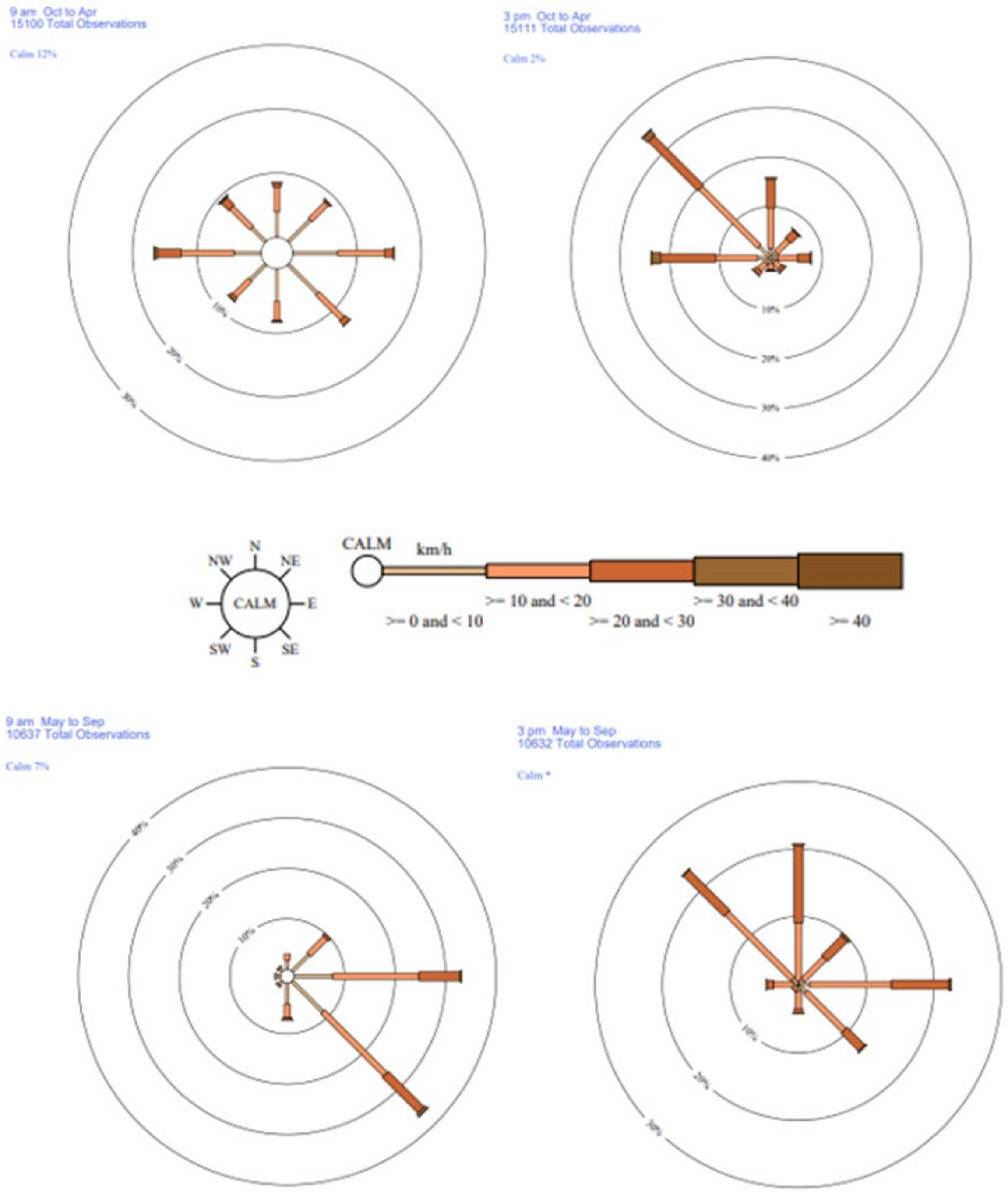

Figure 3-1: Indicative wet season and dry season wind roses for Darwin Airport based on data from 1942 to 2016 (BOM 2021c)

3.1.2 Bathymetry and seafloor geology

Darwin Harbour is a large ria (drowned river valley) system flanked by shoreline platforms and subtidal flats (Nicholas et al. 2019; Siwabessy et al. 2019) and covers 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 natural channel for the Port of Darwin is around 15 to 30 m deep, with a maximum depth of 42 m (Figure 3-2) (INPEX 2010; Nicholas et al. 2019). 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 15 m below LAT and leads into the Projects access channel and turning basin, which was dredged to 13.5 m below LAT. A deeper channel extends into Middle Arm, up to the western side of Channel Island (INPEX 2010; Nicholas et al. 2019). While parts of the channel seabed are comprised of bedrock, most areas of Darwin Harbour are dominated by unconsolidated sediment forming a range of features including mud flats, ripples and sub-aqueous dunes (Nicholas et al. 2019).

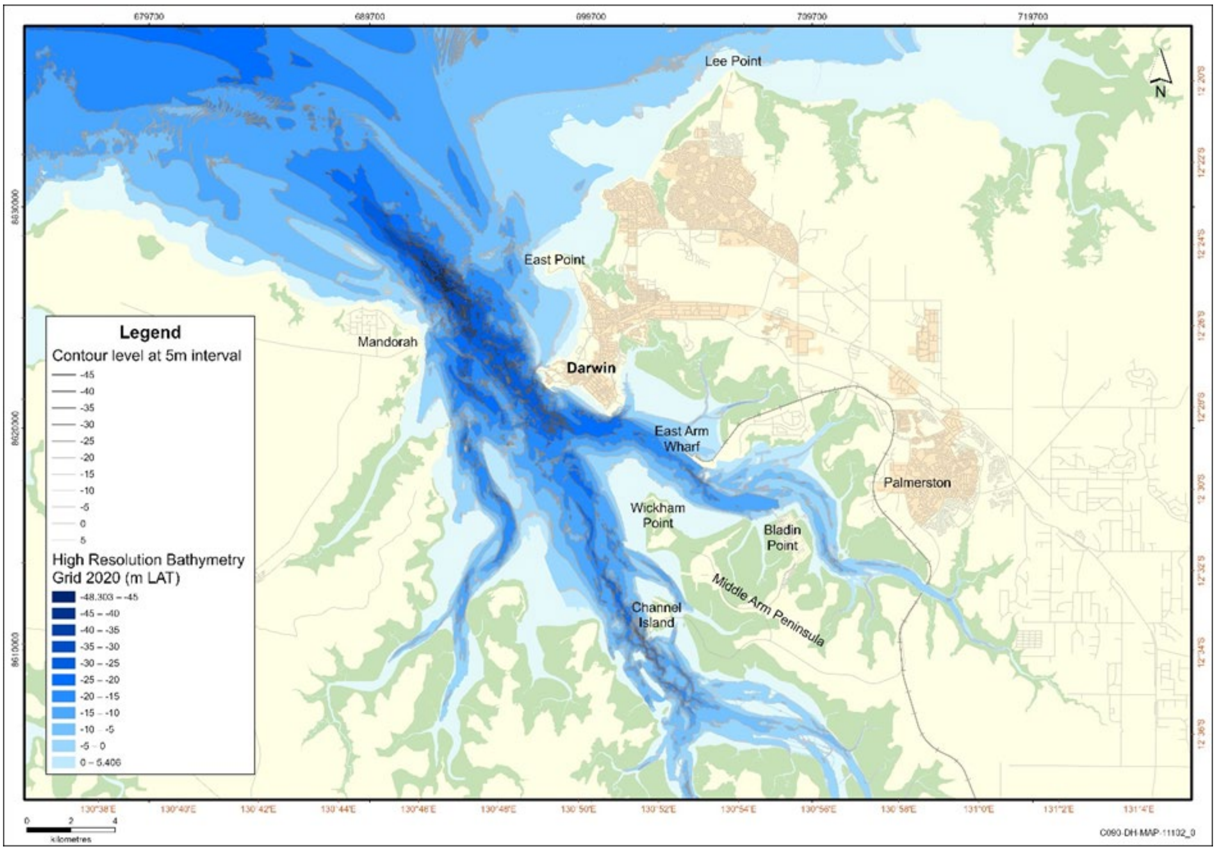

Figure 3-2: Bathymetry of Darwin Harbour

3.1.3 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, Li 2013). 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 m^{s-1} during spring tides (HRW 2013a) (Figure 3-3).

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).

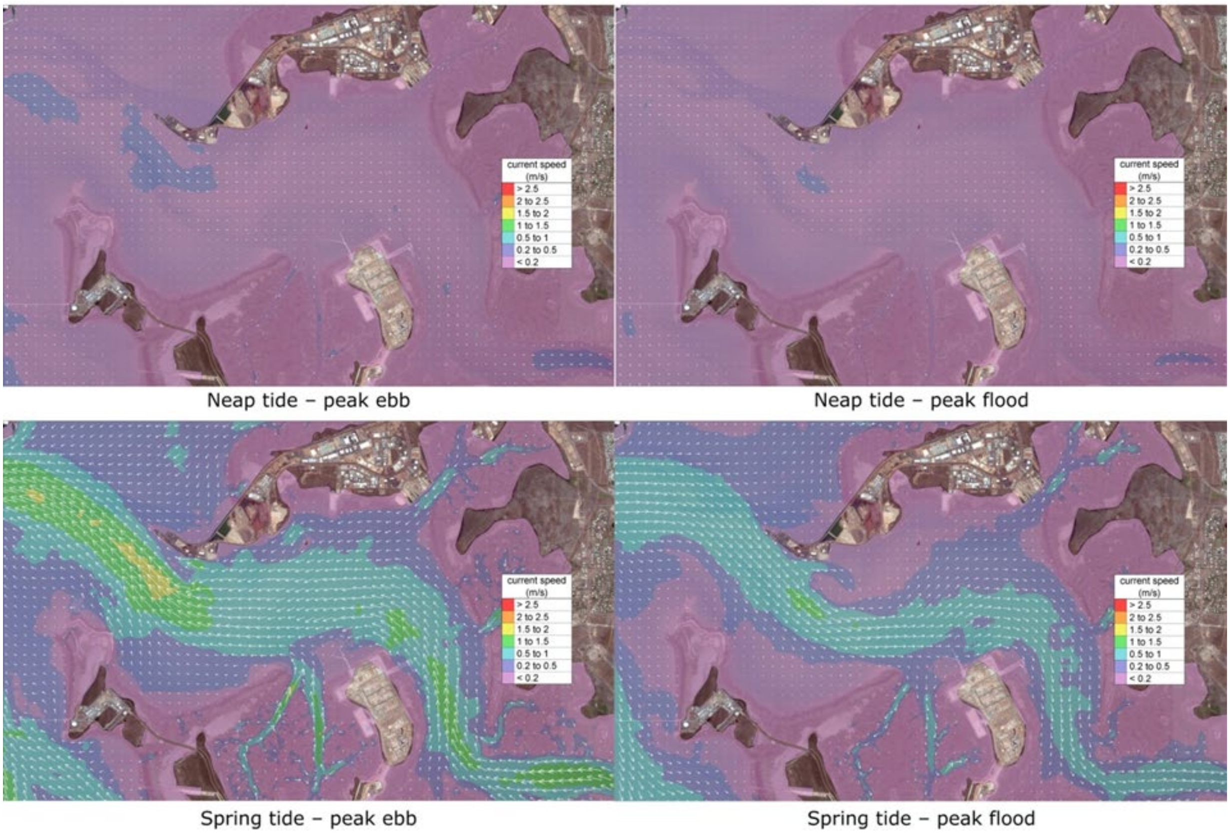

Figure 3-3: Modelled peak current speeds for each tidal state

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 Beagle 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).

3.1.4 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 to 35 PSU in the mid-Harbour down to near 0 PSU further up rivers (Makarynska 2019), 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 between 35 and 40 PSU in upstream waters where there is limited tidal flushing (Cardno 2014b, Makarynska 2019).

Turbidity

Turbidity is a measure of the amount of light scattering through the water column caused by particles of suspended sediment (Stoddart & Anstee 2004), and can also be affected by large concentrations of dissolved organic matter (Cassilles Southgate and Fortune 2018). 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 dredging referral (Section 5).

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 (Cassilles Southgate and Fortune 2018). 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 3-4).

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 3-5) 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 to 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).

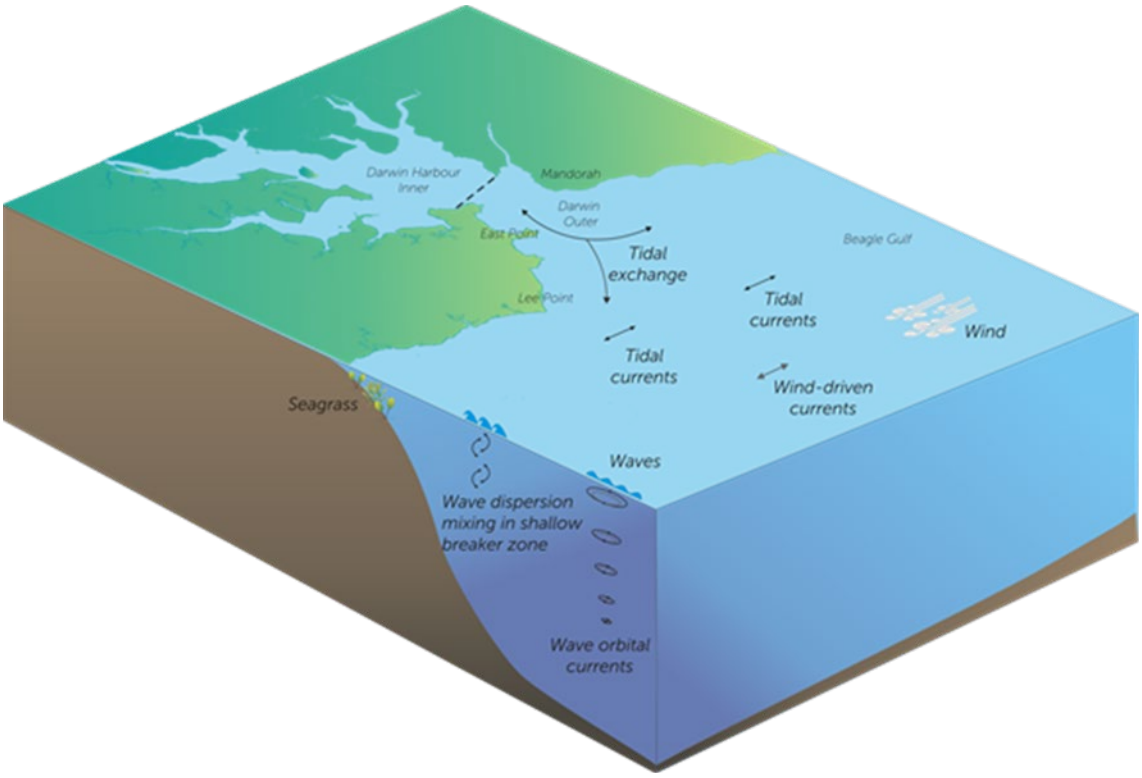

Figure 3-4: Key oceanographic processes that affect turbidity in Darwin Harbour and the Beagle Gulf (Cardno 2014b)

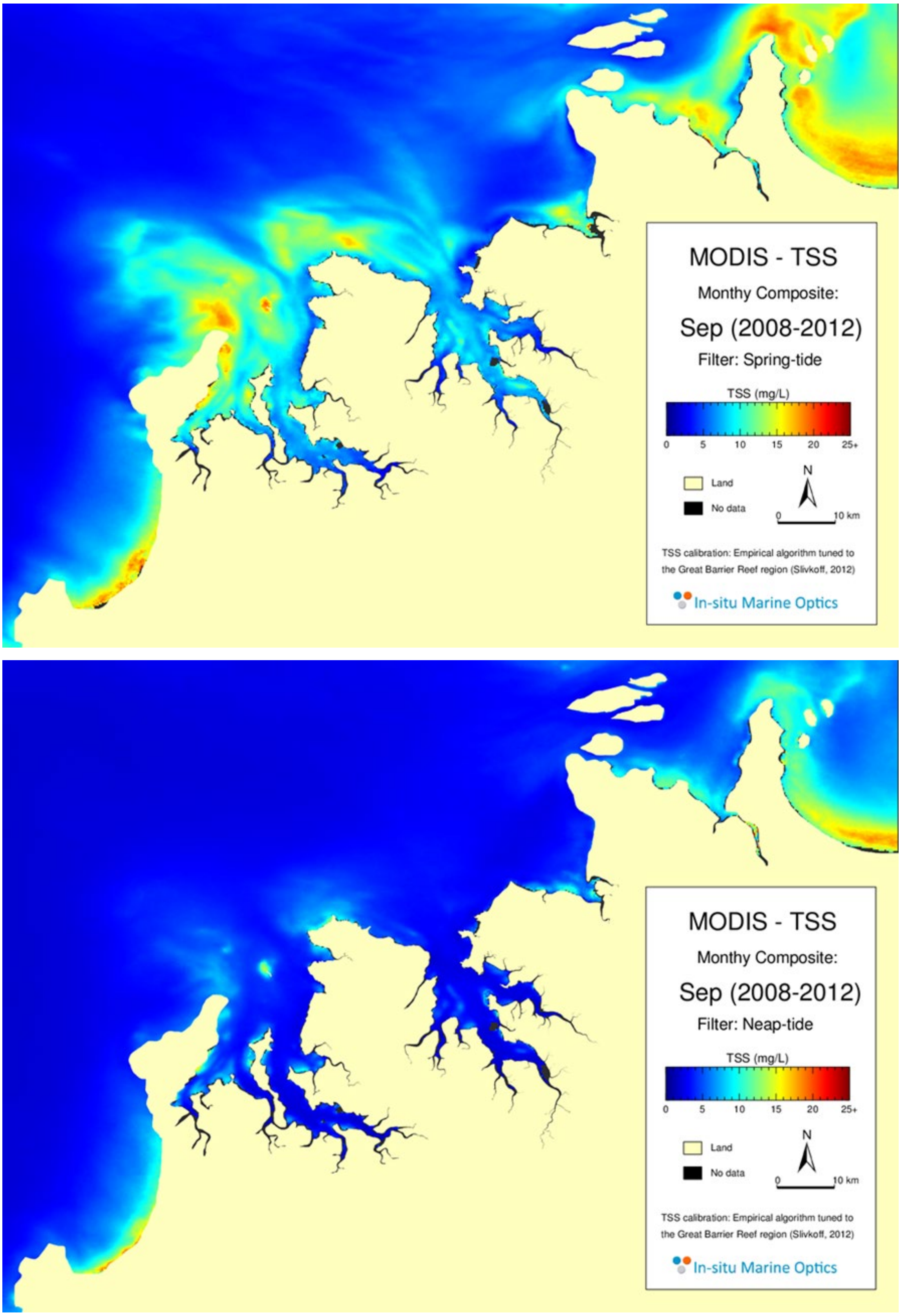

Figure 3-5: Composite MODIS imagery for September (2008-2012) spring tide (top) and neap tide (bottom) periods

Light availability

The intensity of underwater light (measured as photosynthetically 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).

3.1.5 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). Additional sediment samples have also been collected in 2019, 2020 and 2021 from within the dredge area to support the Projects onshore approvals (Jacobs 2019, 2020; INPEX 2021a). The results of these sediment samples along with other recent sediment data for Darwin Harbour (Radke et al. 2020a, 2020b) were presented in a report (INPEX 2021b) to the NT EPA. The intent of this report was to seek an exemption from further sediment sampling and analysis based on availability of recent sediment data to inform the maintenance dredging exemption. The Department of Environment, Parks and Water Security (DEPWS; representing the NT EPA) agreed in principal with INPEX's rational for not undertaking a sediment sampling and analysis survey. A summary of the existing sediment data is summarised below.

The particle size distribution (PSD) of sediment samples from 2016 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). Similar to 2016, samples collected in 2019 and 2020 from within the Jetty Pocket had high fines content (76-79%). 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. Samples have also been recently collected and analysed for PSD in 2019 (INPEX 2019) and 2020 (INPEX 2020) to inform the Projects onshore approvals as well as opportunistic samples in 2021 (INPEX 2021c). This data has identified some interannual and fine scale spatial variability in PSD; however, there was general agreement in the proportion of fines between 2016 and recent datasets (HRW 2022).

The National Assessment Guidelines for Dredging (NAGD; Commonwealth of Australia 2009) Screening Levels are considered appropriate for assessment of sediment quality for unconfined ocean disposal. Sediment samples collected between 2016 and 2021 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) in 2016 and two sites (5 and 10 µg/kg) in 2019 and were all significantly below the respective NAGD Screening Level (10,000 µg/kg). Total recoverable hydrocarbon (TRH[9]) concentrations for all sites in 2016, 2019, 2020 and 2021 were also well below the respective NAGD Screening Level (550 mg/kg). Benzene, toluene, ethylbenzene and xylene (BTEX) compounds have all been below the laboratories LOR across all years.

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 NAGD Screening Levels at a site in 2016. 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).

[9] TRH and total petroleum hydrocarbons (TPHs) are equivalent as they are the same defined class of compounds, and both may include biogenic (biological) and petrogenic (petroleum) hydrocarbons. Surveys generally included TPH as a default guideline value is provided in ANZG (2018), however the use of TRH is also considered acceptable.

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 2016 sediment quality assessment, the sediment that had deposited within the dredge area was found to be uncontaminated and therefore considered suitable for dredging and open water disposal at the DSDA. Sampling in 2019, 2020 and 2021 has shown that sediment within the dredge area has remained uncontaminated, and therefore is still 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 (Radke et al. 2021; Radke et al. 2020a; AECOM 2020; INPEX 2019, 2020, 2021b; Munksgaard et al 2013; URS 2009; Fortune 2006). Results from published monitoring studies in East Arm 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 inorganic contaminants in Darwin Harbour such as metals (including metalloids) found that arsenic concentrations commonly exceed the ANZG (2018) sediment quality guideline value (SQGV) of 20 mg/kg. 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. antimony, chromium, copper, lead, mercury, nickel and silver) have also been recorded to exceed SQGVs; however, their mean concentrations have always remained below SQGVs and typically associated with individual samples.

Few programs in East Arm have analysed samples for other contaminants such as organic compounds. Sampling undertaken during the Ichthys LNG EIS phase (URS 2009) was the most comprehensive dataset until 2019, when the Northern Territory Government implemented a comprehensive sediment quality assessment of East Arm (Radke et al. 2020a). Polychlorinated biphenyls (PCBs), BTEX, polychlorinated biphenyls (PCBs) and organophosphate pesticides (OPPs) have all been below laboratories LOR. Organochlorine pesticide (OCP; Dieldrin) and tributyltin (TBT) have each reported a single positive detection in East Arm. Majority of samples analysed for PAHs have also been below laboratories LOR. Majority of samples analysed for TRHs have also been below laboratories LOR, however this likely reflects the use of standard LORs for comparison against SQGVs rather than actual concentrations of TRHs. Analysis of samples using ultra-trace LORs in East Arm indicate that the majority of samples contain low levels of TRHs[9].

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 NAGD Screening Level, where specified (INPEX 2012). The majority of PAHs samples were also below LOR with only two samples slightly above (≤2 µg/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.

3.1.6 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 µPa2/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 (sound pressure level (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).

3.2 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 Ichthys LNG EIS Supplement, a comprehensive baseline marine habitat survey was completed, which informed the original benthic habitat layer (INPEX 2011). The benthic habitat layer includes both "high-confidence" and "inferred" habitat areas as described in the Ichthys LNG 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 2015d), this baseline layer was updated (Figure 3-6 and Figure 3-7).

Additional habitat data using varying methods throughout Darwin Harbour have been collected by a number of organisations for project specific requirements or research purposes in recent years (see Table 3-2 and Figure 3-8). Some of this habitat data was used by Galaiduk et al. (2019) to create a predictive habitat map (e.g. model areas where habitat types could occur based on modelled variables and habitat data) and this model was subsequently updated (e.g. spatial coverage, modelled variables and additional habitat data) by Streten (2022).

Table 3-2: Recent benthic habitat data collected in the Darwin Harbour region

Year	Data type	Location	Collected by
2014	Drop camera	Fannie Bay	AIMS

Year	Data type	Location	Collected by
2015	Drop camera	Woods Inlet, West, Middle and East arms	AIMS
2016	Drop camera	Primarily West and Middle arms	AIMS
2018	Towed video	Entrance to Darwin Harbour as well as Shoal Bay region	AIMS for the Northern Territory Government
2019	Towed video	Mandorah	Cardno on behalf of the Northern Territory Government
2020	Towed video	South Shell Island, Old Man Rock and East Arm Wharf	AIMS for AECOM on behalf of the Northern territory Government
2020	Towed video	Locations throughout Darwin Harbour (e.g. Woods Inlet, West and Middle arms, Wickham Point)	AIMS for the Northern Territory Government
2021	ROV/Towed video	Sections along the proposed pipeline route through Darwin Harbour to Wickham Point	Santos
2022	ROV/Towed video	Sections along the proposed pipeline route through Darwin Harbour to Wickham Point and selected locations to confirm habitat	Santos

Galaiduk et al. (2019) used bathymetric, physical and biological data to produce spatial predictive habitat models for major biotic groups and to produce predictive benthic habitat maps showing where benthic habitat types may occur. However, the modelling and subsequent habitat maps were primarily limited to subtidal areas due to lack of bathymetric data for intertidal areas. To address this, Streten (2022) incorporated data from a topographical LiDAR survey undertaken in Darwin Harbour intertidal areas during spring low tide in November 2022. Physical oceanographic variables were also trialled to try and improve the predictive benthic model's precision and accuracy, coupled with additional benthic habitat data. The revised predictive habitat map for Darwin Harbour from Streten (2022) is presented in Figure 3-9.

Review of the revised predictive habitat map presented in Streten (2022), identified it did not consider the seagrass habitat mapping data (10 surveys between June 2012 and August 2014) undertaken as part of the NEMP seagrass monitoring program. As such, mapped seagrass communities between East Point and Lee Point are significantly under-represented/absent in the revised predictive habitat map (see Section 3.2.3). If this known seagrass data is included in the habitat model it may influence (e.g. reduce) the predicted seagrass habitat within Darwin Harbour given the different physical and oceanographic variables at these sites compared to those within the Harbour. The revised predictive habitat map is also limited to areas south of an arbitrary line between Charles Point and Lee Point and therefore does not include all habitats relevant to this maintenance dredging proposal (i.e. habitats in the outer harbour where the DSDA is located).

Habitat modelling used to inform the revised predictive habitat map also does not predict any hard coral communities at Northeast Wickham Point or Channel Island, which have known coral communities (see Figure 3-10 and Table 3-3). Channel Island coral communities have been declared and are protected under the Heritage Act 2011 (NT) for its unique position and species diversity in a large ria system characterised by stressors (high turbidity, currents, sedimentation and depressions in salinity) that are not normally considered conducive to coral growth or presence (DTFHC 2021). This is likely because the habitat model outputs "represent the potential fundamental ecological niche for the habitats analysed based on environmental suitability derived from the model covariates, however, do not represent the realised ecological niche (i.e. whether a habitat will or will not be found at any location at any point in time)" (Streten 2022).

Benthic habitat surveys in vicinity of South Shell Island were also completed by AIMS (Case et al. 2021) to inform the Darwin Ship Lift proposal (AECOM 2021). The outcomes of the habitat survey in AECOM (2021) demonstrated that the seabed within vicinity of the proposed Ship Lift was predominantly bare substrate, with only scattered filter feeds with small confirmed coral communities at South Shell Island and Old Man Rock (AECOM 2021), consistent with INPEX habitat map (Figure 3-6 and Figure 3-7). It is noted that the predictive habitat map presented in Streten (2022) shows a substantial increase in potential coral habitat in vicinity of South Shell Island and Old Man Rock (Figure 3-9), including within the dredge footprint associated with East Arm Wharf and Supply Base. However, this is inconsistent with the habitat data used to inform the model, indicating the predictability of coral habitat in this area is erroneous. Further, AECOM (2021) found that predictive habitat map in Galaiduk et al. (2019).[10] had poor predictive ability in vicinity of the proposed Ship Lift (e.g. South Shell Island, Old Man Rock and Catalina Island) due to uncertainty driven by very subtle ecological and geomorphic gradients over a mosaic of patchy benthic communities. As aforementioned, modelling represents the potential ecological niche rather than realised niche. As such, where there is available data (e.g. realised niche) this should be used in preference of modelled data.

Given recent habitat modelling (Streten 2022) did not include extensive areas of known seagrass habitat between Fannie Bay and Lee Point and does not cover the spatial extent of the proposed maintenance dredging activity and to ensure appropriate impact assessment, the INPEX benthic habitat layers have been used to inform impact assessment (Figure 3-6 and Figure 3-7). The INPEX coral benthic habitat layers are also more appropriate for impact assessment in vicinity of the dredge area as it is more reflective of the actual habitat data collected for the area compared to modelled habitat, which does not show any coral communities at Northeast Wickham Point and over represents potential coral habitat at South Shell Island.

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

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[10] Note, for the Darwin Ship Lift proposal only the Galaiduk et al. (2019) predicated habitat map was available and this was used to inform their EIS (AECOM 2021).

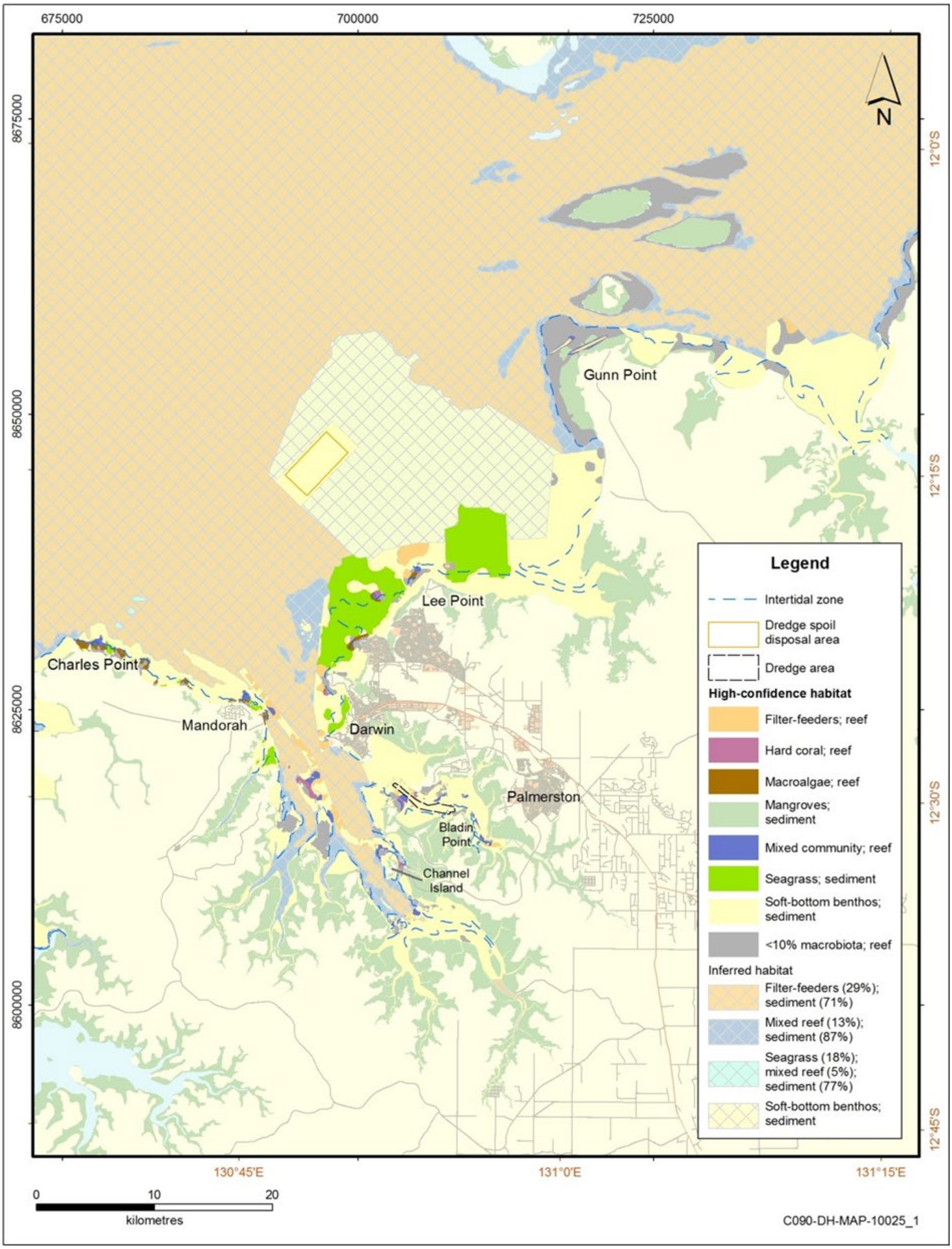

Figure 3-6: Benthic habitat map of the greater Darwin region

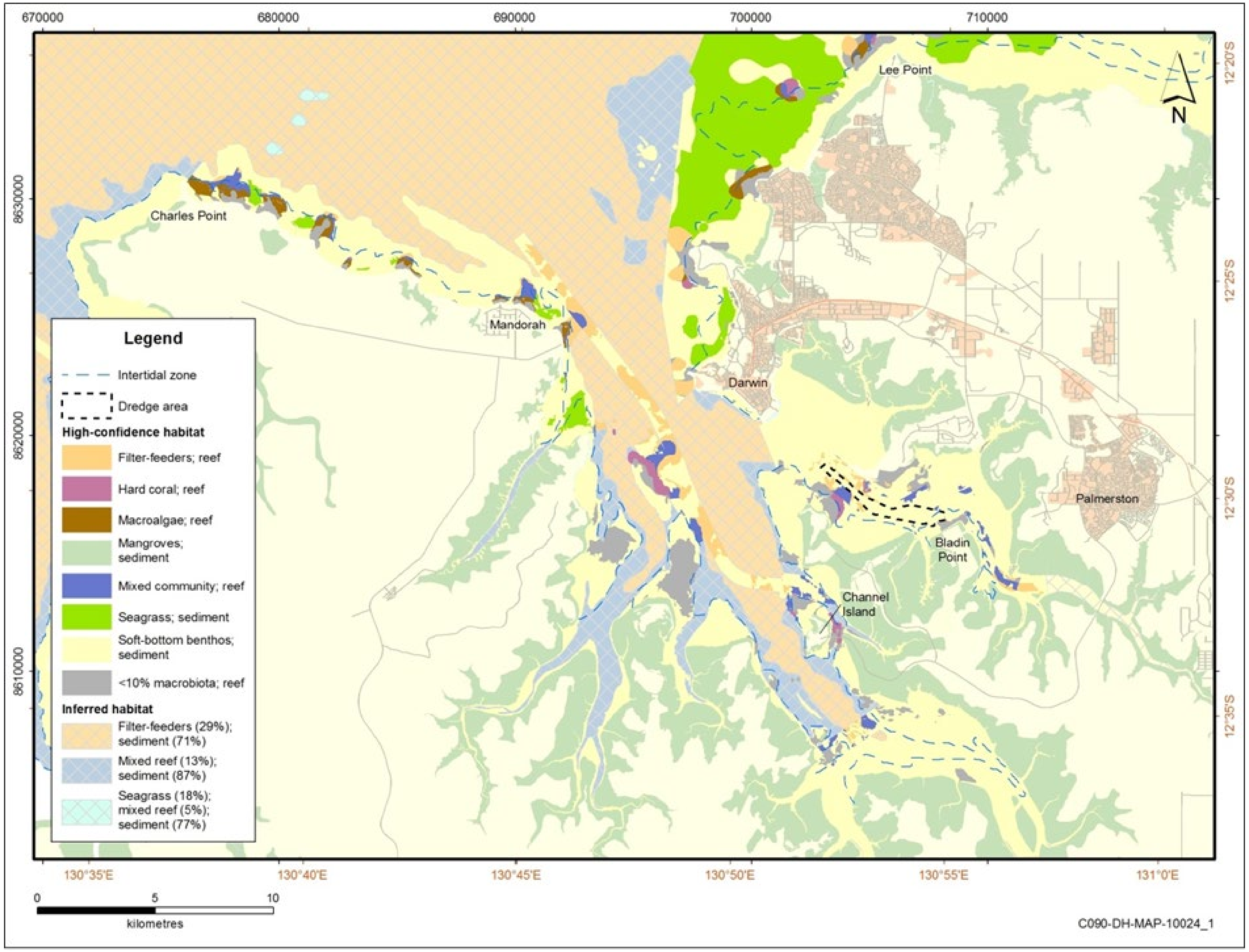

Figure 3-7: Benthic habitat map of Darwin Harbour

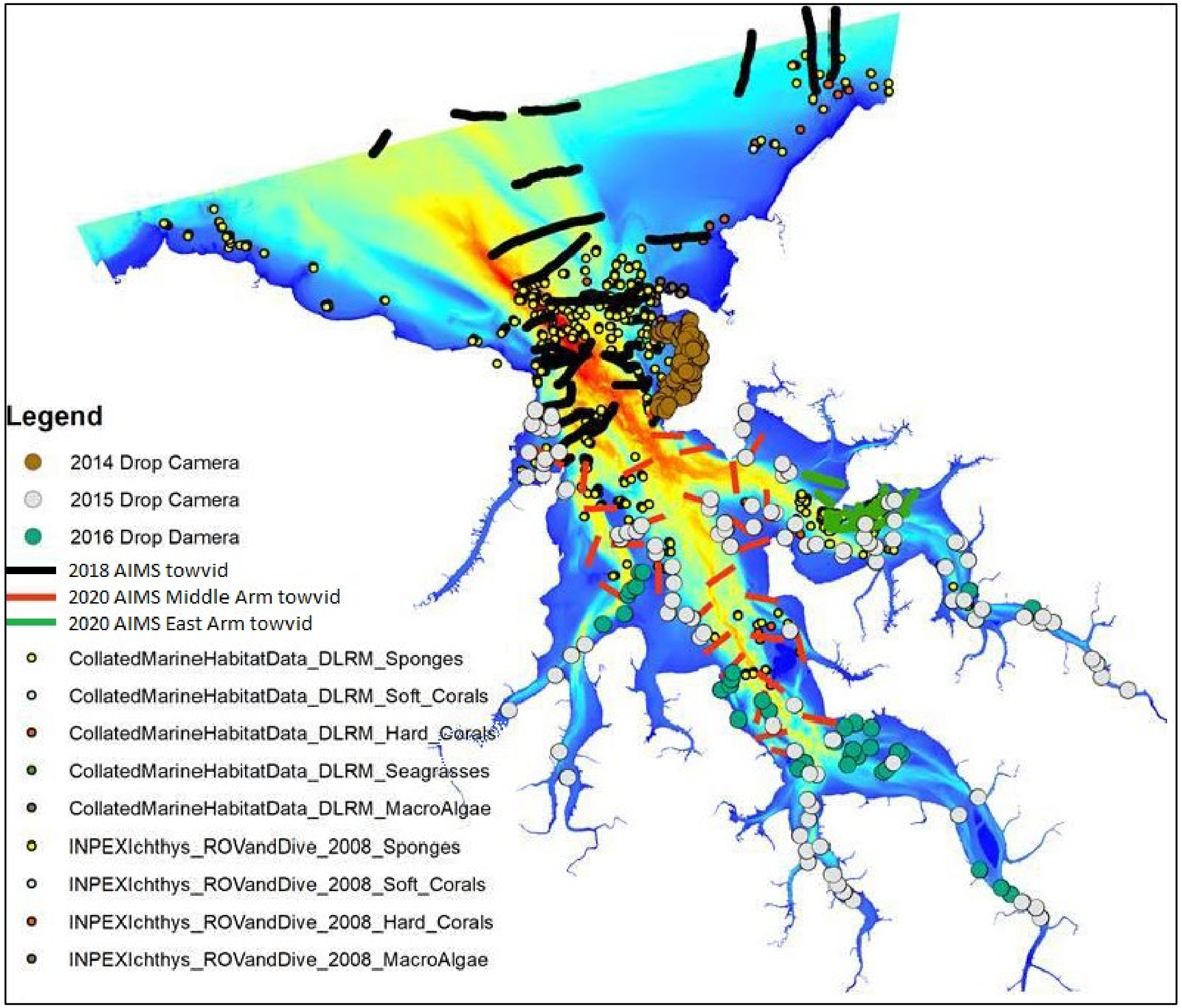

Figure 3-8: Location of historic and recent (2014 to 2020) AIMS benthic habitat data (adapted from Streten 2022)

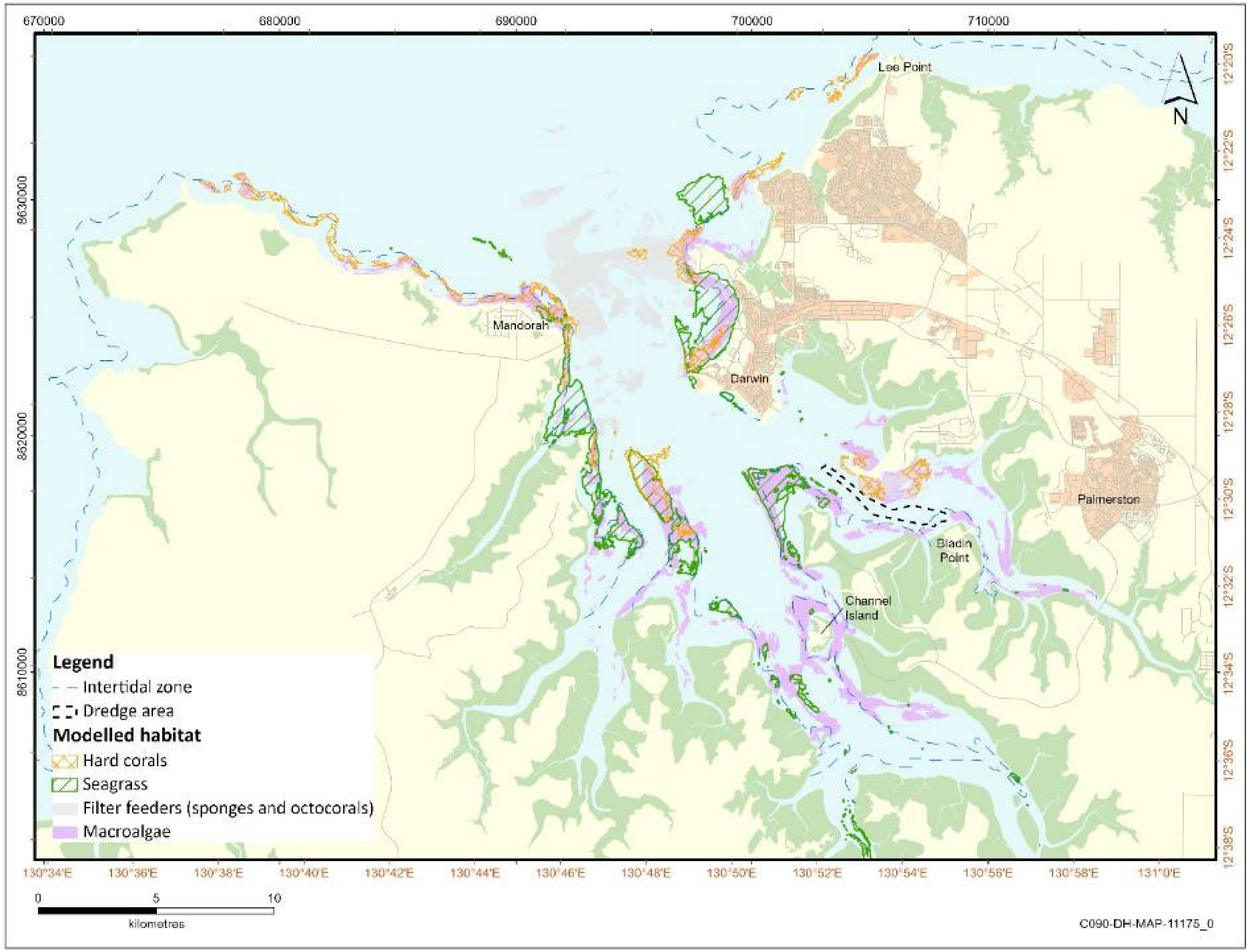

Figure 3-9: Revised predictive habitat map for Darwin Harbour adapted from Streten (2022)

Figure 3-10: Channel Island coral community on a spring low tide

3.2.1 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). Mangrove extent mapping has been completed by Cardno (2014c) between Tapa Bay (Charles Point) and Shoal Bay using WorldView II satellite imagery and more recently by Brocklehurst and Edmeades (2018) using high resolution aerial imagery between Charles Point and Gunn Point. Mangrove extent has been reported as 25,199 ha and 26,729 ha[11] respectively.

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 3-11 (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).

[11] Reported mangrove extent in Brocklehurst and Edmeades (2018) is 31,576 ha; however, this includes 4,846.8 ha of salt flats which are excluded in Cardno (2014c). To allow comparison between methods, the salt flat extent was subtracted from the Brocklehurst and Edmeades (2018) mangrove extent.

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 (Datt & Staben 2020; Cardno 2015b). 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).

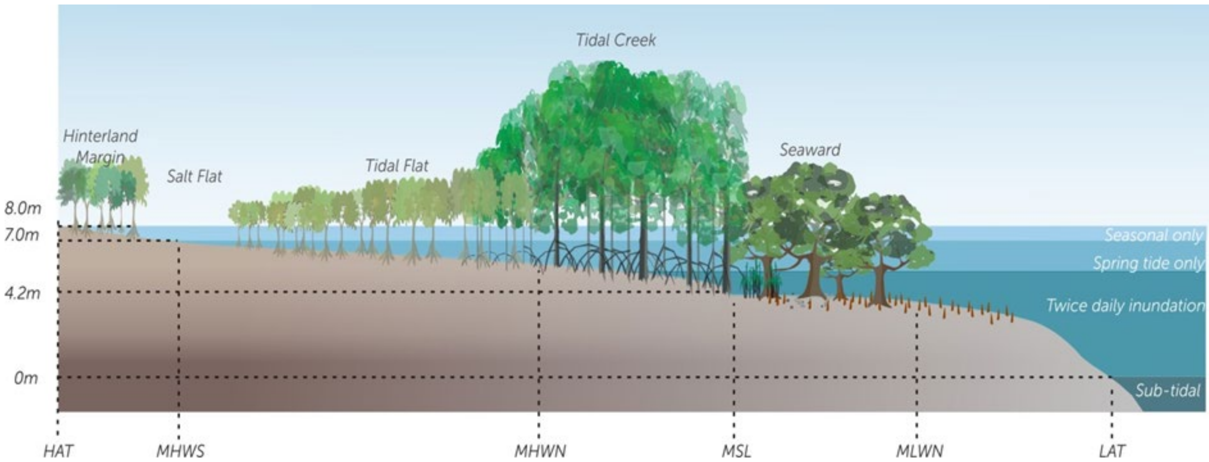

Figure 3-11: Major mangrove assemblages of Darwin Harbour and their position in the tidal profile (adapted from Brockelhurst & Edmeades 1996) (Cardno 2014b)

3.2.2 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 3-3 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 (DTFHC 2021).

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, duration of increased water temperatures and 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 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 2021). 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 (1,077 mm compared to 1,606 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 2021). There is also the possibility that bleaching may have occurred over the 2017/2018 wet season as the National Oceanic and Atmospheric Administration issued an Alert Level 2 for water off the Northern Territory, the highest alert for the risk of bleaching (Ward 2018). During this same period, extensive bleaching was reported in off the coast of Coburg Peninsula in western Arnhem Land (Ward 2018), approximately 200 km north-east of Darwin.

Table 3-3: 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
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**

3.2.3 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 beds were 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 (seasonal and inter-annual; see Figure 3-12 and Figure 3-13) 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 3-14 (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.

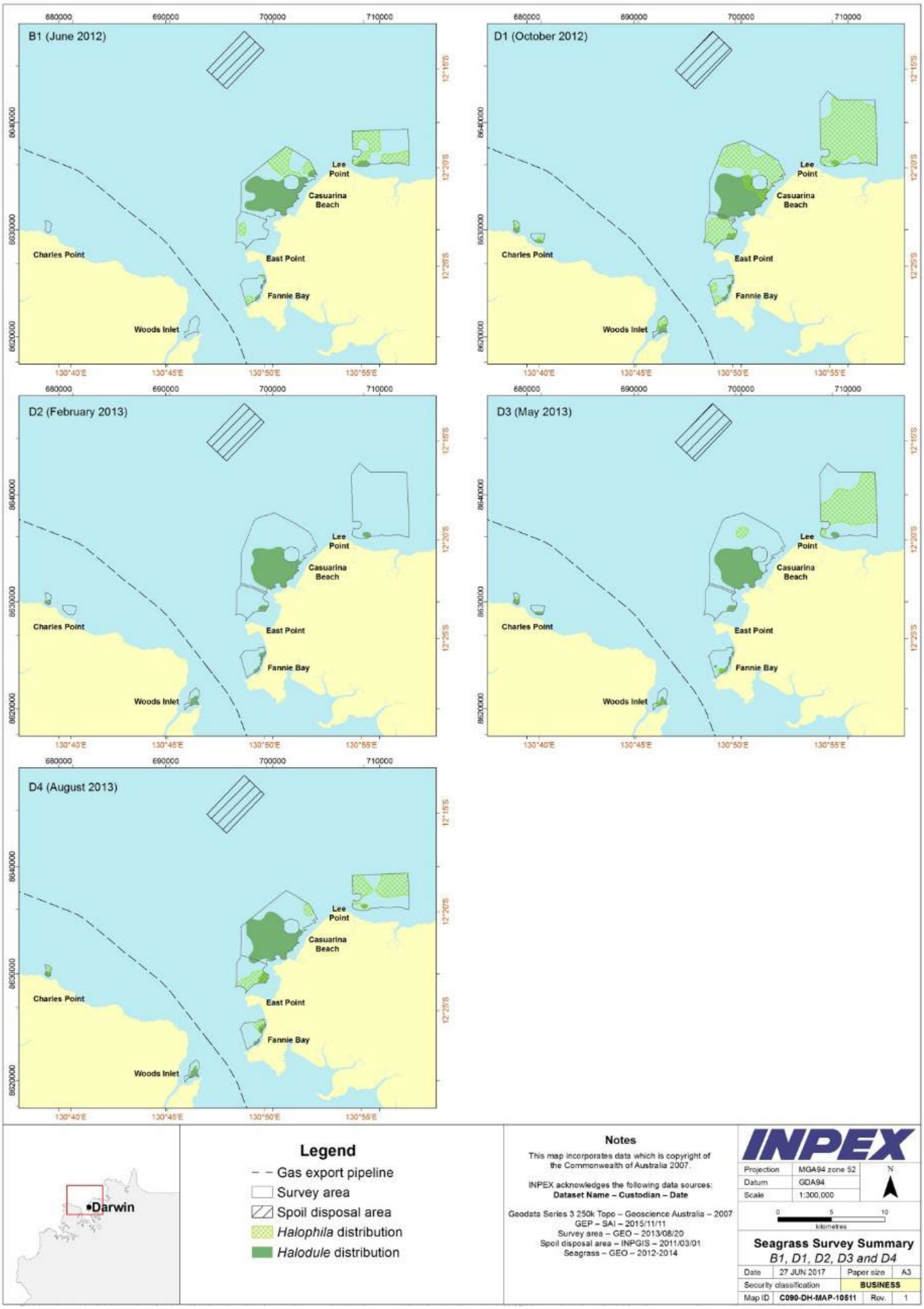

Figure 3-12: Seagrass distribution for the Darwin region measured through the Seagrass Monitoring program between June 2012 and August 2013

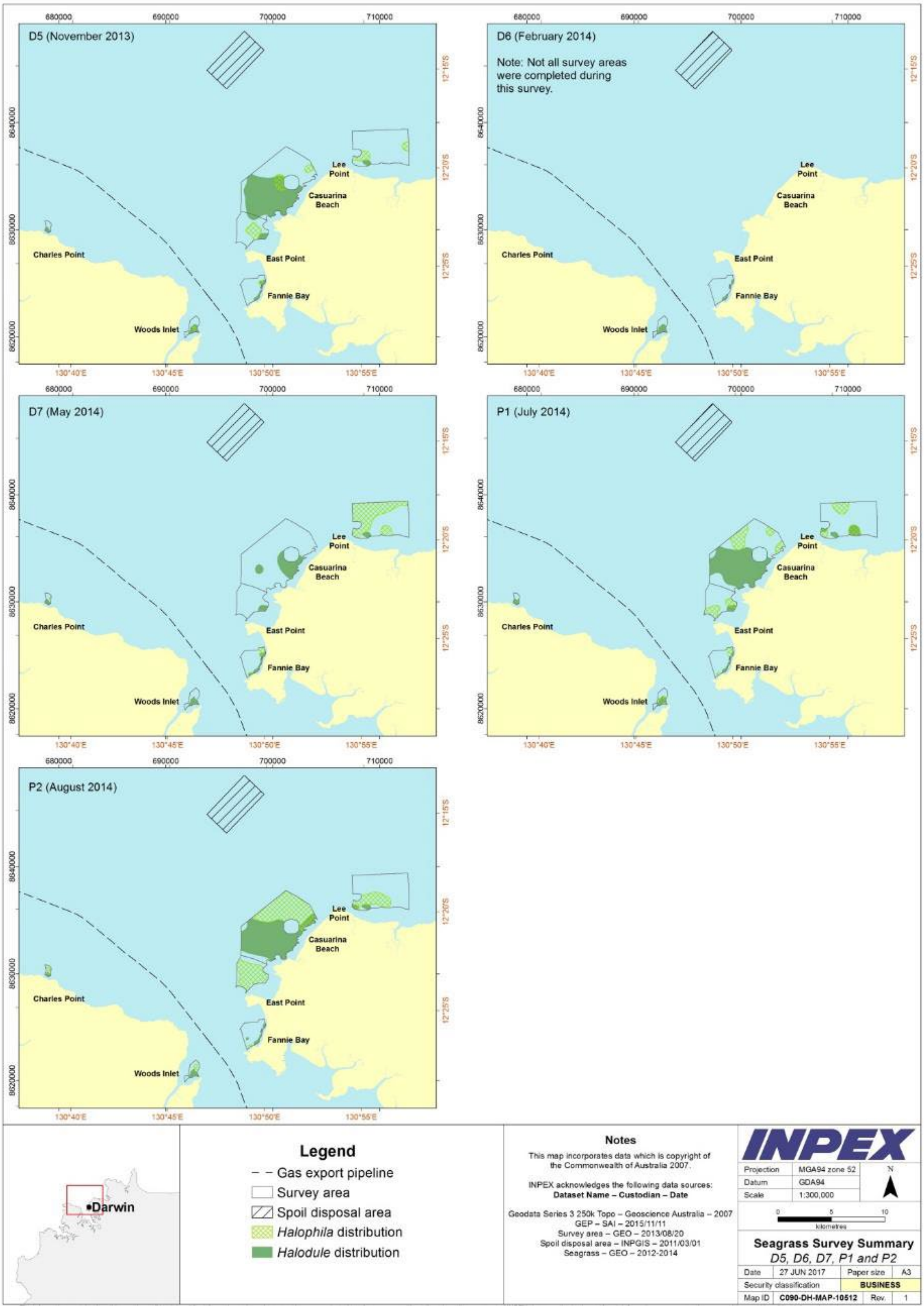

Figure 3-13: Seagrass distribution for the Darwin region measured through the Seagrass Monitoring program between November 2013 and August 2014

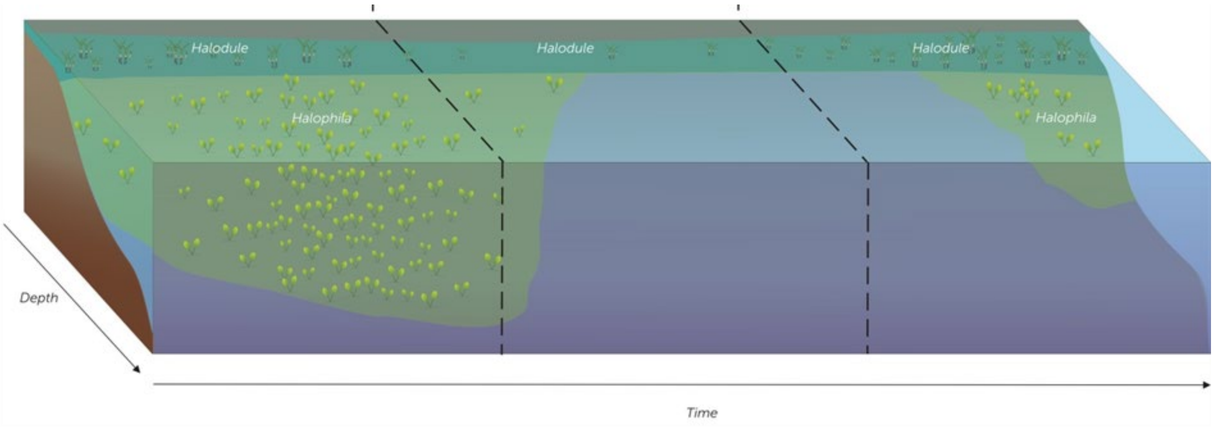

Figure 3-14: Temporal and spatial dynamics of Halodule uninervis and *Halophila decipiens* seagrass habitat in Darwin found through the capital dredging program (Cardno 2014b)

3.2.4 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).

3.2.5 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 (i.e. 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 that 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. 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 and 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).

3.3 Pelagic environment

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

3.3.1 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. Long-term monitoring (2011 to 2019) highlighted a small, mobile and variable nature of dolphin populations in the Darwin region (Griffiths et al. 2020). Population estimates for the Darwin region between surveys varied between 75 and 169 dolphins with an average of 141 dolphins. Darwin Harbour has been identified as an biological important area (BIA) for breeding and foraging, for all three dolphin species. The dredge footprint overlaps a small portion of the much larger BIAs.

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, recordings of these species are rare and represent vagrant individual sightings. A review of the NT WildWatch database identified historical sightings of humpback whales in areas around Fog Bay, the Peron Islands and Bathurst Island (ALA 2021). More recently, in 2020, humpbacks were sighted in the East Alligator River; although this was consider highly unusual (ABC 2020). NT WildWatch had no records of sightings for either the pygmy sperm whales or sperm whales (ALA 2021).

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). These population estimates are higher than those from the 2015 aerial surveys completed across the entire Northern Territory, which had a population estimate of 122 dugongs for the greater Darwin region (Groom et al. 2017). This could somewhat be expected given the greater survey effort and number of surveys completed as part of the NEMP.

Dugongs feed almost exclusively on seagrass and their distribution is broadly coincident with seagrasses in tropical and sub-tropical waters (DAWE 2021a). During the NEMP, 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 3-4.

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

Scientific name	Common name	Conservation status	
		Commonwealth*	Northern Territory†
K. simus	Pygmy sperm whale	Cetacean	Not listed
P. macrocephalus	Sperm whale	Migratory Cetacean	Not listed
M. novaeangliae	Humpback whale	Migratory Cetacean	Not listed
P. crassidens	False killer whale	Migratory Cetacean	Not listed
O. heinsohni	Australian snubfin dolphin	Migratory Cetacean	Not listed
S. sahulensis	Australian humpback dolphin	Migratory Cetacean	Not listed
T. aduncus	Spotted bottlenose dolphin (Arafura/Timor Sea)	Migratory Cetacean	Not listed
D. dugon	Dugong	Migratory	Not listed

* DAWE 2021b

† NTG 2021a

3.3.2 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 (NTG 2006a; DAWE 2021c). 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 (NTG 2012a; DAWE 2021d). Flatback turtles inhabit shallow, soft-bottomed seabeds and feed on soft corals and soft bodied animals such as jellyfish and sea cucumbers (NTG 2006b).

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 dredge footprint and DSDA overlaps a small portion of a large flatback turtle internesting BIA, which covers more than 70,000 km^2 stretching from Goulbourn Islands (west Arnhem Land) to Anson Bay encompassing the Tiwi Islands and Coburg Peninsula.

The saltwater crocodile (*Crocodylus porosus*) is a common resident of Darwin Harbour and surrounds. In 2020 a total of 246 crocodiles were removed from Northern Territory waters with a majority of these being caught within Darwin Harbour (NTG 2021b). 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 (DAWE 2021e). 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 3-5.

Table 3-5: 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
C. mydas	Green turtle	Vulnerable Migratory	Not listed

Scientific name	Common name	Conservation status	
		Commonwealth*	Northern Territory†
Dermochelys coriacea	Leatherback turtle	Endangered Migratory	Critically endangered
E. imbricata	Hawksbill turtle	Vulnerable Migratory	Vulnerable
Lepidochelys olivacea	Olive ridley turtle	Endangered Migratory	Vulnerable
N. depressus	Flatback turtle	Vulnerable Migratory	Not listed
C. porosus	Saltwater crocodile	Migratory	Not listed

* DAWE 2021b

† NTG 2021a

3.3.3 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 (NTG 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 (NTG 2006c).

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 (NTG 2006d).

The conservation status of sawfish species that may occur in the Darwin region is presented in Table 3-6.

Table 3-6: Protected marine sharks which may be present in Darwin Harbour

Scientific name	Common name	Conservation status	
		Commonwealth*	Northern Territory†
P. clavata	Dwarf sawfish	Vulnerable Migratory	Vulnerable
P. pristis	Freshwater sawfish	Vulnerable Migratory	Vulnerable
P. zijsron	Green sawfish	Vulnerable Migratory	Vulnerable

* DAWE 2021b

† NTG 2021a

3.3.4 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).

3.4 Introduced marine pests

Introduced marine pests are defined as non-native marine plants or animals that harm Australia's marine environment, social amenity or industries that use the marine environment; or have the potential to do so if they were to be introduced, established (that is, forming self-sustaining populations) or spread in Australia's marine environment (DAWR 2018).

A number of targeted marine pest monitoring programs were executed in Darwin Harbour between 2010 and 2015 (Cardno 2015i; Golder Associates 2010), and through the course of these programs the following marine pest species have been detected; *Magallana gigas* (presence of one shell valve) and Caulerpa racemosa var. lamourouxii (Golder Associates 2010), *Amphibalanus amphitrite* (barnacle), *Bugula neritina* (bryozoan) and the ascidians *Botryllus schlosseri*, *Botrylloides leachi* and *Didemnum perlucidum* (Cardno 2015i). Of these species, *D. perlucidum* is the only species listed as an aquatic pest in the NT. Routine monitoring by the Northern Territory Government Aquatic Biosecurity Unit between 2015 and 2020 has also identified D. perlucidum within Darwin Harbour (DITT 2020 and DPIR 2016, 2017, 2018 and 2020 in AECOM 2021).

In addition to monitoring program outcomes, in 1999 an outbreak of black striped mussels was recorded in three Darwin Harbour marinas. Following, a national response to the outbreak this species was successfully eradicated from invaded locations (Ferguson 2000).

3.5 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 3 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 2021c).

Table 3-7: 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 a). 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 a). 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 a).

Name	Description
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 Undated b). 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 Undated b). 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 Undated b).
Dolphin Habitat Reserve	The Reserve comprises an area of 50 ha adjacent to the Shoal Bay Coastal Reserve. The key natural value protected in the Reserve is dolphin habitat (NTG 2017).
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 2016).

3.6 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, and these are described in more detail in the following sections.

3.6.1 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 2021). 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 Aboriginal Areas Protection Authority (APPA) 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 3-8.

Table 3-8: 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 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.

3.6.2 Underwater cultural 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 *Underwater Cultural Heritage Act 2018* (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 3.2.2) are considered significant due to their relatively diverse coral community, which is not consistent with their location well inside a large ria system (DTFHC 2021).

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 3-15.

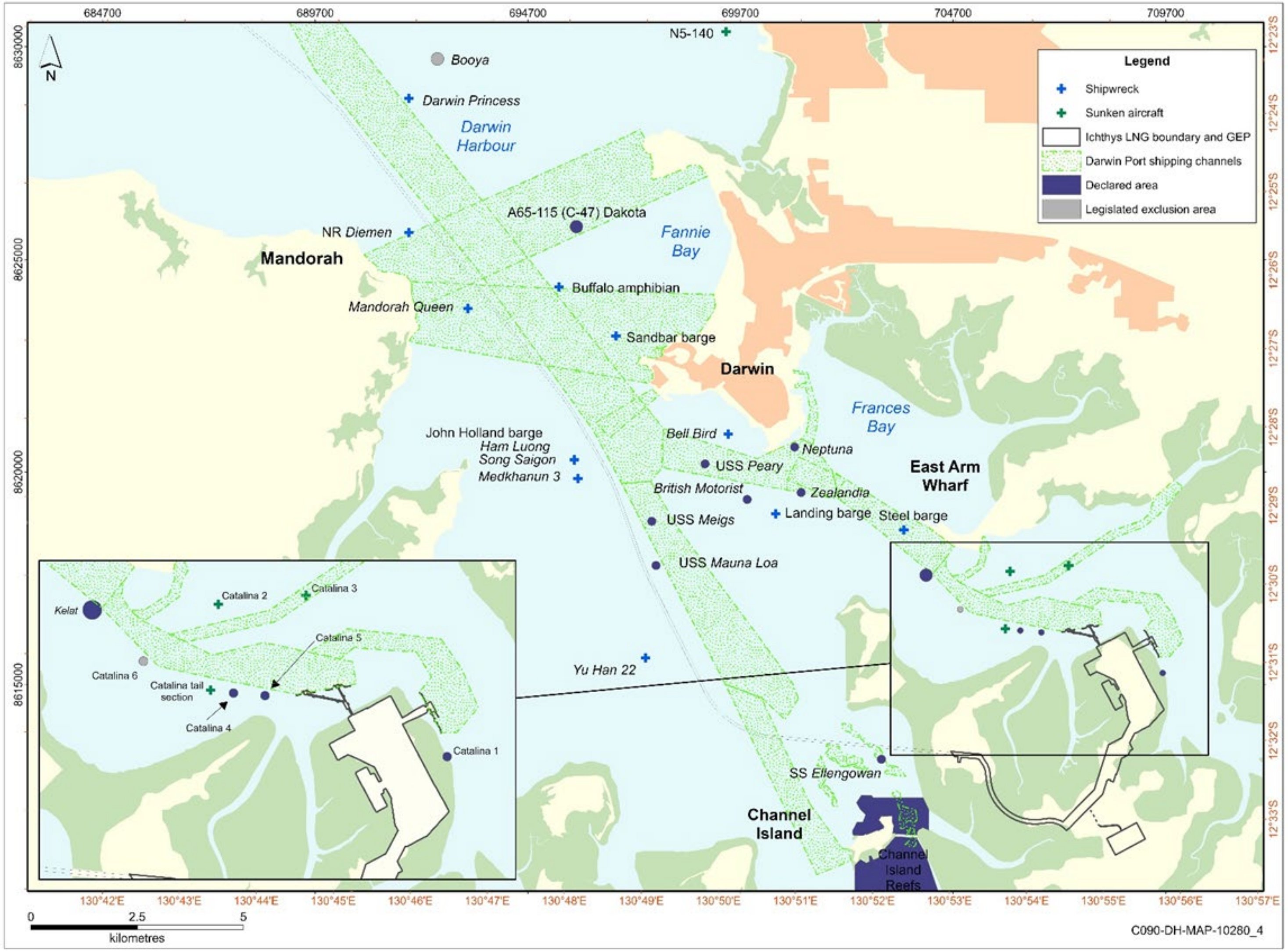

Figure 3-15: Shipwrecks and sunken aircraft in Darwin Harbour

3.7 Social and economic environment

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

3.7.1 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.

3.7.2 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 2020/2021 the Port of Darwin serviced 90 general cargo (container) vessels and a total of 1,416 trading vessels (import and export) (Darwin Port 2021).

3.7.3 Tourism

Tourism is a large economic driver of the Northern Territory economy. During 2020/2021 reporting period there were 899,000 visitors to the Northern Territory (Tourism NT 2021). This a significant decrease in visitor numbers, when compared to the previous 2019/2020 period where visitor numbers were 1,962,000 (Tourism NT 2021). This decrease is a direct consequence of the ongoing COVID-19 pandemic and the associated border restrictions/closures (international and domestic) in place. In 2019/2020 the tourism industry contributed $852 million to the local economy (NTG 2021d).

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).

3.7.4 Commercial fishing and aquaculture

A number of commercial fisheries operate within Northern Territory waters; however, most are prohibited from operating within Darwin Harbour (NTG 2019). The following fisheries are permitted to operate within Darwin Harbour in areas that are not designated protected areas[12]:

- 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 (DITT 2021). The centre is currently researching ways to farm sandfish, giant clam and tropical oyster. In addition to this, the centre produces barramundi fingerlings for restocking Manton Dam (and other approved areas) and has a golden snapper breeding program for stock enhancement of Darwin Harbour (DITT 2021).

3.7.5 Recreational and traditional fishing

Results from a recreational fishing survey of the Greater Darwin area (Dundee Beach to mouth of the Adelaide River), undertaken between March 2015 and November 2015, indicate that waterways within Darwin Harbour account for 40% of the recreational fishing effort for Greater Darwin, with zones immediately adjacent to Darwin (Bynoe Harbour and Shoal Bay) attracting a further 20% (Mathews et al. 2019).

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 and Torres Strait Islander peoples 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.

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

4 NT EPA ENVIRONMENTAL FACTORS AND VALUES ASSESSMENT

The NT EPA has identified 14 environmental factors categorised under five themes of Land, Water, Sea, Air and People. These environmental factors are broad divisions of the environment that may be impacted by a proposed action and provide for a systematic approach for organising information for the purpose of environmental impact assessment (NT EPA 2021a).

To determine if the proposed maintenance dredging and dredge disposal activity could impact on any environmental factors identified by the NT EPA, a preliminary assessment was undertaken. This assessment was informed by information presented in Section 3 on the existing environment. Outcomes of the preliminary assessment are presented in Table 4-1.

In summary, the preliminary assessment identified that the proposed maintenance dredging and dredge disposal activity had the potential to impact on the following environmental factors:

- marine environmental quality
- marine ecosystems
- culture and heritage

A detailed assessment of the potential impacts and their significance, and proposed to controls to manage/mitigate these is provided in Section 6.

Table 4-1: Preliminary assessment of potential to impact environmental values

NT EPA guidance (NT EPA 2021a)				**INPEX assessment**		
Theme	Factor	Environmental objective	Indicative values and sensitivities relevant to each environmental factor	Environmental context	Potential to be impacted (Yes/No/Uncertain/Not applicable)	Assessment statement
Land	Landforms	Conserve the variety and integrity of distinctive physical landforms.	• distinctive features in the landscape, either geological or anthropogenic • subterranean karstic terrain and faults • craters, gorges, ranges, caves, massifs, escarpments, plateaus • monuments • tourism related to landform	Not Applicable	Not Applicable	The proposed action will not impact on the integrity of distinctive terrestrial landforms. The proposed maintenance dredging and spoil disposal activities are located wholly in the marine environment.
	Terrestrial environmental quality	Protect the quality and integrity of land and soils so that environmental values are supported and maintained.	• good quality soils, including chemical, physical, biological and aesthetic qualities that support life • the biological processes that depend on soil quality	Not Applicable	Not Applicable	The proposed action will not impact on the quality and integrity of terrestrial land and soils. The proposed maintenance dredging and spoil disposal activities are located wholly in the marine environment.
	Terrestrial ecosystems	Protect terrestrial habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.	• sensitive or significant' vegetation or buffers (as defined in the NT Land Clearing Guidelines) • vegetation that provides an important ecological function • listed threatened species and their habitat (NT and Commonwealth) • listed migratory species and their habitat (Commonwealth) • listed threatened ecological communities (Commonwealth) • locally endemic species or species with restricted habitat • species of social, cultural, livelihood and/or economic significance • species that are data deficient and their status is unknown • protected area or reserve, including Indigenous Protected Area • existing conservation and management activities • introduced species and/or invasive species • integrity of terrestrial ecosystems and the ecological services they provide • biological and functional diversity • provision of refuge • food supply	Not Applicable	Not Applicable	The proposed action will not impact on terrestrial habitats. The proposed maintenance dredging and spoil disposal activities are located wholly in the marine environment.

NT EPA guidance (NT EPA 2021a)				**INPEX assessment**		
Water	Hydrological processes	Protect the hydrological regimes of groundwater and surface water so that environmental values including ecological health, land uses and the welfare and amenity of people are maintained.	• the supply and quantity of water in surface water features including rivers, lakes, wetlands, swamps, creeks, billabongs, intermittent streams, floodplains, mangroves and drainage lines • the supply and quantity of water in groundwater features including aquifers, aquitards and water tables • declared beneficial uses • present and future uses, and users of water • current or potential water supplies, including regional scale aquifers • culturally important water features or other features affected by water level	Not Applicable	Not Applicable	The proposed action will not impact on hydrological regimes of groundwater or surface water. The proposed maintenance dredging and spoil disposal activities are located wholly in the marine environment.
	Inland water environmental quality	Protect the quality of groundwater and surface water so that environmental values including ecological health, land uses and the welfare and amenity of people are maintained.	• the quality of water in surface water features including rivers, lakes, wetlands, swamps, creeks, billabongs, intermittent streams, floodplains, mangroves and drainage lines • the quality of water in groundwater features including aquifers and water tables • declared beneficial uses • present and future uses and users of water • current or potential water supplies, including regional scale aquifers • potability / drinkability • culturally important water features	Not Applicable	Not Applicable	The proposed action will not impact on the quality of groundwater or surface water. The proposed maintenance dredging and spoil disposal activities are located wholly in the marine environment.
	Aquatic ecosystems	Protect aquatic habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.	• threatened species • the health of the biota in inland waterways • the habitats that support the lifecycle of aquatic biota • groundwater dependent ecosystems • Ramsar wetlands • species of social, cultural, livelihood and/or economic significance • integrity of aquatic ecosystems and the ecological services they provide • biological and functional diversity • provision of refuge	Not Applicable	Not applicable	The proposed action will not impact on freshwater aquatic habitats. The proposed maintenance dredging and spoil disposal activities are located wholly in the marine environment.

NT EPA guidance (NT EPA 2021a)				**INPEX assessment**		
Sea	Coastal processes	Protect the geophysical and hydrological processes that shape coastal morphology so that the environmental values of the coast are maintained.	• processes that support marine ecosystems (see Marine Ecosystems Factor below) such as coral reefs, mangroves, salt marshes, seagrass meadows and sponge gardens • primary productivity • nutrient cycling • carbon storage • climate regulation • conservation significant low lying areas including tidal creeks, deltas and river mouths • storm surge protection • unique coastal landforms • cultural and aesthetic values • active or passive recreation	Refer to sections 3.1.2 and 3.1.3.	No	The proposed action will not impact on geophysical and hydrological processes that shape the coastal morphology. The proposed maintenance dredging activity is within the boundaries of the existing capital dredging footprint (depth and width). Further, site selection of the DSDA is informed by modelling (e.g. movement of dredged sediments and turbid plumes), and considered optimal as fine sediments drift north-east and west with the tides without impinging upon Darwin Harbour or inshore habitats. The depth and location of the DSDA also does not impinge on any shipping routes or reduce the under keel clearance for commercial ships.
	Marine environmental quality	Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.	• quality of the water, sediment and biota • ecosystem health condition • physical parameters that support fishing and aquaculture • physical parameters that support recreation and aesthetics • industrial water supply • cultural and spiritual values	Refer to sections 3.1.4, 3.1.5, 3.1.6, 3.3 and 3.7.1.	Yes	The proposed action, has the potential to impact on marine environmental quality as a result of the following: • sediment-related impacts to sensitive receptors (mangroves, coral and seagrass) • routine vessel discharges • mismanagement of waste • unplanned events resulting in loss of containment chemicals or hydrocarbons. The impact assessments and proposed controls for managing/mitigating any impacts are presented in Section 6.2.
	Marine ecosystems	Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.	• conservation significant marine and coastal fauna and critical habitat such as nesting, breeding or foraging habitat • conservation significant marine and coastal benthos, flora and vegetation (seagrass meadows, sponge gardens, coral reefs, mangrove communities and salt marshes) • groups of species (species richness and assemblages of species) • ecological functions and processes • species of social, cultural, livelihood and/or economic significance. • integrity of marine ecosystems and the ecological services they supply • biological diversity • functional diversity • provision of refuge • food supply	Refer to sections 3.2, 3.3 and 3.4.	Yes	The proposed action, has the potential to impact on marine ecosystems as a result of the following: • introduction of marine pests • interactions (vessel collision) or entrainment of marine megafauna during dredging activities • smothering or removal of habitat beyond the approved maintenance dredging and disposal footprints. The impact assessments and proposed controls for managing/mitigating any impacts are presented in Section 6.3.

NT EPA guidance (NT EPA 2021a)				**INPEX assessment**		
Air	Air quality	Protect air quality and minimise emissions and their impact so that environmental values are maintained.	• the chemical, physical and biological characteristics of quality air • the biological processes that depend on the air quality	Not Applicable	No	The proposed action will not significantly impact on air quality in Darwin. Air emissions associated with the activity are limited to the operation of a single dredge vessel and any crew support vessel/s. Any emissions as a result of vessel operations will be temporary and highly localised.
	Atmospheric processes	Minimise greenhouse gas emissions so as to contribute to the NT Government's goal of achieving net zero greenhouse gas emissions by 2050.	• a contribution to the NT's greenhouse gas emissions • adaptation to a changing climate • capacity of communities and country to respond or adapt to climate change	Not Applicable	No	The proposed action will not contribute significantly to greenhouse gas emissions in the Northern Territory. Greenhouse gas emissions associated with the activity are limited to the operation of a single dredge vessel and any crew support vessel/s. Any emissions as a result of vessel operations will be temporary and highly localised.

People	Community and economy	Enhance communities and the economy for the welfare, amenity and benefit of current and future generations of Territorians.	• dwellings, homelands, communities, towns and suburbs where people live
			• liveable environment
			  • good amenity – air quality, noise, aesthetics
			  • access to natural resources including bush food
			  • recreational use of the natural or built environment (e.g. fishing, cycling, sports, picnics)
			  • access to social infrastructure and services including transport and logistics
			• Healthy lifestyles
			  • sense of wellbeing
			  • good mental health
			  • community aspirations
			• Financial security
			  • affordable access to food, water, electricity, transport and communication networks
			  • livelihoods
			  • participation in jobs, businesses and education
			  • existing industries such as agriculture, pastoralism, tourism, fisheries
			• vulnerable sectors of the community
			• connections to culture and community (that are not explicitly protected under culture and heritage legislation addressed in the Culture and heritage factor)
			  • Aboriginal rights and interests, including right of access
			  • cultural practices
			  • sense of belonging, inclusion, connectedness and cohesion
				Refer to sections 3.7.2, 3.7.3, 3.7.4 and 3.7.5.	No	The proposed action will not significantly impact on the economy or welfare, amenity of the community (both current and future generations. Any impacts to amenity will be temporary and localised.

NT EPA guidance (NT EPA 2021a)				**INPEX assessment**		
			• healthy social relationships			
	Culture and heritage	Protect sacred sites, culture and heritage.	• sacred sites • historic heritage and places • world heritage	Refer to Section 3.6.	Yes	The proposed action, specifically the dredge area, is located in close proximity to several Catalina flying-boat wrecks, ship wrecks declared areas and sacred sites. No aircraft/ship wreck declared areas or sacred sites are located in proximity to the dredge spoil disposal area. If vessel movements/anchoring is not appropriately managed there is the potential to impact on the values of aircraft/ship wreck declared areas and sacred sites in proximity to the maintenance dredging footprint. The impact assessment and proposed controls for managing/mitigating any impacts are presented in Section 6.4.
	Human health	Protect the health of the Northern Territory population.	• drinking water • recreational water • air quality • bush tucker • radiological limits • biting insects	Refer to Section 3.7.	No	The proposed action will not significantly impact human health in Darwin. • drinking water - the proposed maintenance dredging and spoil disposal activities are located wholly in the marine environment and have no interaction with drinking water. • recreational water - treated sewage discharges will be managed in accordance with the intent of MARPOL 73/78 and occur when vessel is en route and is ≥3 nm from the nearest land. Any sewage discharges as a result of vessel operations will be temporary and highly localised. • air quality – see assessment statement for Factors under Theme - Air • bush tucker – sediment quality assessment within dredge area in accordance with Commonwealth of Australia (2009) found dredge material to be uncontaminated and safe for open water disposal. • radiological limits - sediment quality assessment within dredge area in accordance with Commonwealth of Australia (2009) found dredge material to be uncontaminated and safe for open water disposal. • biting insects - the proposed maintenance dredging and spoil disposal activities are located wholly in the marine environment and have no interaction with biting insects.

5 SEDIMENT AND PLUME MODELLING

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 (suspended sediment concentration) and sedimentation associated with a maintenance dredging campaign.

5.1 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 5.3).

A summary of the modelling aspects as relevant to the worst-case credible scenario is provided in Table 5-1. The percentage fines within the material to be dredged have been inferred from the 2016 sediment quality assessment (INPEX 2016; Section 3.1.5), in addition to the values considered during the capital dredging program based on geotechnical information (INPEX 2013). Recent sediment data collected from within the dredge footprint in 2019, 2020 and 2021 (INPEX 2019, 2020, 2021c) has also been reviewed. This review identified interannual and fine scale spatial variability, however there was general agreement in the proportion of fines between 2016 and recent data which is likely to have limited overall impact on modelled excess SSC (HRW 2022). As such, the previously conducted modelling is considered valid (HRW 2022). 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 5-1 and data inputs described in Section 5.3.2. 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.

Table 5-1: 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

Description	Fines content* (%)	Overflow (min)	Overflow height (m)	Volume (m^3)
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)

5.2 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 Ichthys LNG Draft EIS (INPEX 2010).

The assessment consists of three major components:

1. verified and validated two-dimensional hydrodynamic model (Section 5.3) 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 5.4) 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 geographic information systems (GIS; Section 6.2.3) to quantify and depict potential impact on derived habitats on the basis of tolerance limits (Section 6.2.3).

A summary of the modelling approach as it relates to maintenance dredging is presented in Figure 5-1. It is noted that since modelling for maintenance dredging was completed the Guideline on *Dredge Plume Modelling for Environmental Impact Assessment* (Sun et al. 2020) has since been released. In review of this guideline, the modelling informing this maintenance dredging referral is considered appropriate, as modelling is based on verified and validated data specific to Darwin Harbour which was collected during the capital dredging program; as described in the following sections..

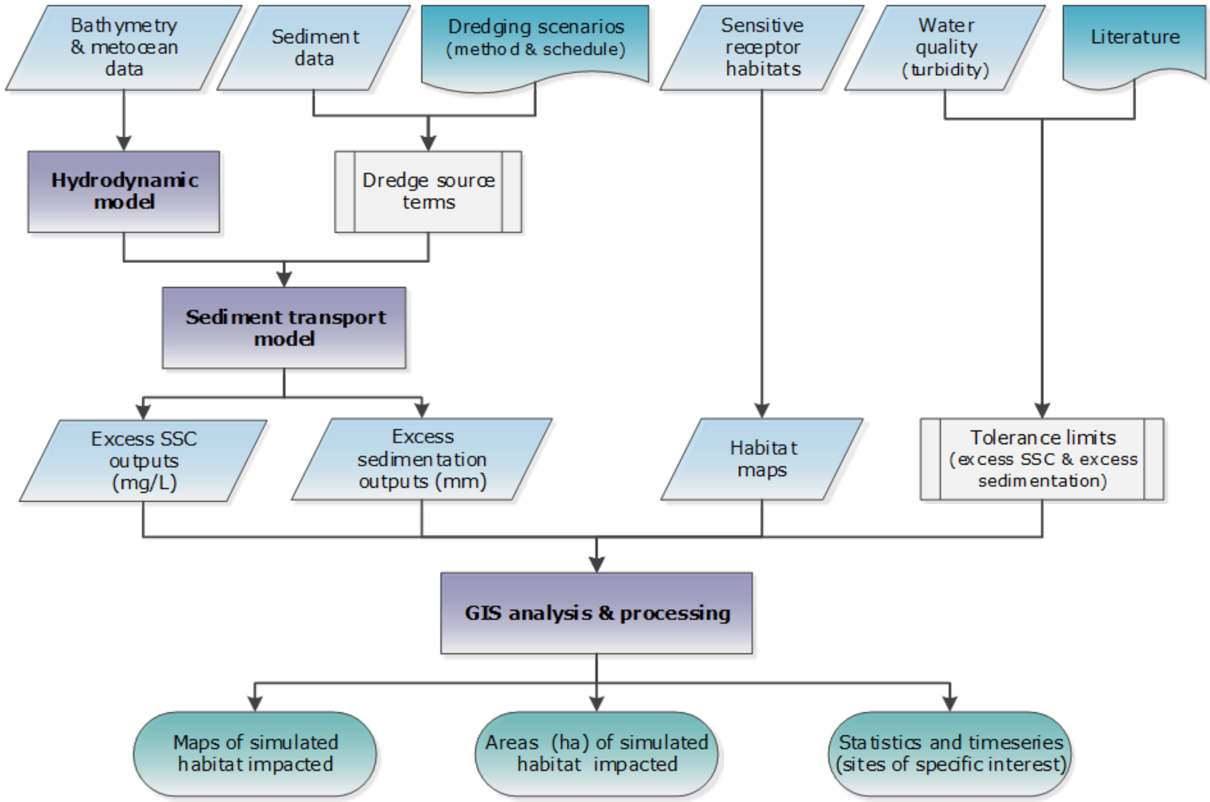

Figure 5-1: Synthesis of modelling assessment approach

5.3 Hydrodynamic model

5.3.1 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 Ichthys LNG 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 5-2 illustrates the boundary and mesh resolution of the calibrated model.

The 2D hydrodynamic model assumes that three dimensional (3D) estuarine circulation, resulting from 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 dredging referral. Further, several studies by the Australian Institute of Marine Science have shown that the vertical distribution of currents over the Harbour are regular and without stratification and that a 2D assumption is valid (Brinkman & Logan 2019).

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 6.2.3).

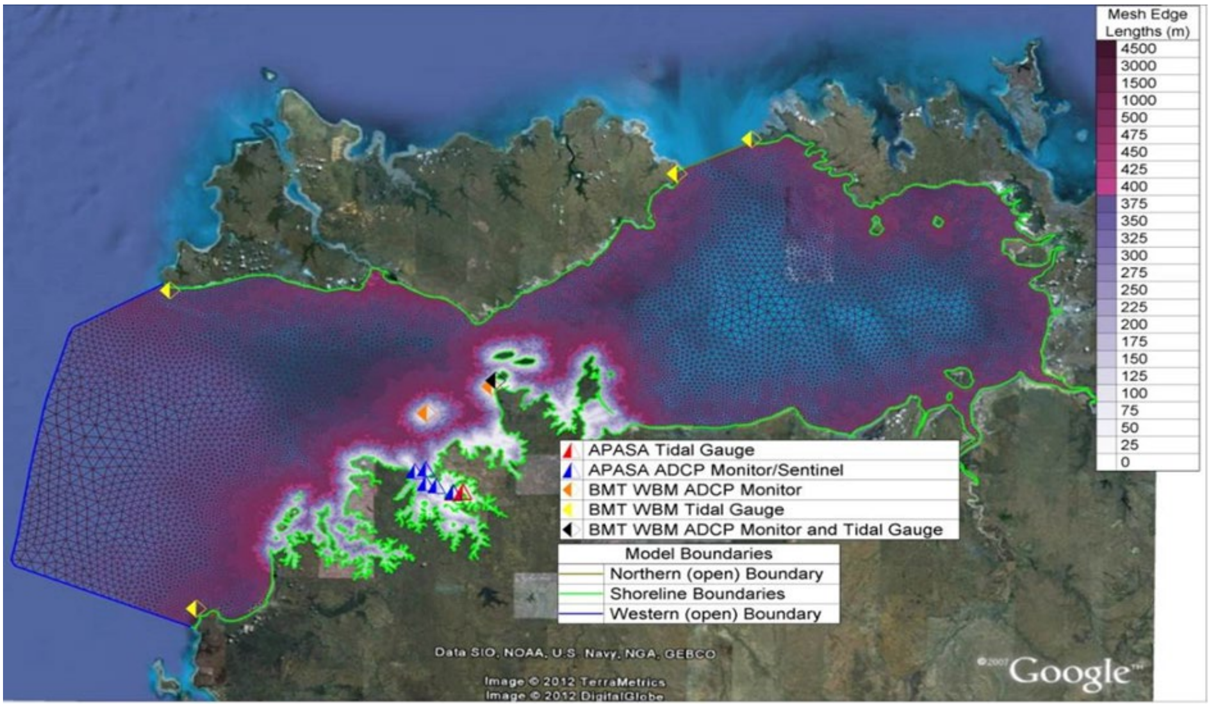

Figure 5-2: Model extent and mesh resolution of the revised hydrodynamic model and sediment transport model

5.3.2 Data inputs

For this maintenance dredging referral, 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.

5.4 Sediment transport model

5.4.1 General description

The dispersion and settling patterns of fine sediments (<75 μm) 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 5.3. 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 5-2).

5.4.2 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 5-3. For this maintenance dredging referral, 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 5.1
- 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 5-2) 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.

[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.

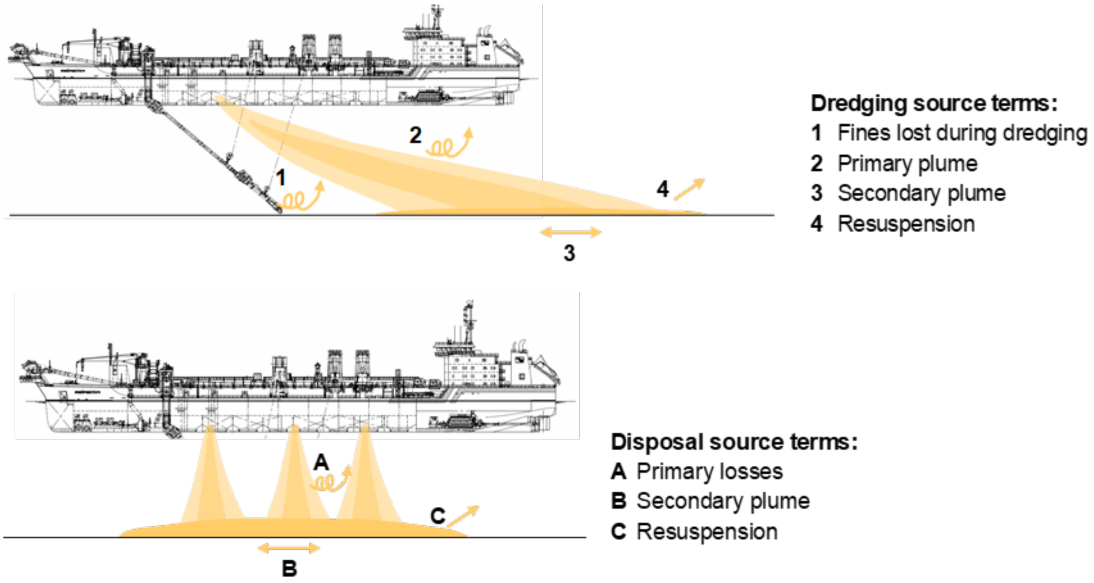

Figure 5-3: Visual representations of the source terms for fine sediment released into the environment during dredging and spoil disposal activities

Table 5-2: 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%*
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% 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.

5.5 Model outputs

5.5.1 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 (SN) 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 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 6.2.3). For ease of reference, the outputs from this period are provided in Figure 5-4, Figure 5-5 and Figure 5-6, 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 3.1.1 and 3.1.2). 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 6.2.3.

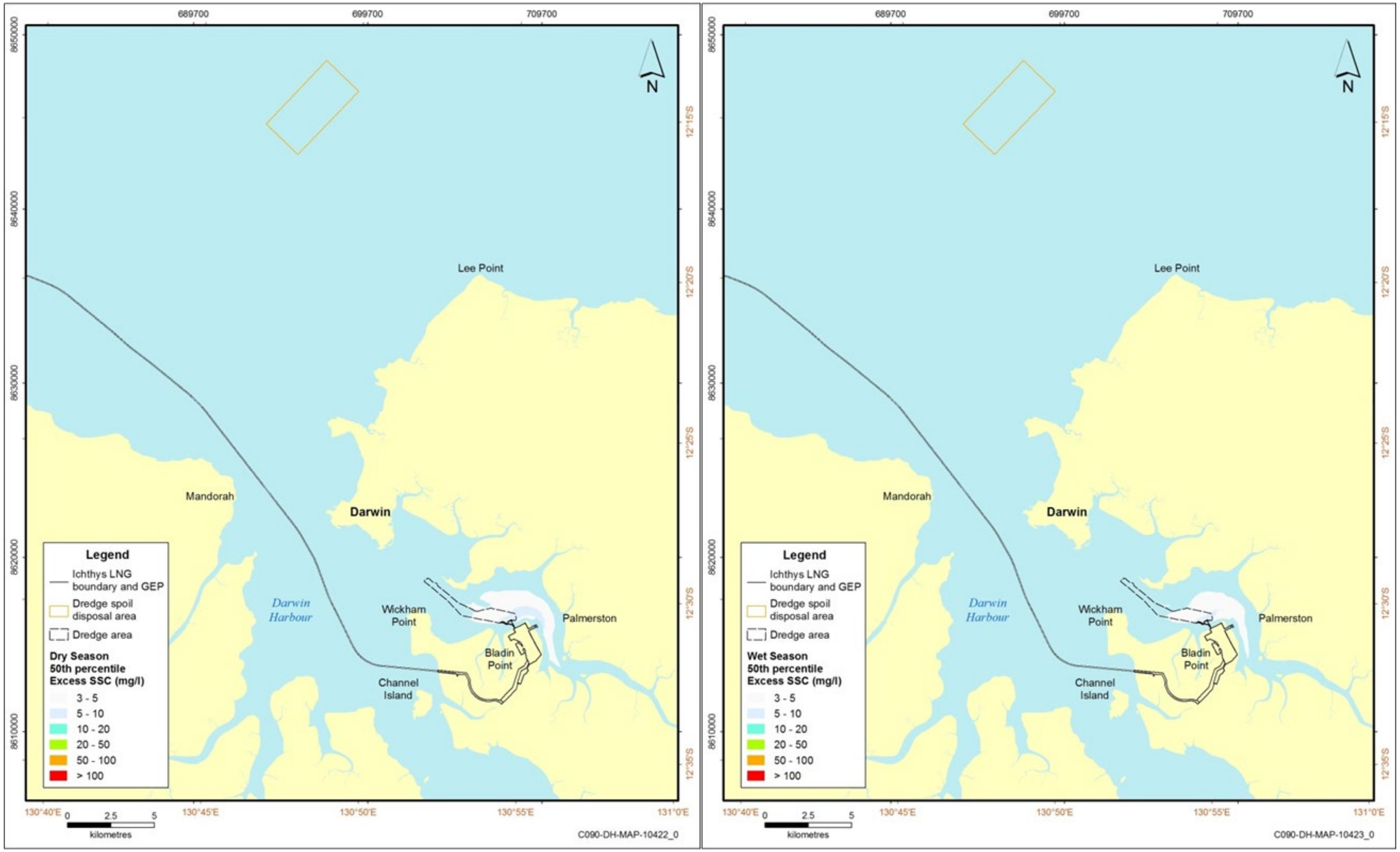

Figure 5-4: Worst-case credible scenario model results representing the 50th percentile excess SSC (mg/L) for the highest intensity phase (SN2; 15 to 29 days) in both representative dry season conditions (left) and representative wet season conditions (right)

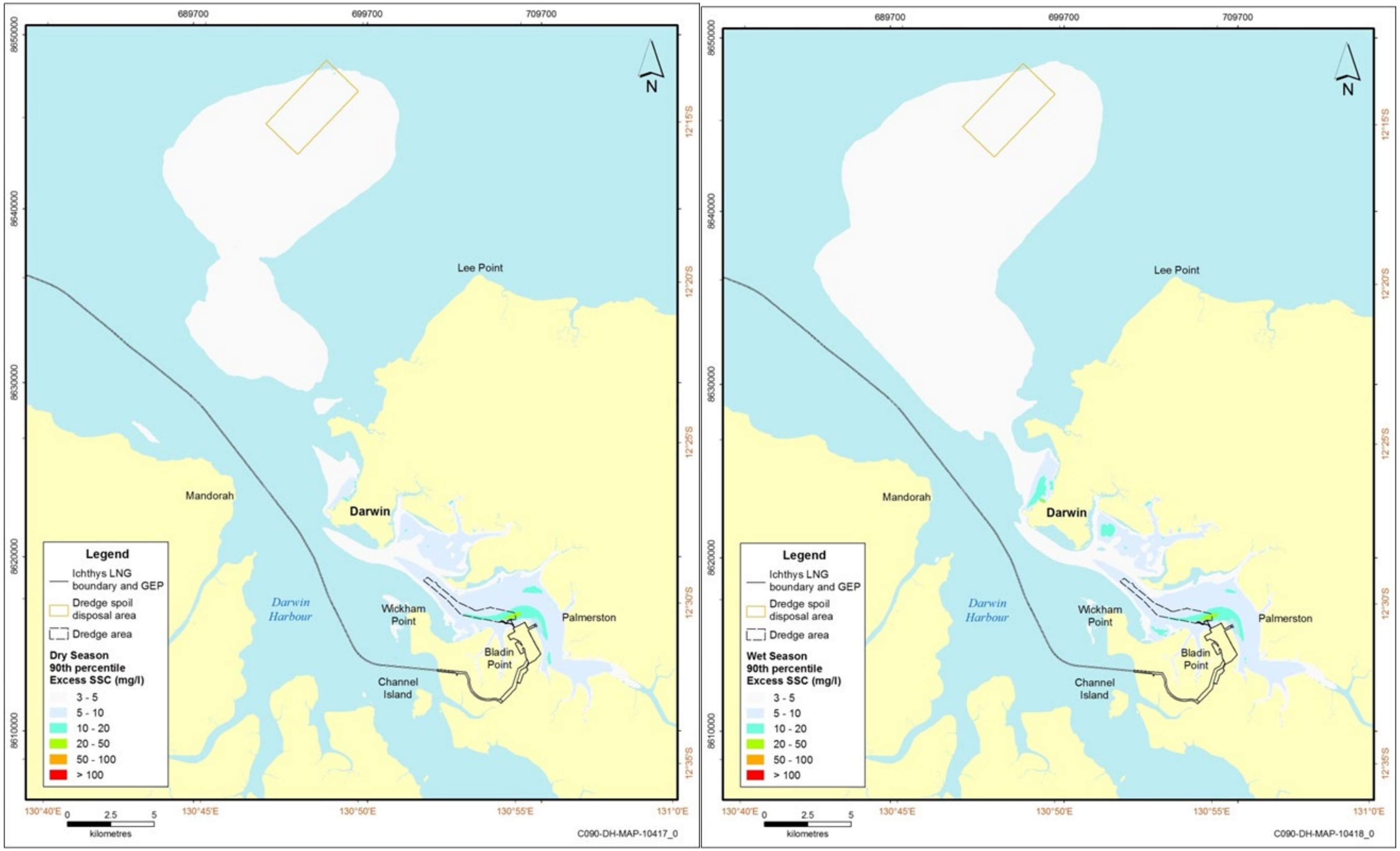

Figure 5-5: Worst-case credible scenario model results representing the 90th percentile excess SSC (mg/L) for the highest intensity phase (SN2; 15 to 29 days) in both representative dry season conditions (left) and representative wet season conditions (right)

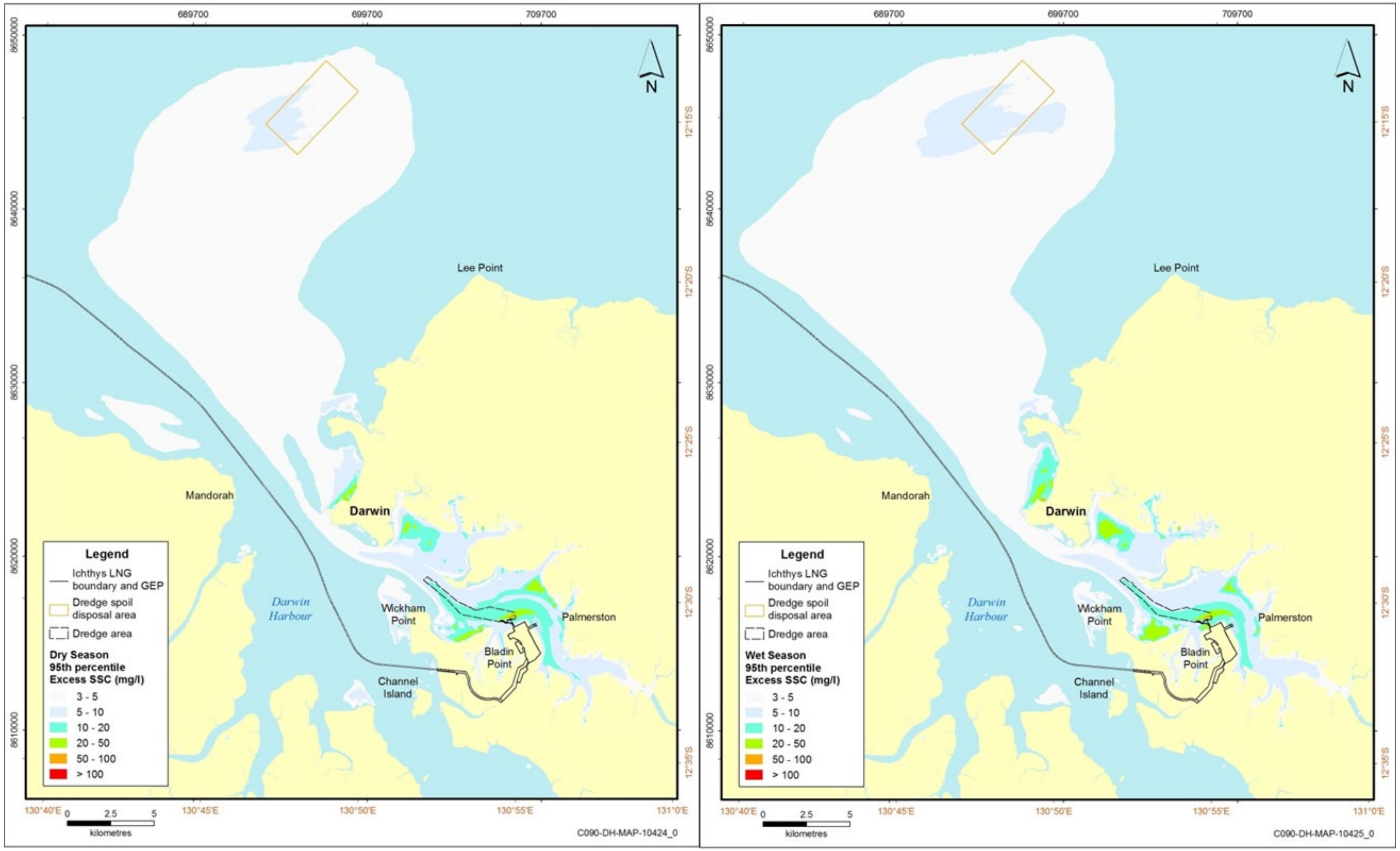

Figure 5-6: Worst-case credible scenario model results representing the 95th percentile excess SSC (mg/L) for the highest intensity phase (SN2; 15 to 29 days) in both representative dry season conditions (left) and representative wet season conditions (right)

5.5.2 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 5-7 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, or greater than 5 mm within the Beagle Gulf.

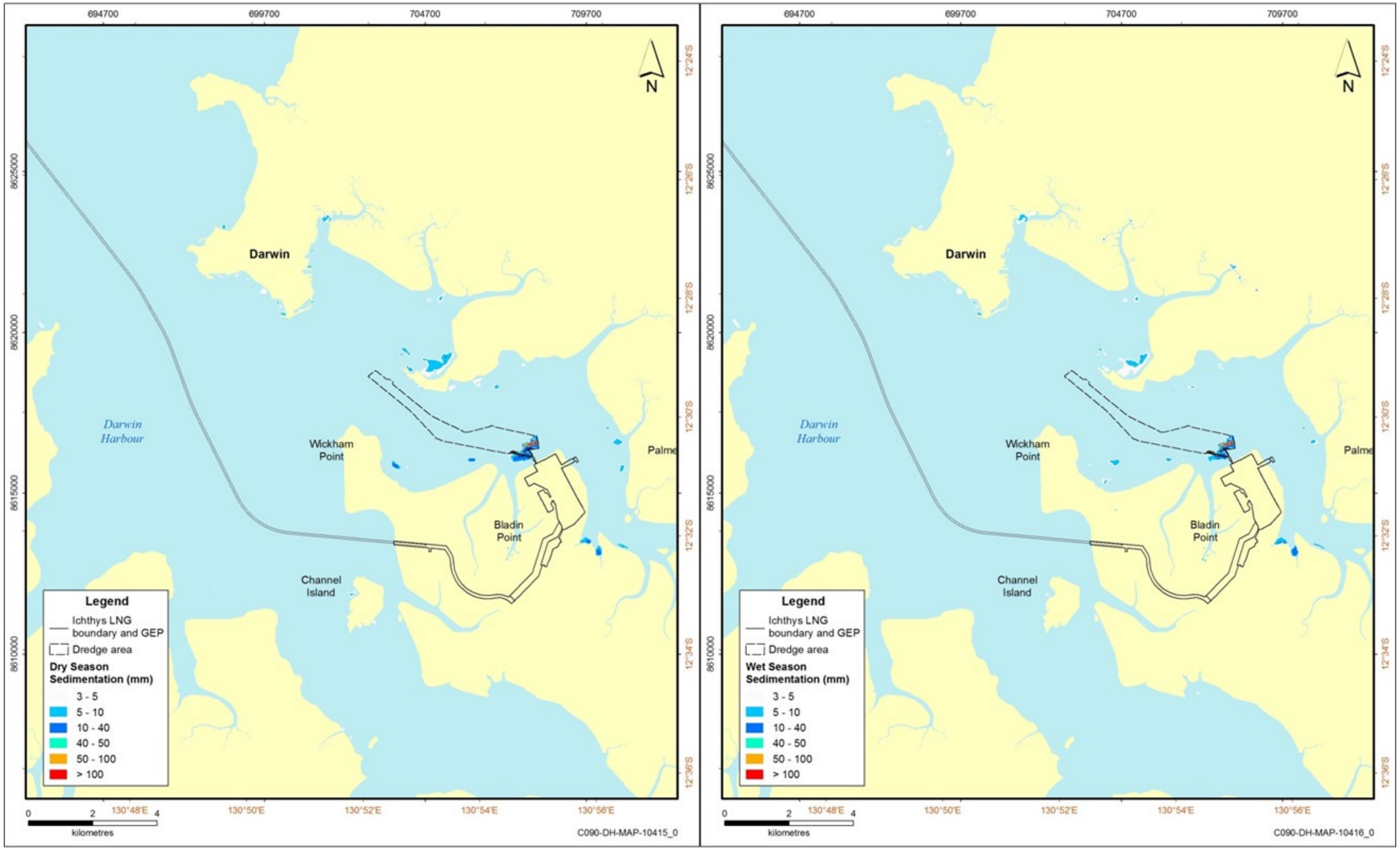

Figure 5-7: Worst-case credible scenario modelled excess (dredging-induced, above background) sediment deposition (mm) at the end of modelling simulation for representative dry season conditions (left) and representative wet season conditions (right)

6 POTENTIAL ENVIRONMENTAL IMPACTS AND MANAGEMENT

6.1 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 Ichthys LNG 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 Ichthys LNG 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 Ichthys LNG Final EIS (INPEX 2010, 2011).

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

6.1.1 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 2 to determine the mechanisms/sources of potential environmental impact. The information provided in Section 3 (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 6-1.

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 6-2. The key interacting factors that drive sediment dynamics in Darwin Harbour and the natural cycles of light availability are described in Sections 3.1.1 (Climate), 3.1.3 (Oceanography) and 3.1.4 (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 6-1: Maintenance dredging conceptual site model

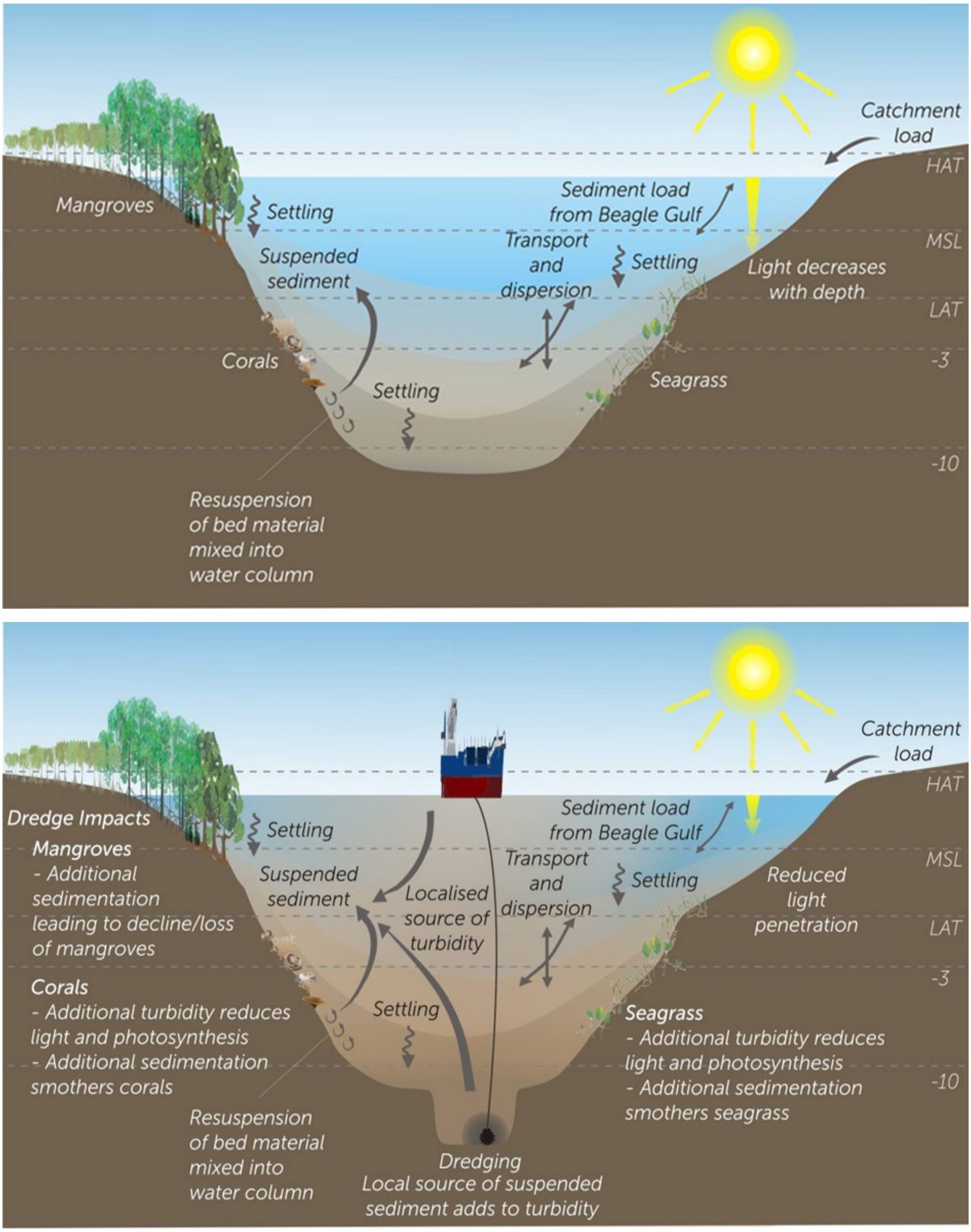

Figure 6-2: Conceptual site model related to the natural (top) and dredging derived (bottom) turbidity and sedimentation on sensitive receptors (Cardno 2014b)

6.1.2 Risk assessment process

The maintenance dredging risk assessment was informed by the conceptual site models described in Section 6.1.1. 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"[15] of implementing them, the control measure was not included, and the risk was considered to be managed to ALARP.

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 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 6-3.

The outcomes of the risk assessment as they relate to NT EPA environmental factors and values and cumulative impacts, are presented in sections 6.2, 6.3 and 6.4 of this referral report and in the Maintenance DSDMP (Appendix A).

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

INPEX

Risk Matrix

Refer to the Risk Management Guideline [0000-A0-GLN-60010] for guidance on how to apply the 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 Level	Financial NPV (USD)	Health & Safety	Environment	Reputation	Cultural & Social Heritage	Legal
A	>$1B	>20 fatalities or permanent total disabilities	Regional scale event, permanent impact on environment. Eradication of local populations of protected species	Prolonged international multi-NGO and media and by public protests. Loss of host government support and/ or social licence to operate. Company reputation severely tarnished	Permanent, long-term impact on social structure, and destruction of highly valued heritage, aesthetic, economic or recreational items	Criminal prosecution, potential jail sentences for directors and senior officers. Civil prosecution, class actions. Heavy fines, threat to licence to operate or future approvals
B	$100M – $1B	2 – 20 fatalities or permanent total disabilities	Large scale event, long term impact on environment. Extensive impact on populations of protected species	International multi-NGO and media condemnation. Host government registers concerns. Prolonged large protests. Company reputation seriously impacted	Widespread disruption to a number of communities with damage to highly valued heritage, aesthetic, economic or recreational items	Criminal prosecution for directors and senior officers. Civil prosecution and class actions. Heavy fines, threat to licence to operate
C	$10M – $100M	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	Serious public or national media outcry. Damaging NGO campaign. Large protests. Company reputation impacted	Significant impact to regional communities, and to heritage, aesthetic, economic or recreational items of significant value	Significant, multiple breaches of regulation or licence conditions. Significant litigation and fines
D	$1M – $10M	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	Major adverse national media, public or NGO attention. Significant protests. Asset reputation impacted	Regional community disruption with moderate impact on heritage, aesthetic, economic or recreational values	Serious breach of regulation. Investigation by regulatory authorities. Potential litigation and moderate fines
E	$100K– $1M	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	Attention from regional media with heightened concern with local community. Criticism by community or NGOs	Isolated community disruption with limited adverse impact on heritage, aesthetic, economic or recreational values	Minor legal issues. Report provided to regulatory authorities. Potential for minor fines
F	<$100K	Slight injury or illness, first aid injury	Local scale event with temporary impact on environment. Behavioural responses inconsequential ecological significance to protected species	Short term local concern or complaints. Low level media or regulatory issue	Minor impact on heritage, aesthetic, economic or recreational values	Breach of internal standards. Potential scrutiny by regulatory authorities

Likelihood Level

Severity	6 Remote	5 Highly Unlikely	4 Unlikely	3 Possible	2 Likely	1 Highly Likely
A Catastrophic	6	5	4 Critical Risk	3	2	1
B Major	7	6	5	4	3	2
C Significant	8	7	6 High Risk	5	4	3
D Moderate	9	8	7	6	5	4
E Minor	10	9	8 Moderate Risk	7	6	5
F Insignificant	10	10	9 Low Risk	8	7	6

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Figure 6-3: INPEX risk matrix

6.2 Sea – Marine environmental quality

As identified in Section 4, maintenance dredging activities have the potential to impact on the following environmental factor – *Marine environmental quality*. The following sections provide a description of the potential impacts and proposed key management controls to mitigate any potential impacts.

6.2.1 Relevant policy and guidelines

The following conventions, legislation, policy and guidelines are relevant:

- International Convention for the Prevention of Pollution from Ships, 1973, as modified by the Protocol of 1978 thereto (MARPOL 73/78)
- *Protection of the Sea (Prevention of Pollution from Ships) Act 1983* (Cwlth)
- *Dangerous Goods Act 1998* (NT)
- *Fisheries Act 1988* (NT)
- *Waste Management and Pollution Control Act 1998* (WMPC Act; NT)
- *Water Act 1992* (NT)
- *Marine Pollution Act 1999* (NT)
- Australian and New Zealand guidelines for fresh and marine water quality (ANZG 2018)
- National Assessment Guidelines for Dredging (NAGD; Commonwealth of Australia 2009)
- National Water Quality Management Strategy: Australian Guidelines for Water Quality Monitoring and Reporting (ANZECC/ARMCANZ 2000)
- Guidelines for Environmental Assessment of Marine Dredging in the Northern Territory (NT EPA 2013)
- Declaration of Beneficial Uses and Objectives, Darwin Harbour Region, Northern Territory Government Gazette No. G27, 7 July 2010.
- Water Quality Objectives for the Darwin Harbour Region - Background document (NRETAS 2010)
- Darwin Harbour Water Quality Protection Plan (DLRM 2014)

6.2.2 Environmental context

Darwin Harbour water and sediment quality is described in Sections 3.1.4 and 3.1.5, respectively.

6.2.3 Potential impacts

The following activities have the potential to impact on marine environmental quality in Darwin Harbour if not managed appropriately:

- dredging and dredge disposal activity
- waste and liquid discharges
- accidental chemical and hydrocarbon spills

Potential impacts associated with these activities include:

- dredging and spoil disposal activities causing increased turbidity resulting in indirect impacts to sensitive receptors (e.g. coral, seagrass)
- dredging and spoil disposal activities causing release of contaminants from sediments into the water column and indirectly impacting sensitive receptors (e.g. coral, seagrass)
- waste and liquid discharges may result in localised nutrient enrichment or marine pollution
- accidental loss of chemicals or hydrocarbons resulting in localised marine pollution

Sediment related effects

Sensitive receptors (Coral, seagrass and mangroves)

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. 2017; Mills & Kemps 2016). Direct effects include the removal of substrate within the dredge area and smothering of substrate at the DSDA during disposal. Direct effects are discussed in Section 6.3 as it relates to loss of habitat (e.g. marine ecosystems).

Dredging and spoil disposal activities 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. 2017).

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 3.1.5), the deposited sediment to be dredged during a maintenance dredging campaign were found to consist of uncontaminated silt and fine sands and safe for open water disposal. The risk of chemical effects is therefore not considered further.

Physical effects relate to elevated concentrations of suspended sediment (turbidity), changes in light quality and quantity, and sedimentation (Jones et al. 2016), with the latter covered in Section 6.3 in regards to direct removal and burial within the dredge area and DSDA respectively. 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) (Luter et al. 2021), 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, life history of species affected and morphology (Duarte et al. 1997; Erftemeijer & Lewis 2006; Jones et al. 2019b). The ability of bleached corals to actively clear settled sediments has also been shown to be substantially impacted, with 3-to 4-fold greater sediment accumulation than normally pigmented corals (Bessell-Brown et al. 2017).

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)[16] 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 2.3, 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 2.3.2), 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 2.3.3 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 5), as recommended in Mills and Kemps (2016). Results from the sediment plume modelling and impact assessment are described in Habitat impact assessment outcomes. Overall, it was found that <1 ha of coral (as a component of Mixed Community; Reef habitat[17]) is simulated to be indirectly impacted due to maintenance dredging operations. No impacts to high-confidence or inferred seagrass communities are predicted.

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

[17] 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.

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 will be implemented. 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.

Reproductive cycle of corals

In a review undertaken by Jones et al. (2015a), 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 3.2.2. 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 5. Specifically, spawning, fertilisation and 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 suspended sediment concentration (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 5.5.1).

Buoyancy of egg-sperm bundles for broadcast spawning corals is critical to maximise fertilisation (Ricardo et al. 2016b). Ricardo et al (2016b) found that elevated SSC can reduce the buoyancy of egg-sperm bundles through a ballasting effect whereby suspended sediment sticks the mucous coating of the egg-sperm bundle. This can prevent the egg-sperm bundles from reaching the ocean surface and subsequently reduce egg-sperm encounter rates. Model ascent probabilities from this indicated a 10% reduction in egg-sperm encounters at 106 mg/L for a 5 m deep reef and 53 mg/L for a 10 m deep reef. Sediment composition has also been shown to influence fertilisation with sediments containing mineral clays and organic matter likely promoting flocculation of the coral sperm, thus reducing fertilisation (Ricardo et al. 2018). Fertilisation success can also be impacted by SSC. Ricardo et al. (2015) found that some sediments adhere to sperm causing sediment-sperm flocs and decreasing sperm numbers for fertilisation, however sediment did not appear to stick to eggs, which lack a mucous coating. Fertilisation was more sensitive to organic rich clay sediment, and for all sediment types, the effect was more pronounced at sub-optimal sperm concentrations (Negri et al. 2019).

Coral embryo and larval development are the least sensitive to SSC (Ricardo et al. 2017a). A study undertaken by Humphrey et al. (2008) found no effect to early embryonic development at the highest concentrations tested on *Acropora digitifera* (100 to 150 mg/L) and *Acropora millepora* (200 mg/L) respectively (Jones et al. 2015a). More recently, a study by Ricardo et al. (2016a) found there were no lethal effects at SSCs greater than 100s mg/L and there was also no clear legacy effects (i.e. ability to settle) of the elevated SSC (Ricardo et al. 2017a).

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 egg-sperm bundles and fertilisation success through reduction in sperm concentrations. No effects to early embryonic or larval development are expected.

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 Darwin Harbour coral communities 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). Elevated SSC can also result in increased sediment deposition, covering surfaces suited to larval settlement, with a recent study by Ricardo et al. (2017b) indicating that only a few mg/cm^2 (e.g. a thin veneer) can cause an effect (e.g. preference from upward to downward facing sediment free surfaces that may not be optimal for longer-term survival). However, Ricardo et al. (2017b) also noted that this level of deposited sediment occurs within common natural background levels, indicating these effects are already likely to occur to some degree on most reefs. Given the modelled SSC over known coral communities is well below the levels from Te (1992), it is unlikely that significant effects to settlement will occur. Darwin Harbour is also a natural turbid environment with deposition levels that likely exceed those reported in Ricardo et al. (2017b), nonetheless additional sediment deposition dredging related SSC could affect larval settlement. Given the modelled spatial extent of the suspended sediment plume and the naturally turbid water experienced in Darwin Harbour, the risk to Darwin Harbour coral communities 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.

Tolerance limits for habitats

To interpret the modelling outputs described in Section 5.5 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 Ichthys LNG 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 dredging referral are presented in Table 6-1, 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 SSC tolerance limits.

Table 6-1: Tolerance limits for excess SSC and sedimentation

Habitat	Location	Season	Capital dredging DSDMP		Current analysis	
			SSC (mg/L)*	Sedimentation (mm)	SSC (mg/L)*	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	

Habitat	Location	Season	Capital dredging DSDMP		Current analysis	
			SSC (mg/L)*	Sedimentation (mm)	SSC (mg/L)*	Sedimentation (mm)
	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	Anyway	dry	12.8	40	13.3	40
		wet	51.7		60.6	

* 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)

SSC tolerance limits

For this maintenance dredging referral, 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 Ichthys LNG Final EIS (INPEX 2010, 2011) were derived from a one year (2010 to 2011) baseline turbidity dataset collected for the Ichthys LNG 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 dredging referral, 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 Ichthys LNG 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 published as a part of the Western Australian Marine Science Institute (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, 2019b) and Fisher et al. (2019), 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, 2017) 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. 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).

Sedimentation tolerance limits

For this maintenance dredging referral, 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 Ichthys LNG 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, 2017, 2019a, 2019b) state there are currently no suitable techniques for measuring relevant sediment deposition over appropriate scales (e.g. mg per cm^2) to be effective as a monitoring tool for dredging programs.

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 dredging referral. 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.

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[18] (WA EPA 2016). 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 3.2.5) 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 6-1) are exceeded for 10% of the time or where the simulated sedimentation depth exceeds their respective sedimentation tolerance limits (Table 6-1) 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 (i.e. within five years 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 2016).

Sensitive receptor communities are predicted to be indirectly influenced where their respective ecological tolerance limits for SSC (Table 6-1) 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 2016).

[18] irreversible means 'lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less'

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 5.1) will have no impacts on high-confidence or inferred seagrass or mangrove communities. While only a minor area (0.8 ha; Table 6-2) 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 (see Tolerance limits for habitats).

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, 2019b, 2020).

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 will be implemented to monitor the actual turbidity at each of the sensitive receptor sites.

Table 6-2: 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 6-4 (left)) and is classified as Mixed Community; Reef habitat[19]. 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.

[19] Based on the outcomes of habitat mapping and classification undertaken for the Ichthys LNG 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.

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 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 3.2.2, the hard coral composition at Northeast Wickham Point is 2.4% made up primarily of species from the Faviidae, Pectiniidae, Dendrophylliidae 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. A recent study that included species from two (Dendrophylliidae and Poritidae) of the four primary coral families from Northeast Wickham Point showed that these species were able to survive extended (i.e. 42 days) exposure to a range of SSC concentrations (0 to 100 mg/L) and light levels (12.6 to 0 mol quanta m^{-2} d^{-1}) (Jones et al. 2020).

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 6-5). 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 substantially lower (see Tolerance limits for habitats). 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 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 6-6). Given these areas are predicted to receive <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.

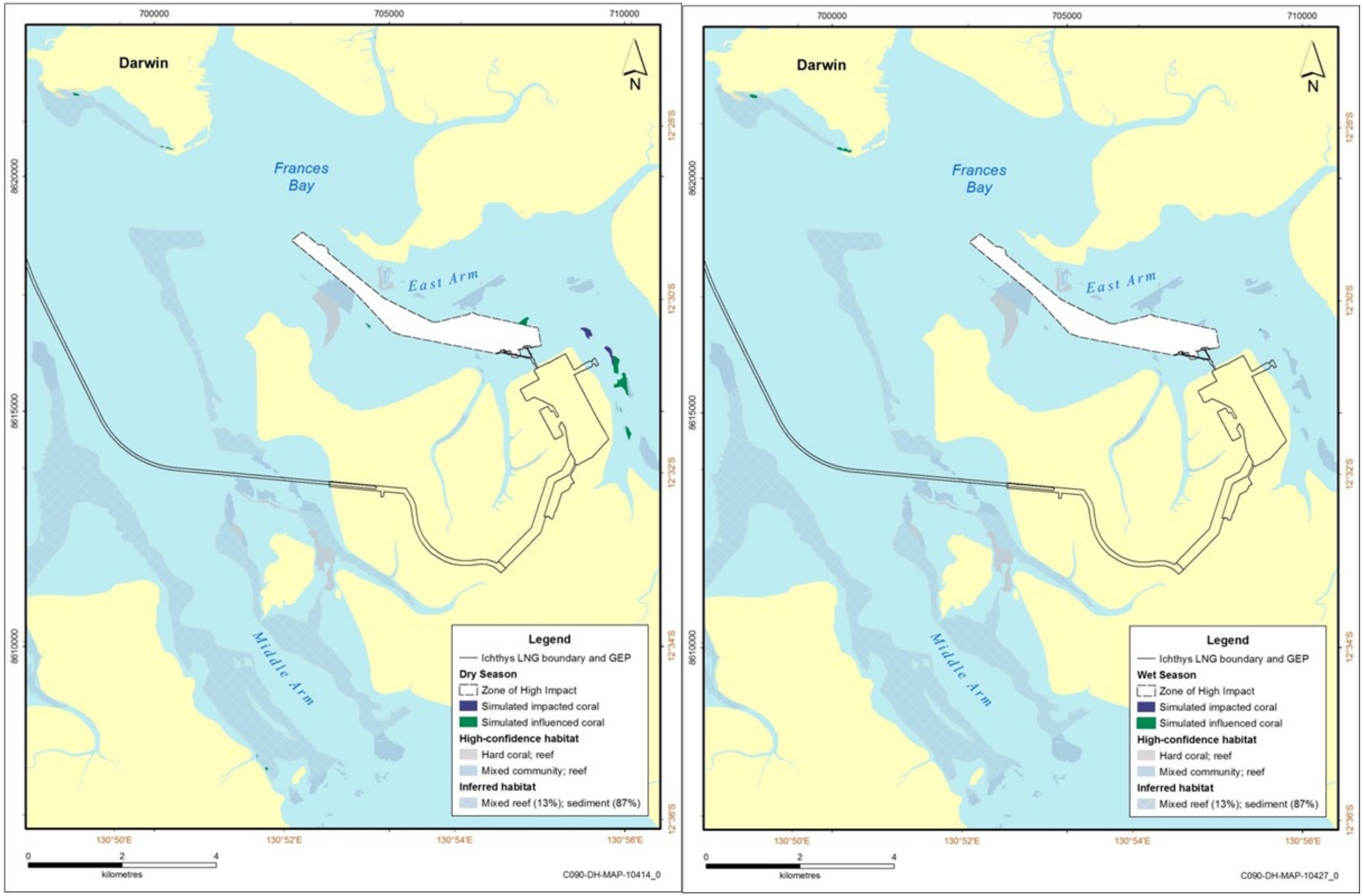

Figure 6-4: Areas of coral habitat simulated to be impacted and influenced by excess SSC and sedimentation based on highest intensity period (SN2; 15 to 29 days) during the dry season (left) and wet season (right)

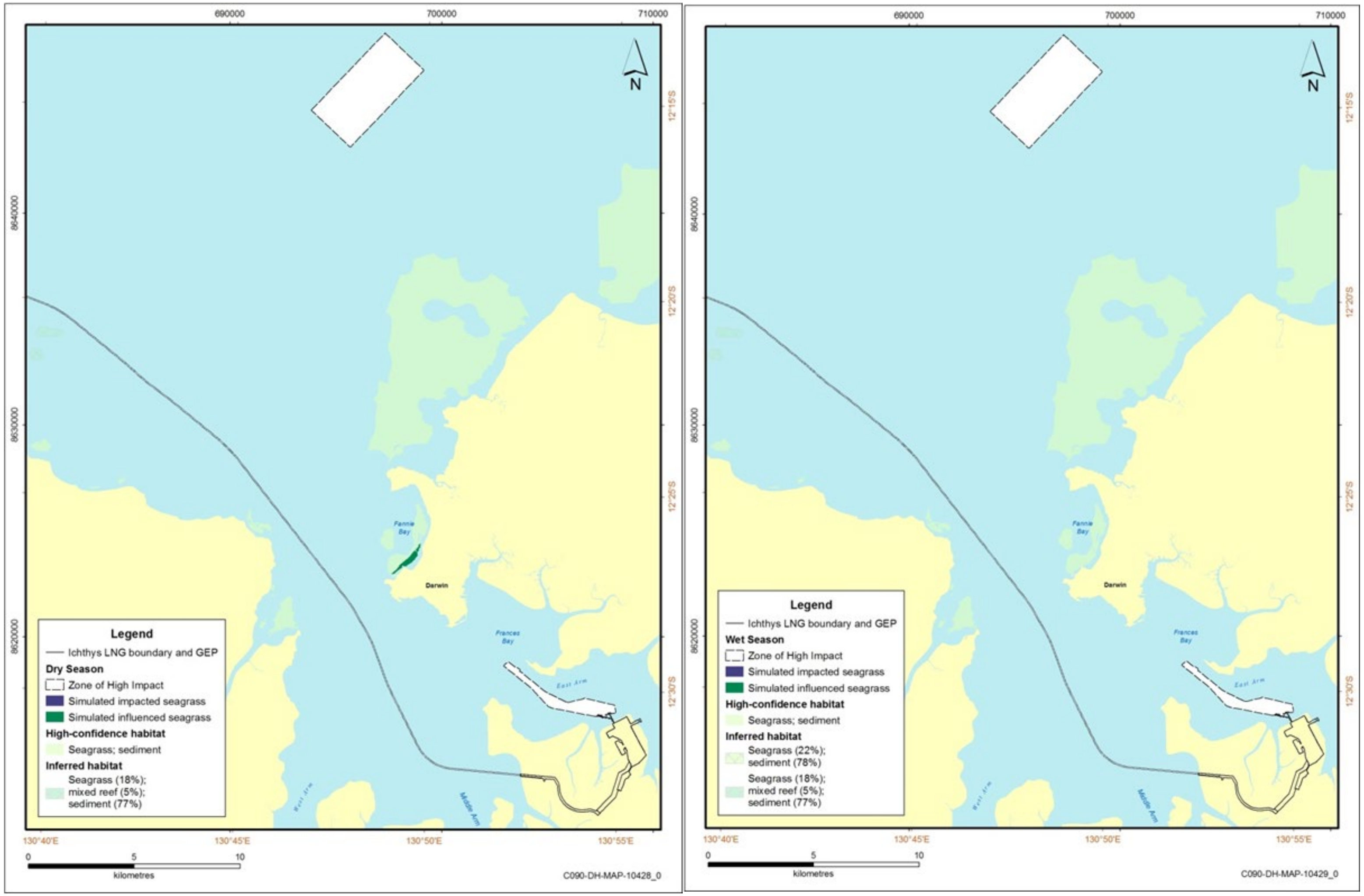

Figure 6-5: Areas of seagrass habitat influenced by excess SSC and sedimentation based on highest intensity period (SN2; 15 to 29 days) during the dry season (left) and wet season (right)

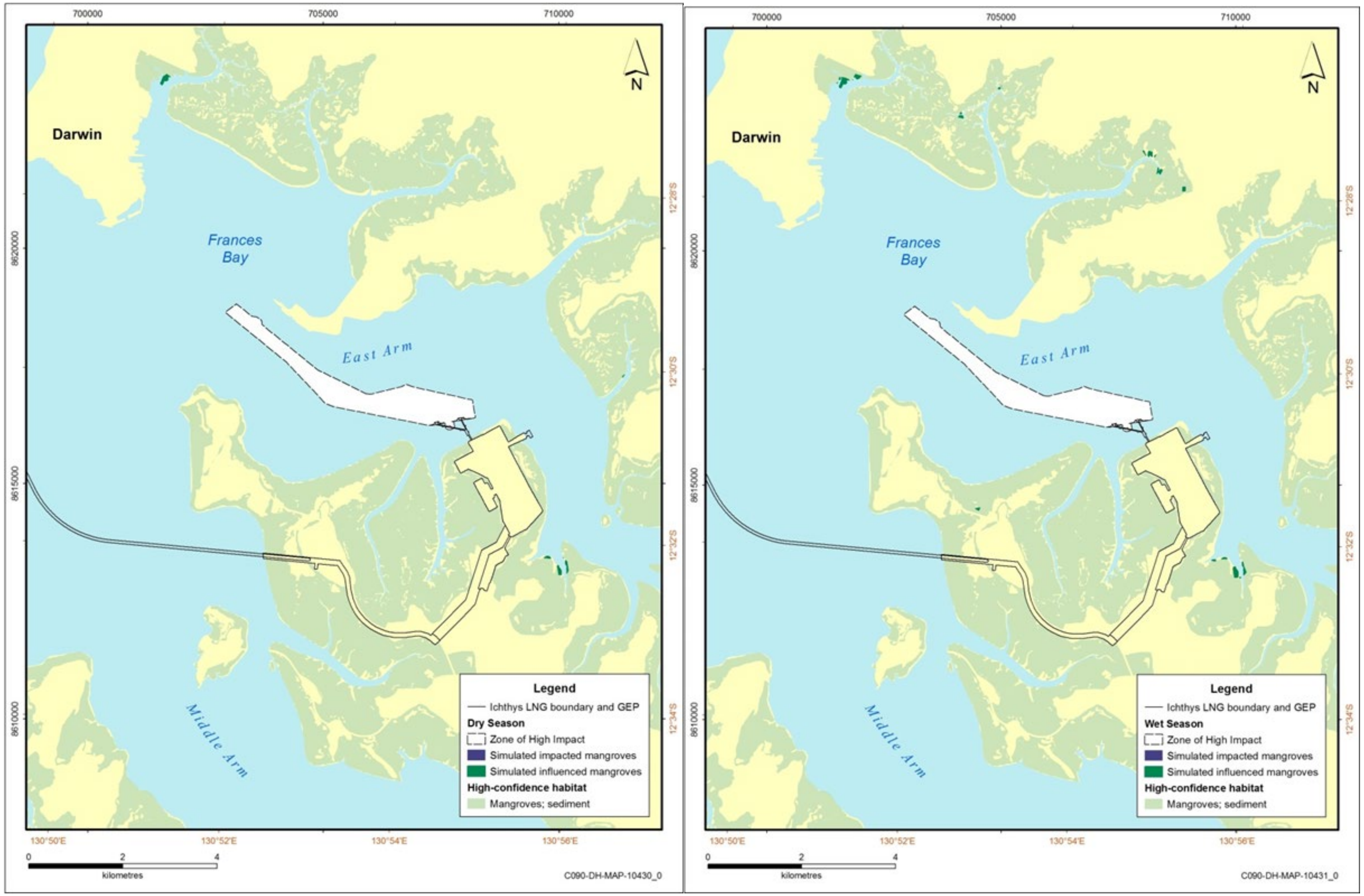

Figure 6-6: Areas of mangrove habitat influenced by excess sedimentation based on highest intensity period (SN2; 15 to 29 days) during the dry season (left) and wet season (right)

Incorrect waste disposal and routine vessel discharges

During the dredging and spoil disposal activities, waste and liquid discharges will be generated as result of routine vessel activities. Routine discharges have the potential to cause localised nutrient enrichment, while mismanagement of waste and liquid discharges also has the potential to result in 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 (Section 6.2.4).

Unplanned chemical and hydrocarbon spills

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 hydrocarbons 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 (Section 6.2.4).

Cumulative impacts

The following sections describe the assessment of the potential for cumulative impacts on environmental factors due to sequential 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.

Sequential Ichthys LNG 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 2.1, this maintenance dredging referral 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[20] and no dredging-related effects to protected marine megafauna[21]. 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 2021a) and cyclone data (BOM 2022) for the Darwin region[22] has been completed and as expected, Figure 6-7 shows that majority 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 above the mean) are infrequent with only two wet seasons (1997/1998 and 2010/2011) having recorded rainfall exceeding this criteria between 1941 and 2021. 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.

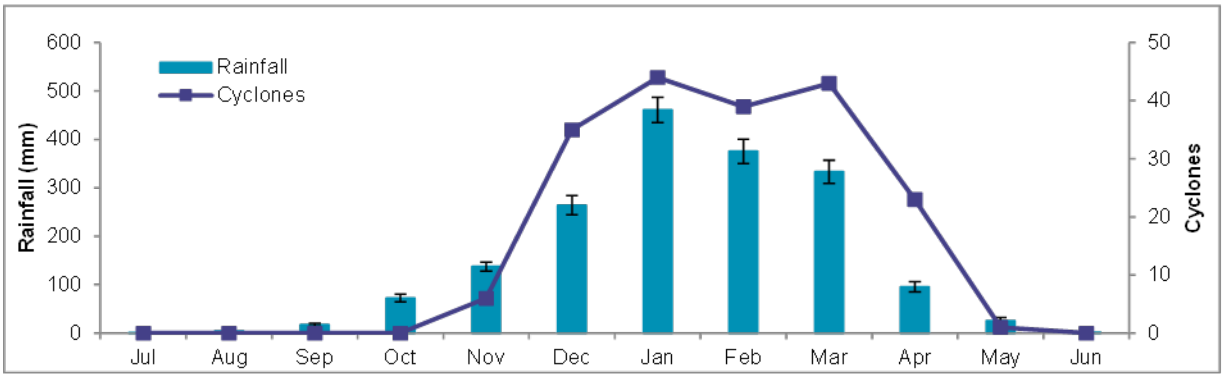

Figure 6-7: Darwin airport monthly average rainfall (mm ±SE) and number of cyclone formation per month between 1964 and 2021

[20] 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.

[21] 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 2015).

[22] 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 (2021a, 2022) and water quality observations during capital dredging (Cardno 2014b).

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 five year timeframe applicable to the approval being sought for maintenance dredging activity. INPEX also reviewed the register of projects currently under assessment by the NT EPA to identify projects that contain dredging activity or activities that could result in cumulative impacts (e.g. trenching). Four projects are currently under assessment that contain dredging activities and one project that contains trenching. Potential for cumulative impacts for each project is described below.

Darwin Pipeline Duplication Project

The Darwin Pipeline Duplication Project proposes pipeline trenching along some sections of the pipeline route adjacent to the existing Bayu-Undan pipeline between Darwin LNG to north of Wagait Beach. The proposed spoil ground for trenching is adjacent to the north-east boundary of DSDA described in Section 2.2.2. Anticipated trenching dredge volume is approximately 250,000 m^3 (Santos 2021). The indicative project schedule states dredging and spoil disposal activities will occur within a 15 month construction period commencing quarter one 2023. Note the construction schedule includes all pre-lay works as well as pipeline installation and pre-commissioning, with dredging and spoil disposal activities likely to be of a much shorter duration within this construction period.

Sediment transport modelling outputs (i.e. GIS layers for 95th percentile modelled excess SSC) were shared by Santos to inform this cumulative impact assessment prior to the finalisation of their modelling report. The maximum excess SSC concentration in the provided modelling outcomes is 2.5 mg/L, which occurs over a small localised area off Wagait Beach and adjacent to Darwin LNG. While the 1 mg/L excess SSC layer extends almost along the entire length of the proposed pipeline route from Darwin LNG to Charles Point; as well as to the north of the DSDA in the vicinity of the proposed Santos spoil ground.

If dredging operations were to occur concurrently, there is potential for overlap of SSC plumes, however the concentration of the overlapping plume associated with trenching and spoil disposal is negligible (e.g. ≤1 mg/L) and over areas of soft bottom benthos/sediment. The only exemption is a small localised area off Wagait Beach and Darwin LNG where modelling predicts small localised areas of excess SSC up to 2.5 mg/L. There is a small area of potential overlap of these modelled outputs with those described in Section 5.5.1, in particular the 3 to 5 mg/L contour in both the wet and dry season off Wagait Beach and 5 to 10 mg/L contour in both the wet and dry season adjacent to Darwin LNG. Based on this overlap, there is potential for cumulative 95th percentile excess SSC for the Project maintenance dredging and Santos pipeline duplication dredging to reach 7.5 mg/L off Wagait Beach and 12.5 mg/L adjacent to Darwin LNG for short periods of time. This is also on the basis that the most intensive dredging for both dredging campaigns is undertaken simultaneously. However, the area of SSC overlap occurs over soft bottom benthos/sediment, with no overlap with coral or seagrass habitat.

Darwin Ship Lift and Marine Industries Project

The Northern Territory Government is delivering the Darwin Ship Lift and Marine Industries Project, which includes the construction of northern Australia's largest common user ship lift and adjacent maintenance facility in East Arm (AECOM 2021). Construction requires the dredging of approximately 500,000 m^3 to create an access channel, manoeuvring/turning basin and berth pockets. All dredged material will be placed onshore, and where possible utilised for land reclamation. The construction schedule indicates dredging operations will occur between quarter four 2022 and quarter two 2024 inclusive (AECOM 2021).

Sediment transport modelling for the proposed dredging indicates a maximum 95th percentile modelled excess SSC of between 5 and 7.5 mg/L in vicinity of the projects dredge footprint (AECOM 2021). There is a small potential overlap of modelled outputs with those described in Section 5.5.1, in particular the 5 to 10 mg/L contour in both the wet and dry season. Based on this overlap, and assuming worst-case (i.e. 10 mg/L and 7.5 mg/L) there is potential for cumulative 95th percentile excess SSC for the Projects maintenance dredging and ship lift dredging to reach 17.5 mg/L for short periods of time. This is also on the basis that the most intensive dredging for both dredging campaigns is undertaken simultaneously. However, the area of SSC overlap occurs over soft bottom benthos and macrobiota reef, with no overlap with coral or seagrass.

Tailwater from onshore settlement ponds for dredge spoil will be discharged on the north side of East Arm Wharf, with a maximum 95th percentile modelled excess SSC of between 10 and 11 mg/L adjacent to the discharge location with the plume returning to background within a few hundred meters (AECOM 2021). There is a small potential overlap of modelled outputs (2 to 3 mg/L contour) with those described in Section 5.5.1, in particular the 5 to 10 mg/L contour in both the wet and dry season. Based on this overlap, and assuming worst-case (i.e. 10 mg/L and 3 mg/L) there is potential for cumulative 95th percentile excess SSC for the Projects maintenance dredging and ship lift tailwater to reach 13 mg/L for short periods of time. This is also on the basis that the most intensive dredging for both dredging campaigns is undertaken simultaneously. However, the area of SSC overlap occurs over soft bottom benthos and sediment, with no overlap with coral or seagrass.

Mandorah Marine Facilities

The Northern Territory Government has identified the need to develop a safer and more weather resistant ferry berthing facility at Mandorah (Cardno 2022b). The proposed development is located adjacent to the existing Mandorah jetty and includes the construction of two large breakwaters, dredging, new single boat ramp and ferry terminal facilities (e.g. pontoon, gangway etc.). Dredging for the referral includes approximately 15,000 m^3 by CSD and 70,000 m^3 by BHD. Dredge spoil from the CSD will be disposed at a designated spoil ground approximately 1.2 km northeast of the referral location, while dredge material from the BHD will be retained onshore for use in construction (e.g. breakwaters, causeway, boat ramp etc.) (Cardno 2022a).

Sediment transport modelling for the proposed dredging indicates a maximum 95th percentile modelled excess SSC of more than 50 mg/L within the projects dredge footprint (Cardno 2022c). Modelled excess turbidity quickly reduces to below 5 mg/L within hundreds of meters at both the dredge and spoil disposal location based on spring tides. For neap tides, modelled excess turbidity stretches further north in a narrow band along the tidal axis at both the dredge and spoil disposal location; dropping below 5 mg/L within approximately 1.5 to 1.8 km. Based on review of modelling outputs, cumulative impacts from activities occurring at Mandorah are unlikely as there is no overlap of model outputs; as such cumulative impacts does not warrant further consideration.

HMAS Coonawarra

The Commonwealth Department of Defence are planning to expand their facilities within HMAS Coonawarra harbour. The referral currently includes deepening of the existing basin, and potential for future expansion of the basin to the east with dredging operations to commence in late 2022 and expected to take one month. Dredging for the referral includes approximately 85,000 m^3 by CSD with potential for another 16,000 m^3 of over-dredge (101,000 m^3 total) (KBR 2022a). The dredge spoil will be pumped via a pipeline to a location approximately 300 m southwest of HMAS Coonawarra breakwater for disposal into the channel. A small amount of hard pegmatite rock may need to be removed by BHD if the CSD cannot remove, if this is the case, associated BHD spoil will be disposed onshore.

Sediment transport modelling for the proposed dredging indicates maximum modelled excess SSC will occur along the tidal axis away from the dredge spoil discharge location. Maximum 95th percentile modelled excess SSC of more than 100 mg/L is modelled for the discharge location (dry and wet season) (KBR 2022b). Concentrations above 20 mg/L extend approximately 1.5 km along the tidal axis to the northwest towards the mouth of the Harbour and east southeast towards and into East Arm, while lower concentrations (i.e. less than 5 mg/L) stretch 8 to 10 km to the east southeast and north respectively.

Modelled excess SSC concentrations above 20 mg/L overlap with those described in Section 5.5.1, in particular the 3 to 5 mg/L contour in both the wet and dry season. This overlap occurs over predominantly soft bottom benthos (sediment), although it is noted that in direct vicinity of the HMAS Coonawarra dredge spoil discharge location, were the associated modelled SSC concentrations may exceed 100 mg/L there is some mixed reef/sediment habitat. Lower (i.e. less than 5 mg/L) modelled excess SSC concentrations from HMAS Coonawarra also appear to overlap with 10-20 and 20-50 mg/L contours described in Section 5.5.1 in both the wet and dry season. In East Arm, this overlap occurs over the large intertidal area (mud flats) adjacent to Charles Darwin National Park. Similar overlap also occurs in Fannie Bay to the west of Mindil Beach, covering soft bottom benthos including potential seagrass habitat.

Based on the above assessment there is potential for cumulative 95th percentile excess SSC for the Projects maintenance dredging and HMAS Coonawarra dredge spoil disposal. Majority of the overlap occurs over soft bottom benthos (sediment) with a small overlap in Fannie Bay coinciding with potential seagrass habitat. Although impacts to seagrass are not predicted for the area of overlap in Fannie Bay by the Projects maintenance dredging or HMAS Coonawarra dredging, given the potential for influence (e.g. at some time may experience detectable elevations in SSC) water quality monitoring is proposed by HMAS Coonawarra in Fannie Bay and for the Projects maintenance dredging during the dry season. These water quality monitoring programs would be used to determine if there is any detectable elevations in SSC at monitoring locations. Further, both dredging management plans have adaptive management processes in place to mitigate potential impacts should measured SSC exceed trigger criteria at monitoring sites.

The potential for cumulative impacts is on the basis that the most intensive dredging for both dredging campaigns is undertaken simultaneously. This is unlikely to be the case as HMAS Coonawarra dredging is planned for late 2022; which if completed, will be prior to the implementation of this Referral and any Project maintenance dredging. The Project maintenance dredging is not planned for 2022 and unlikely to occur prior to quarter two 2023. As such, the potential for cumulative impacts is highly unlikely given dredging activities will not overlap. This cumulative impact assessment is therefore relevant if HMAS Coonawarra dredging is delayed and dredging campaigns overlap.

Australia-Asia Powerlink

The Australia-Asia PowerLink (AAPowerLink) by Sun Cable proposes to install three subsea cable systems extending from a cable transition facility near Gunn Point to Singapore (Sun Cable 2022). There are currently two proposed cable routes, both run west from Gunn Point and either pass to the south or north of the DSDA. Installation requires open trenches (one for each cable) to be excavated through the intertidal zone using conventual excavators (shore or barge based), which will be back filled with excavated material once cable pull is complete. Subtidal cable once laid, will be buried using high-pressure water injection or jet trenching, with the latter suited to intertidal and shallow water sections. The jetting system works by fluidising the seabed sediment causing the cable to sink under its own weight through the fluidised sediment, with sediment returning to their pre-jetted condition once jetting ceases. Jetting and subsequent fluidisation causes sediment to enter the water column where it can be transported to the far-field and potential impact sensitive receptors similar to dredging and spoil disposal. Modelling of jetting was completed assuming simultaneous burial of all three cables starting at the Gunn Point shore crossing moving along the cable route for 50 km over a seven day period and repeated three times (i.e. three passes of jet trencher) to achieve modelled burial depth.

Sediment transport modelling for the proposed jet trenching indicates a maximum 95th percentile modelled excess SSC of over 200 mg/L at the location of trenching activity close to Gunn Point (MDS 2021). Modelling also indicates that excess SSC in the Shoal Bay region will be 10 to 20 mg/L, with higher concentration closer to the modelled cable route and shore crossing. Excess SSC between 3 and 10 mg/L is also predicted between the Vernon Islands and mouth of Darwin Harbour. As such, there is large spatial overlap of modelled outputs with those described in Section 5.5.1, in particular the 5 to 10 mg/L contour in vicinity of the DSDA and 3 to 5 mg/L to the southwest of the DSDA towards the mouth of the Harbour. This overlap largely coincides with soft bottom benthos (sediment), however there is some overlap with seagrass habitat off East Point and Fannie Bay, and thus potential for cumulative impact.

The likelihood of cumulative impacts on seagrass off East Point and at Fannie Bay is considered highly unlikely due to the conservatism described in MDS (2021). For instance, the modelling assumes all three cables are being buried simultaneously, but then further states cables will be buried individually effectively reducing sediment loss intensity by two thirds. Modelled burial depth (1.2 m) is also double that recommended in the burial risk assessment by Sun Cable (MDS 2021). This directly influences the number of passes required by the jet trencher, as the modelling includes three passes, each one week apart. However, in consideration of the shallower burial depth only two passes would likely be required (MDS 2021), reducing jetting activities from three to two weeks as well as associated sediment losses to the water column.

Note no sediment transport modelling is provided in Sun Cable (2022) for the excavation or backfill of the cable shore crossing using convention excavators. As such, cumulative impacts for this activity cannot be assessed; however it is highly unlikely there would be potential cumulative impacts given the small volume to be excavated[23] and likely sandy composition of material to be excavated (Sun Cable 2022).

Future dredging campaigns

Other dredging (capital and/or maintenance) campaigns may occur within the next 5-year timeframe that are not specified here due to being in their infancy and information on dredging volumes, dredging and disposal methods and timing can be shared with INPEX or are not currently planned.

[23] Excavation volume is estimated to be 6,000 m^3 based on 500 m long, 2 m deep and 2 m wide trench for each of the three cables (Sun Cable 2022)

It is considered unlikely that any foreseeable dredging activities within Darwin Harbour, if undertaken concurrently with 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 Projects 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 Projects GEP. During such concurrent dredging periods, only minimal dredging-related effects to sensitive receptors at sites in proximity to dredging[20] and no dredging-related effects to protected marine megafauna[21] were observed.

In conclusion, based on projects currently under assessment there is potential to be areas of modelled excess SSC overlap if the most intensive dredging for dredging campaigns are undertaken simultaneously. Therefore there is potential for cumulative impacts related to marine environmental quality (i.e. water quality). The potential cumulative impacts are however considered insignificant as they are not predicted to impact environmental values and sensitivities (e.g. marine ecosystems such as seagrass or coral). Therefore, the risk of potential cumulative impacts during a maintenance dredging campaign resulting from concurrent activities is considered low and ALARP, and no controls are proposed. Although no controls are directly proposed for cumulative impacts, controls to manage potential sediment related effects associated with the Projects maintenance dredging, in particular water quality monitoring, will be implemented (see Section 6.2.4), which are also applicable to cumulative impacts risks.

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 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 1,150 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^3 s^{-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^3 s^{-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 in hydrographic survey results (Appendix C), which favour settlement of mobilised sediment around the less energetic jetty pocket.

6.2.4 Management

> ***NT EPA environmental objective:***
>
> *Protect the quality and productivity of water, sediment and biota so that environmental values are maintained.*

To meet the NT EPA environmental objective for marine environmental quality, the following key management controls will be implemented to minimise/mitigate any potential impacts to water, sediment and biota quality:

- Management of sediment related effects
  - To reduce potential impacts on coral reproduction in Darwin Harbour, the use of overflow will ceased three days prior to and for seven days post the predicted coral spawning window in April
  - To reduce potential impacts on coral communities during marine heatwaves, the use of overflow during dredging will be ceased if the 21-day rolling average water temperature exceeds 31 °C
  - Water quality monitoring to inform adaptive management of potential sediment-related impacts will be implemented during maintenance dredging:
    - turbidity data will be reviewed daily for the purpose of assessment against tiered management trigger criteria with escalating management responses commensurate with the risk to sensitive receptor communities, namely coral and seagrass.
    - Level 1 management 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 management 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.
    - Level 2 management triggers represent the upper bound of background conditions naturally experienced by the receptor. In the event of a Level 2 management 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 management trigger). Responsive management practice/s can only cease (i.e. return to normal operations) once turbidity returns to below the Level 1 turbidity management 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 management trigger. Normal operations can only recommence once turbidity returns to below the Level 1 turbidity management trigger.

    - The use of turbidity as an early warning indicator has been tried and tested for decades, 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. However, INPEX acknowledges that based on recent research, some other Australian jurisdictions are integrating light (measured as PAR), in addition to or in place of turbidity, as the management trigger. This is because turbidity provides a direct measure of sediment suspended by dredging related activities, these suspended sediments attenuate light and affect benthic light availability that is relied upon by photosynthetic primary producers (e.g. coral and seagrass). The primary guidance documents (Collier et al. 2016, Jones et al. 2019b) relating to light-based management triggers, recommends the development of locally-specific guidelines as these capture inherent site conditions (including tidal exposure). This is particular relevant to Darwin Harbour, which is a naturally turbid environment with low benthic light levels. The development of light-based management triggers for Darwin Harbour is a complex task and to ensure meaningful management triggers are developed engagement with Northern Territory Government is required to ensure alignment with the Darwin Harbour dredging strategy currently under development. INPEX will work with relevant stakeholders and Northern Territory Government to develop light-based management triggers for incorporation into this Maintenance DSDMP by the end of 2023.

- Waste and liquid discharge management:
  - All 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.
  - Vessel garbage logs and waste receipts (including sewage receipts) will be maintained on board the dredge vessel, in accordance with MARPOL 73/78, Annex III.
  - Records of listed wastes will be maintained on the dredge vessel in accordance with the Waste Management and Pollution Control Act 1998 (NT).
  - Only approved and licensed waste contractors will be engaged for the transport and disposal of vessel waste.
  - Oily water discharges from vessel bilge systems will be managed and recorded, in accordance with the Marine Pollution Act 1999 (NT), and the intent of MARPOL 73/78, Annex I.
  - Vessel food scraps will be managed in accordance with the Marine Pollution Act 1999 (NT) and subordinate regulations, and the intent of MARPOL 73/78, Annex V.
  - Vessel sewage discharges will be managed in accordance with the intent of MARPOL 73/78, Annex IV.
- Hydrocarbon and chemical management

- The Dredge Vessel Master will maintain and implement vessel specific Shipboard Oil Pollution Emergency Plan (SOPEP) in accordance with MARPOL 73/78, Annex I.
- 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 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.
- 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.
- 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 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, Annex I requirements.

Further detail on the key management controls described in this section and additional controls that will be adopted to mitigate impacts are described in the Maintenance DSMDP (Appendix A).

Residual risk statement

Given the proposed mitigation measures to be implemented during maintenance dredging activities, the expected residual impact associated with marine environmental quality is considered low (Table 6-3).

Table 6-3: Marine environmental quality – residual risk

Potential impact	Consequence	Likelihood	Residual Risk
Dredging and spoil disposal activities causing increased turbidity resulting in indirect impacts to sensitive receptors (e.g. coral, seagrass)	Insignificant	Highly unlikely	Low

Potential impact	Consequence	Likelihood	Residual Risk
Dredging and spoil disposal activities causing release of contaminants from sediments into the water column and indirectly impacting sensitive receptors (e.g. coral, seagrass)	Insignificant	Remote	Low
Waste and liquid discharges may result in localised nutrient enrichment or marine pollution	Insignificant	Unlikely	Low
Accidental loss of chemicals or hydrocarbons resulting in localised marine pollution	Insignificant	Unlikely	Low
Major hydrocarbon spill associated with equipment/ operator failure (e.g. loss of containment during bunkering)	Moderate	Highly unlikely	Moderate

6.3 Sea – Marine ecosystems

As identified in Section 4, maintenance dredging activities have the potential to impact on the following environmental factor – Marine ecosystems. The following sections provide a description of the potential impacts and proposed key management controls to mitigate any potential impacts. Further detail on the key management controls described in this section and additional controls that will be adopted to mitigate impacts are described in the Maintenance DSMDP (Appendix A).

6.3.1 Relevant policy and guidelines

The following conventions, legislation, policy and guidelines are relevant:

- Guidelines for the Control and Management of Ships' Biofouling to Minimize the transfer of Invasive Aquatic Species (IMO 2012)
- International Convention for the Control and Management of Ships' Ballast Water and Sediments 2004 (IMO 2009)
- International Convention on the Control of Harmful Anti-fouling Systems on Ships
- *Biosecurity Act 2015* (Cwlth)
- *Environment Protection and Biodiversity Conservation Act 1999* (Cwlth)
- *Protection of the Sea (Harmful Anti-fouling Systems) Act 2006* (Cwlth)
- *Fisheries Act 1988* (NT)
- *Territory Parks and Wildlife Conservation Act* (NT)
- Australian Ballast Water Management Requirements. Version 8. (ABWM Requirements; DAWE 2020)
- National Biofouling Management Guidance for Non-trading Vessels (MPSC 2018)

- Australian National Guidelines for Whale and Dolphin Watching 2017 (Commonwealth of Australia 2017)

6.3.2 Environmental context

Darwin Harbour marine benthic habitats, pelagic environment (includes marine fauna) and introduce marine pests are described in sections 3.2, 3.3 and 3.4 respectively.

6.3.3 Potential impacts

The following activities have the potential to impact on protected marine fauna and marine habitats in Darwin Harbour, if not managed appropriately:

- import of dredge and/or support vessels from overseas and/or other domestic port locations (discharge of high risk ballast water or presence of biofouling on wet-sides/internal seawater systems)
- dredge and support vessel movements during dredging and dredge disposal activities
- dredging and dredge disposal activity.

Potential impacts associated with these activities include:

- accidental introduction of marine pests
- interactions between protected marine species and vessels (collision and impact)
- accidental entrainment of protected marine megafauna within dredge equipment
- removal or smothering of sensitive receptor habitats outside the approved dredge footprint and DSDA
- increased underwater noise causing localised avoidance of the area by protected marine species
- dredging and spoil disposal activities causing increased turbidity resulting in direct or indirect impacts to fish

These are discussed further in the following sections.

Introduced marine pests

Introduced marine pests are defined as non-native marine plants or animals that harm Australia’s marine environment, social amenity or industries that use the marine environment; or have the potential to do so if they were to be introduced, established (that is, forming self-sustaining populations) or spread in Australia’s marine environment (DAWR 2018). Not all marine species introduced into a new area become pests as not all of them will survive or may not manage to reproduce and establish a viable population. Many introduced marine species that establish self-sustaining populations cause no detectable harm. However, others have the potential to cause significant long-term economic, ecological and health consequences for the marine environment (DoF 2016).

Introduced marine pests pose a significant threat to the environment, economy and social amenity by disrupting ecological processes both directly (through predation or competition with native plants and animals) or indirectly (through habitat alteration). Once established, marine pests can rarely be eradicated, and their impacts are often long lasting (DAWR 2018). Shallow water, coastal marine environments are most susceptible to the establishment of invasive populations, with most introduced marine pests associated with artificial substrates in disturbed shallow water environments such as ports and harbours (e.g. Glasby et al. 2007; Dafforn et al. 2009a, 2009b).

Management actions have been identified and will be implemented to minimise the potential impacts resulting from introduction of marine pests as a result of importing dredge and support vessels (Section 6.3.4).

Interactions with protected marine megafauna (vessel collision)

The dredge area and dredge disposal area are located in areas, where protected marine megafauna, specifically whale, dolphin, dugong and turtle species, frequent or have the potential to be present (Section 3.3.1 and Section 3.3.2). Interaction (vessel collision) 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 impacts resulting from interactions with protected marine megafauna during maintenance dredging and spoil disposal activities (Section 6.3.4).

Entrainment of turtles or sawfish within dredge equipment

The dredge area is located in Darwin Harbour, where green, hawksbill and flatback turtles are known to frequent (Section 3.3.2) and sawfish have the potential to be present (Section 3.3.3). Therefore, depending on the size of the draghead, it is possible that turtles or sawfish residing on the seafloor could potentially be pumped up and become entrained in the hopper.

Management actions have been identified and will be implemented to minimise the potential impacts on marine turtles and sawfish during maintenance dredging activities (Section 6.3.4).

Removal or smothering of sensitive receptor habitats

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. 2017; Mills & Kemps 2016). Direct effects include the removal of substrate within the dredge area and smothering of substrate at the DSDA during disposal. These areas include a 20 m buffer extending outwards from each of these areas.

Management actions have been identified and will be implemented to minimise the potential impacts of accidental removal or smothering during maintenance dredging and spoil disposal activities, beyond the approved footprint (Section 6.3.4).

Underwater noise

Dredging activities in Darwin Harbour will generate additional underwater noise to the existing sound-scape (Section 3.1.6). 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 6 4. This summary indicates that the source level range of TSHDs is within the range of large vessels. Other reviews (Jones et al. 2015; Jones & Marten 2016; Suedel et al. 2019) have also shown that noise levels between individual TSHDs can vary, with most TSHD noise levels within the range of small boats and ships. Sources of noise are most likely to be associated with cavitation noise from TSHD propellers and bow thrusters (de Jong et al. 2010).

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 (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 CSD 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 CSD 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 2015e, 2015h; Brooks and Pollock 2015). Dolphins were observed in East Arm throughout the capital dredging program (Brooks and Pollock 2015) 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 2015e). 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).

Further, the proposed protected marine megafauna controls (see Section 6.3.4) will further reduce noise exposure risk as dredging and spoil disposal activities cannot commence if marine megafauna are observed with the specified observation zones (e.g. 100 to 300 m depending on megafauna). These observation zones although not established directly for underwater noise, will indirectly allow propagation loss and reduction in exposure risk.

In context of the modelling and monitoring results and controls proposed for protected marine megafauna, 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. As such, the risk is considered low and ALARP, and no further controls are proposed.

Table 6-4: 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

Noise source	Source level	Bandwidth	Major amplitude	Duration	Directionality
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

Sediment related effects - fish

Suspended sediments from dredging and spoil disposal activities can have both positive and negative impacts on fish species (Wenger et al. 2017). 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; Harvey et al. 2016); however, this typically occurs at very high concentrations (>300 and 4,000 mg/L respectively) (Gregory & Northcote 1993; Jenkins & McKinnon 2006; Wenger et al. 2018).

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 3.1.4).

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 dredging referral simulates maximum concentrations of SSC of 100 to 200 mg/L to occur in a localised portion of the dredge area (Section 5.5.1). 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. As such, the risk is considered low and ALARP, and no further controls are proposed.

6.3.4 Management

NT EPA environmental objective:

Protect marine habitats to maintain environmental values including biodiversity, ecological integrity and ecological functioning.

To meet the NT EPA environmental objective for marine ecosystems, the following key management controls will be implemented to minimise/mitigate any potential impacts to protected marine megafauna and habitats:

- Introduced marine pest management:
- All vessels will comply with the requirements of the Biosecurity Act 2015 and the ABWM Requirements (DAWE 2020). Specifically, vessels will:
  - have a ballast water management plan and valid ballast water management certificate, unless an exemption applies or is obtained
  - maintain ballast water records.
  - manage ballast water in accordance with one of the approved methods, as follows:
  - use of a ballast water management system
  - ballast water exchange in an acceptable area
  - use of low risk ballast water (such as fresh potable water, high seas water or fresh water from an on-board fresh water production facility)
  - retention of high-risk ballast water on board the vessel
  - discharge to an approved ballast water reception facility.
  - All vessels mobilised from outside Darwin Harbour will complete a vessel biofouling risk assessment and implement mitigation measures commensurate with the level of risk prior to the commencement of activity.
  - All vessels will maintain a biofouling record book in accordance with the Guidelines for the Control and Management of Ships' Biofouling to Minimize the transfer of Invasive Aquatic Species (IMO 2012).
- Marine megafauna management (vessel collision and entrainment in dredge equipment):
  - 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 2017 (Commonwealth of Australia 2017), as far as reasonably practicable.
  - During dredging and spoil disposal activities (daylight hours) the following observation and exclusion zones for protected marine megafauna will be implemented and monitored by a marine megafauna observer (MMO):
    - whales: observation zone 300 m; exclusion zone 100 m. If a calf is present the exclusion zone is extended to 300m
    - dolphins: observation zone 150 m; exclusion zone 50 m. If a calf is present the exclusion zone is extended to 150m
    - dugongs: observation zone 150 m; exclusion zone 50 m
    - turtles: observation zone 100 m; exclusion zone 50 m.
  - 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.

  - Turtle protection chains are installed on draghead/s of the dredge vessel.
  - 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.
  - Screens will be installed and maintained on the overflow to assist in the identification of any marine turtle or sawfish entrainment.
  - Dredge Vessel Masters and specified crew members will be trained as MMOs and the whale, dolphin, dugong and marine turtle interaction procedures.
- Dredge materials management:
  - 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 and remains within the DSDA prior to and during disposal using DGPS.

Further detail on the key management controls described in this section and additional controls that will be adopted to mitigate impacts are described in the Maintenance DSMDP (Appendix A).

Residual risk statement

Given the proposed mitigation measures to be implemented during maintenance dredging activities, the expected residual impact associated with marine ecosystems is considered low-moderate (Table 6-5).

Table 6-5: Marine ecosystems – residual risk

Potential impact	Consequence	Likelihood	Residual Risk
Dredging and spoil disposal activities causing increased turbidity resulting in indirect impacts to sensitive receptors (e.g. coral, seagrass)	Insignificant	Highly unlikely	Low
Dredging and spoil disposal activities causing release of contaminants from sediments into the water column and indirectly impacting sensitive receptors (e.g. coral, seagrass)	Insignificant	Remote	Low
Waste and liquid discharges may result in localised nutrient enrichment or marine pollution	Insignificant	Unlikely	Low
Accidental loss of chemicals or hydrocarbons resulting in localised marine pollution	Insignificant	Unlikely	Low

Potential impact	Consequence	Likelihood	Residual Risk
Major hydrocarbon spill associated with equipment/ operator failure (e.g. loss of containment during bunkering)	Moderate	Highly unlikely	Moderate

6.4 People - Culture and heritage

As identified in Section 4, maintenance dredging activities have the potential to impact on the following environmental factor - Culture and heritage. The following sections provide a description of the potential impacts and proposed key management controls to mitigate any potential impacts. Further detail on the key management controls described in this section and additional controls that will be adopted to mitigate impacts are described in the Maintenance DSMDP (Appendix A).

6.4.1 Relevant policy and guidelines

The following legislation, policy and guidelines are relevant:

- *Underwater Culture Heritage Act 2018* (Commonwealth)
- *Heritage Act 2011* (Northern Territory)
- *Northern Territory Aboriginal Sacred Sites Act 1989* (Northern Territory)

6.4.2 Environmental context

Darwin Harbour contains a variety of historic, spiritual and heritage values that are significant to the people of the Northern Territory and Australia. These are described in further detail in Section 3.6.

6.4.3 Potential impacts

The following activities have the potential to impact on protected heritage and sacred sites in Darwin Harbour if not managed appropriately:

- dredge vessel movements
- anchoring of dredge/support vessels
- dredging activity.

Potential impacts associated with these activities include:

- vessel propeller wash causing sediment scouring resulting in damage to sunken aircraft or shipwrecks
- disturbance or damage to heritage sites resulting from anchoring on or in proximity to shipwrecks or sunken aircraft
- damage to previously unidentified heritage objects.

These are discussed further in the following sections.

Vessel activities – dredge vessel movements

Dredge vessel movements have the potential result in sediment scouring within protected heritage areas around wreck or sunken aircraft sites, as a result of propellor wash.

A specific scour assessment study has not been undertaken to determine the potential sediment scour impacts at wreck sites as result of a TSHD undertaking maintenance dredging activities. However, a similar assessment was undertaken during the capital dredging program (HR Wallingford 2012), and the outcomes of that assessment are considered sufficient to gauge the potential impacts of scour during maintenance dredging.

During the capital dredging program the dredge vessel with the greatest propeller power was considered to be a large TSHD. For the purposes of the assessment the Vox Maxima was selected as representative of a large TSHD (engine power 2 x 14,400 kW).

Predicted erosion rates were determined at nominated distances (i.e. 0 m = wreck site centroid) from the stern of the dredge and were presented in both millimetres per minute and millimetres per second. The one minute erosion rate represented the worst-case scenario, where the TSHD is moving at right angles to the tidal flow with its stern pointed directly towards a wreck site. It should be noted that this is considered highly unlikely, as in most cases during dredging the vessel would be aligned with the tidal flow and continually moving along its dredging track, resulting in it only being at any nominated distance for a matter of seconds.

The assessment concluded that:

- The greatest scour effects occur during low tide periods for all scenarios.
- For the Catalinas 6 and 4 scenarios, the greatest predicted erosion rates (9-36 mm/min and 12-48 mm/min respectively) occur within 20–50 m range from the propeller of the TSHD (12 m draught).
- For the Catalina 5 scenario, the predicted erosion rates are greater overall (6-96 mm/min) and these occur over a much broader range with respect to distances from the propeller of the vessel (9 m draught).

It is important to note that the assessment considered the seabed at its natural state i.e. before capital dredging was completed. Further to this, maintenance dredging during operations is more likely to be undertaken by a medium TSHD versus a large TSHD. Therefore the outcomes of sediment scour assessment undertaken for the capital dredging program are considered conservative, in context of any maintenance program.

In consideration of the results, Catalinas 4, 5 and 6 are unlikely to experience any direct impacts from propeller jet wash generated by a TSHD undertaking maintenance dredging in the nearby area. However, if dredge vessel movements are not restricted from traversing directly across wreck sites then sediment scouring may occur around wreck sites (Section 6.4.4).

Vessel activities - anchoring

Vessels undertaking maintenance dredging activities may be required to anchor from time to time as part of their work scope. Anchoring has the potential to result in disturbance and damage to a protected wreck site, either directly or as a result of anchor drag. This in turn, could potentially result in acceleration of natural degradation processes on a wreck site and/or the diminishment of cultural heritage significance of a protected wreck site[24].

Most vessels used during operations, monitoring and maintenance activities are unlikely to require anchoring. However, in order to prevent damage or disturbance to wreck sites in the event anchoring is required, restrictions will need to be implemented around protected wreck sites (Section 6.4.4).

[24] The scale of impact to a wreck site is mostly assessed by the loss of structural integrity and cohesion. The breaking down or scrambling of a site reduces the ability to understand and interpret it, and therefore contributes to the diminishment of its cultural heritage significance.

Dredging activity – damage to previously unidentified heritage objects

As described in Section 3.6.2, an extensive heritage survey and relocation program was undertaken within the capital dredging footprint prior to the commencement of the capital dredging program (Coroneos 2014). However, despite this extensive survey and relocation program a small number of heritage objects were discovered during the capital dredging program. While, any maintenance dredging activities would only occur within the confines of this footprint, there is still a remote possibility that previously unidentified heritage objects may be discovered.

With consideration of this, a chance find procedure should be in place to manage the discovery of potential heritage objects during maintenance dredging activities (Section 6.4.4).

6.4.4 Management

NT EPA Environmental objective:

Protect sacred sites, culture and heritage

To meet the NT EPA environmental objective for culture and heritage, the following key management controls will be implemented to minimise/mitigate any potential impacts to protected heritage and sacred sites and previously unidentified heritage objects:

- AAPA Authority Certificates relevant to maintenance dredging and monitoring activities are obtained.
- Establishment of maintenance dredging no anchor or exclusion zones around heritage wreck/sunken aircraft sites.
- Provision of sacred site and heritage wreck/sunken aircraft data files (GPS coordinates) to contractors for inclusion in vessel navigation systems.
- For wreck/sunken aircraft which are located directly adjacent to dredging activities, additional buffer zones will be established within on-board dredge vessel navigation systems. These will include an early warning alarm that is activated upon entry into the buffer zone, and a secondary alarm that is activated upon entry into the heritage protection zone.
- Development and implementation of a chance find procedure to be followed in the event of discovery of previously unidentified heritage object during dredging activities.

Further detail on the key management controls described in this section and additional controls that will be adopted to mitigate impacts, are described in the Maintenance DSMDP (Appendix A).

Residual risk statement

Given the proposed mitigation measures to be implemented during maintenance dredging activities, the expected residual impact associated with culture and heritage is considered low-moderate (Table 6-6).

Table 6-6: Culture and heritage – residual risk

Potential impact	Consequence	Likelihood	Residual Risk
Vessel movements and anchoring – damage to protected heritage wreck/sunken air craft or sacred sites.	Moderate	Highly unlikely	Moderate
Dredging – damage to a previously unidentified heritage object	Insignificant	Remote	Low

7 CONSULTATION

INPEX believes effective stakeholder engagement is essential in maximising the safety of Company and Contractor 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 issues and impacts
- easily accessible information
- ongoing monitoring and improvement.

Section 43 of the *Environment Protection Act* (NT; EP Act) outlines the general duty of proponents and includes specific requirements for stakeholder engagement. Specifically, the EP Act requires the following:

A proponent of an action has the following general duties under an environmental impact assessment process:

a. To provide communities that may be affected by a proposed action with information and opportunities for consultation to assist each community's understanding of the proposed action and its potential impacts and benefits;

b. To consult with affected communities, including Aboriginal communities, in a culturally appropriate manner; and

c. To seek and document community knowledge and understanding (including scientific and traditional knowledge and understanding) of the natural and cultural values of areas that may be impacted by the proposed action.

In addition to the EP Act requirements, the NT EPA Stakeholder Engagement and Consultation: Environmental Impact Assessment Guidance for Proponents (NT EPA 2021b; SEC) outlines the expectations of the NT EPA with regards to stakeholder engagement. The SEC outlines that proponents are responsible for undertaking stakeholder engagement from the earliest stage of the environmental impact assessment process, and that stakeholder engagement would continue throughout the life of an activity.

The following sections provided an overview of INPEX’s approach to stakeholder engagement, the stakeholder engagement undertaken to inform the development of the Maintenance DSDMP and supporting approval applications, and the ongoing stakeholder engagement activities that would be undertaken in the event of maintenance dredging campaign.

7.1 Overview of process

The following sections provide an overview of INPEX’s approach to stakeholder engagement. A full description of the approach is provided in the Ichthys LNG Maintenance Dredging Stakeholder Engagement Plan (L383-AH-PLN-70000; Appendix E), which has been provided separately to the NT EPA as a standalone document.

7.1.1 Stakeholder mapping

INPEX has undertaken a stakeholder mapping exercise to identify relevant stakeholders and ensure they are engaged in the most effective manner with targeted and responsive engagement activities for the purposes of the maintenance dredging program.

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

7.1.2 Timing

Timing of stakeholder engagement will be implemented during the following key stages, as follows:

- Pre-referral engagement - the purpose of the engagement was to:
  - obtain advice on appropriateness of proposed management controls
  - obtain advice on required notifications and ongoing engagement requirements.
- Ongoing engagement once a maintenance dredging campaign is determined to be required – the purpose of this engagement is to:
  - provide sufficient notice to key stakeholders prior to the commencement of maintenance dredging to ensure effective communication of the timing of works, and the associated safety and environmental measures
  - provide information throughout maintenance dredging, to support safety outcomes
  - provide confirmation of completion of the maintenance dredging to communicate final results and acknowledge the community’s support.

7.1.3 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 and INPEX enquiries email account.

7.2 Stakeholder engagement – Pre-referral

Stakeholder consultation for the proposed maintenance dredging activity was undertaken to inform the development of the Maintenance DSDMP and applicable approval documentation (referral and waste discharge licence application). To ensure the dissemination of information was consistent and accurate. INPEX prepared an email template and an activity fact sheet. The fact sheet provided to relevant stakeholders included important details of the maintenance dredging activity, as follows:

- description of the activity, including location and map
- schedule
- methodology (i.e. how the activity will be undertaken, as well as general logistics and safety information)
- environmental management approach

- enquiries and feedback information.

As part of the pre-referral engagement both broad and targeted (key aspects/issues) engagement was undertaken. Targeted engagement was undertaken in relation to the following aspects/issues:

- heritage management
- biosecurity management
- protected marine megafauna management
- cumulative impact assessment (i.e. request for details of other planned dredging programs).

The complete stakeholder register, outlining stakeholders who were consulted during the pre-referral stage and any relevant information that was provided to them for consideration, is presented in Appendix D. Where feedback was received a summary of this and how it has been addressed in this Maintenance DSDMP is provided in Table 7-1.

Table 7-1: Summary material inputs to the Maintenance DSDMP from stakeholder engagement

Stakeholder	Summary of material stakeholder feedback	Summary of INPEX action
Territory Families, Housing and Communities - Heritage Branch (Heritage Branch)	Heritage Branch requested confirmation on the following aspects of the activity: • the maintenance dredging footprint did not expand geographically beyond the capital dredging footprint • heritage protection zones align with the same extent adopted during capital dredging and the current maintenance dredging approval • proposed dredge vessels to be used during maintenance dredging are not larger than those previously used during the capital program and do not require elaborate anchoring arrangements. Heritage Branch requested further detail/inclusion of the following: • The notification process to the Heritage Branch in the event of breach of heritage protection zone requirements.	INPEX confirmed the following: • the maintenance dredging footprint does not expand geographically beyond the capital dredging footprint (refer Section 2.2.1) • the heritage protection zones aligned with the same extent adopted previously (Refer to Maintenance DSDMP; Appendix A) • a single TSHD would be used to undertake the activity, and this would not be any larger than those used during the capital program (i.e. jumbo TSHD) (refer Section 2.3.1). The following have been included in the Maintenance DSDMP (Appendix A): • The requirement to notify the Heritage Branch in the event of a breach of a heritage protection zone • Summary of the Dredge Work Supervisor heritage training requirements.

Stakeholder	Summary of material stakeholder feedback	Summary of INPEX action
	• Details of the training Dredge Work Supervisors will receive to determine an object recovered in the TSHD draghead was a heritage object.	
Department of Defence – Northern Territory (Defence NT)	Defence NT advised that it intended to undertake capital/maintenance dredging activities at HMAS Coonawarra within the life of INPEX Maintenance DSDMP (i.e. 2023-2027). Defence NT referred INPEX to the recent referral application submitted to the NT EPA which included specific details for the HMAS Coonawarra dredging campaign/s.	INPEX has considered relevant information provided in the NT EPA HMAS Coonawarra referral as part of the cumulative impact assessment (refer to Section 6.2.3 - Cumulative impacts).
Santos Barossa Pty Ltd (Santos)	Santos advised that it intended to undertake capital dredging for the Darwin Pipeline Duplication Project within the life of the INPEX Maintenance DSDMP (i.e. 2023-2027). Santos referred INPEX to the recent referral application submitted to the NT EPA, which included specific details for the Darwin Pipeline Duplication Project dredging campaign.	INPEX has considered relevant information provided in the NT EPA Darwin Pipeline Duplication Project referral as part of the cumulative impact assessment (refer to Section 6.2.3 - Cumulative impacts).
Department of Infrastructure, Planning and Logistics – Darwin Harbour Infrastructure Projects (DIPL-DHIP)	DIPL-DHIP advised that it intended to undertake capital dredging for the Darwin Ship Lift and Marine Industries Project and Mandorah Marine Facility Upgrade Project within the life of the INPEX Maintenance DSDMP (i.e. 2023-2027).	INPEX has considered relevant information provided in the NT EPA Mandorah Marine Facility Upgrade Project referral and the Darwin Ship Lift and Marine Industries Project EIS as part of the cumulative impact assessment (refer to Section 6.2.3 - Cumulative impacts).

Stakeholder	Summary of material stakeholder feedback	Summary of INPEX action
Department of Agriculture, Water and the Environment (DAWE; former) – Biosecurity Operations Division (DAWE-Biosecurity)	DAWE – Biosecurity advised that the information provided to them in Maintenance DSDMP – Biosecurity extract met all the relevant biosecurity reporting, ballast and biofouling management requirements.	INPEX considered relevant information provided by DAWE and has updated Introduced Marine Pests Management Framework in the Maintenance DSDMP (Appendix A) to include a risk assessment for dredgers that may arrive from other domestic ports in addition to overseas locations.
Department of Environment, Parks and Water Security – Environment Assessment Division (DEPWS-Assessment Division)	DEPWS-Assessment Division agreed in principle with INPEX's reasons for not undertaking a sediment sampling and analysis survey to support a new application for maintenance dredging to be lodged in 2022, due to: • recent survey data of sediment condition in East Arm is available • recent surveys do not identify unexplained exceedances of DGV • • the data are likely to be representative of sediments that may be targeted for a maintenance dredging campaign • INPEX will use sufficient recent data and knowledge when making applications for maintenance dredging to the NT EPA and DEPWS.	INPEX has considered relevant information provided by DEPWS-Assessment Division and has included relevant information in Section 3.1.5.

7.3 Ongoing stakeholder engagement

Stakeholder engagement that will be undertaken once a maintenance dredging campaign is determined to be required is described in the Ichthys LNG Maintenance Dredging Stakeholder Engagement Plan (Appendix E).

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APPENDIX A: DRAFT MAINTENANCE DREDGE AND SPOIL DISPOSAL MANAGEMENT PLAN

Appendix A is provided as a separate document.

APPENDIX B: DRAFT MAINTENANCE DREDGE AND SPOIL DISPOSAL MANAGEMENT PLAN - EXPERT REVIEW

Appendix B is provided as a separate document.

APPENDIX C: ASSESSMENT OF DREDGE AREA SEDIMENT DYNAMICS

Hydrographic surveys have been conducted annually to assess the level of accretion and/or 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, INPEX conducted four additional annual surveys (August 2015, May 2016, June 2017 and April 2018) to assess any changes to the dredge area (e.g. integrity of batters, accretion/erosion, etc.). Annual surveys (2019, 2020 and 2021) have since been undertaken by Darwin Port.

The final hydrographic survey data collected in 2018 by INPEX was analysed to assess the location deposition within the dredge area. This is considered indicative of sediment behaviour in the dredge area prior to use (e.g. berthing of product tankers). Between 2014 and 2018 sediment accretion was primarily observed in the area adjacent to, and north of the jetty infrastructure with a mean increase of 70 cm (Figure 8-1). Localised accretion ranging from 1.2 m to 4.8 m was also observed at the base and top of the batter in the northern sector of the turning basin (Figure 8-1 and Figure 8-2) and likely related to sand wave migration. Higher levels of accretion were also noted at the base of the batters along the eastern and south-eastern sections of the jetty pocket. It is also worth noting that on 17 March 2018, just over one month prior to the final hydrographic survey by INPEX, Tropical Cyclone Marcus passed directly over Darwin Harbour as a very small category 2 cyclone (BOM 2019). A review of hydrographic survey data and measured accretion (see Section 2.1) indicates Marcus may have caused increased accretion. However, the location of accretion measured in 2018 was similar to previous years, as was the depth of accretion. Only a small increase in previously measured annual depths in the jetty pocket area (i.e. +14 cm in 2016, +20 cm in 2017 and +22 cm in 2018) were reported. Based on the available information it is not possible to ascertain if and to what extent Marcus had on measured accretion and further information is need to determine the impact periodic meteorological events such as cyclones have on accretion within the dredge area.

In 2018 the Project commenced production with the first offtake occurring on 30 September 2018. Following start-up onshore production rates and offtakes have been relatively steady. This increased use of the dredged area has seen a change in the sediment dynamics, in particular the area adjacent to, and north of the jetty infrastructure. As discussed in Section 2.1, scouring from vessels resulted in net erosion between 2018 and 2019 hydrographic surveys with further scouring also evident in 2020 and 2021. Comparison of -13.5 m LAT depth contour from 2018 (Figure 8-2) and 2021 (Figure 8-3) clearly shows the extent of scouring from berthing operations adjacent to jetty infrastructure.

Overall, results from the hydrographic surveys suggest that sediment is shifting over time, with locations of accretion and erosion depending on vessel operations and prevailing hydrodynamics that drive resuspension, transport and settlement of sediment.

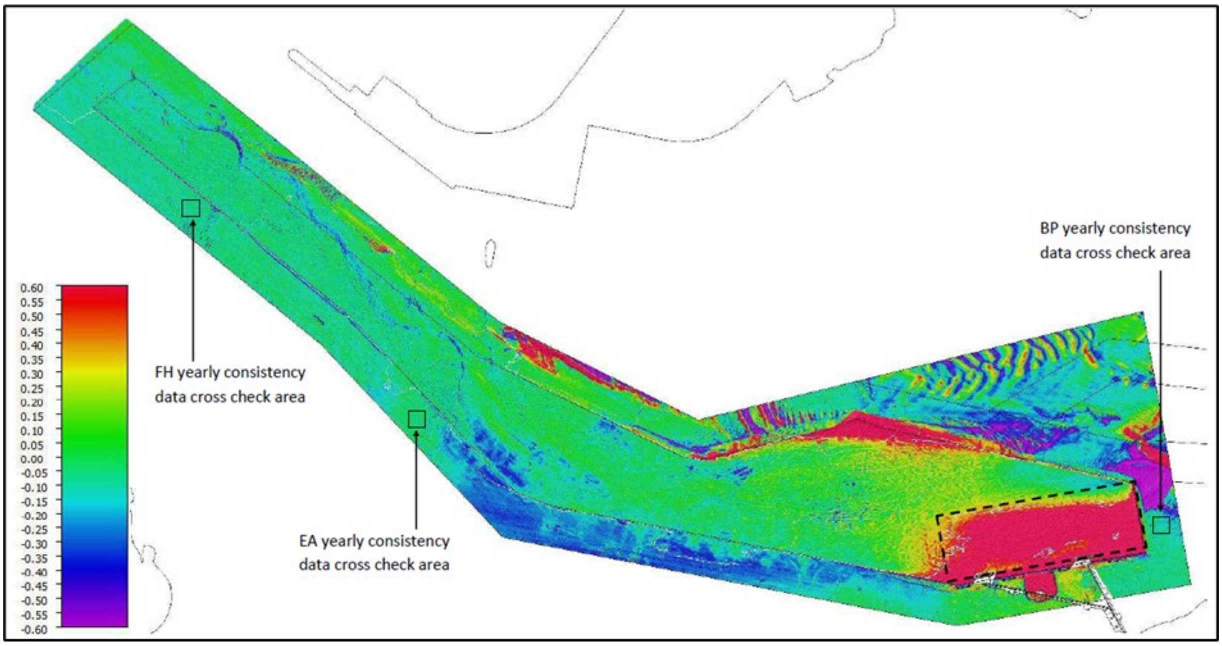


Figure 8-1: Surface difference 2014 to 2018 with mean value of +70 cm in black dashed box (EGS 2018)

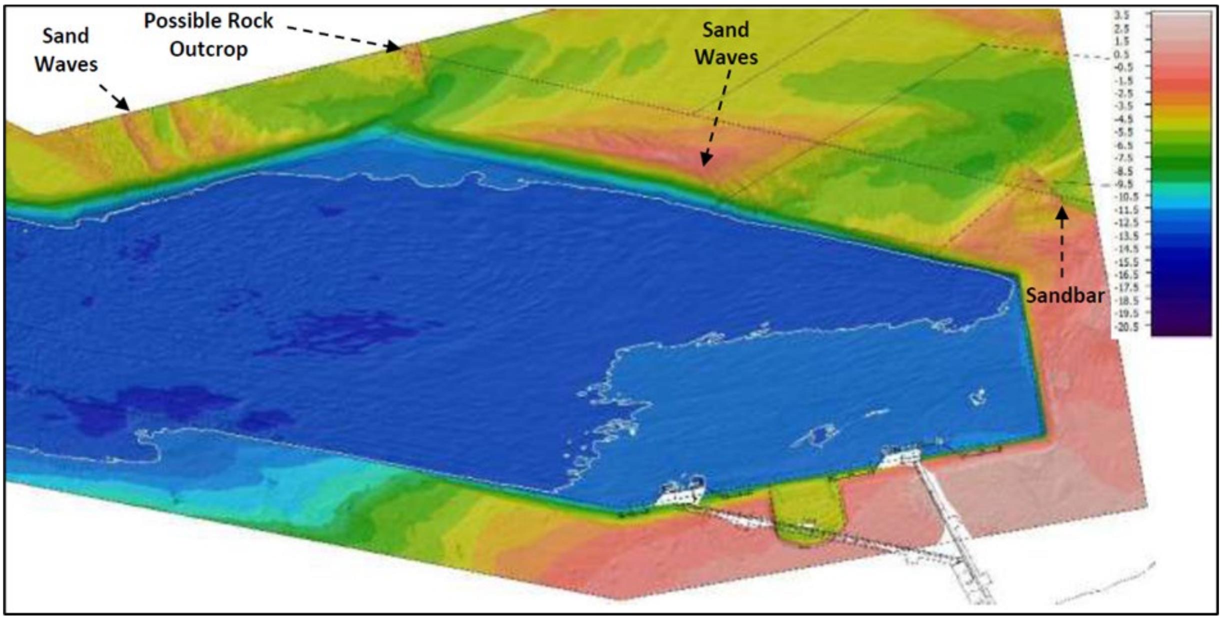


Figure 8-2: Bathymetric overview from 2018 of turning basin with -13.5 m LAT depth contour shown for reference (EGS 2018)

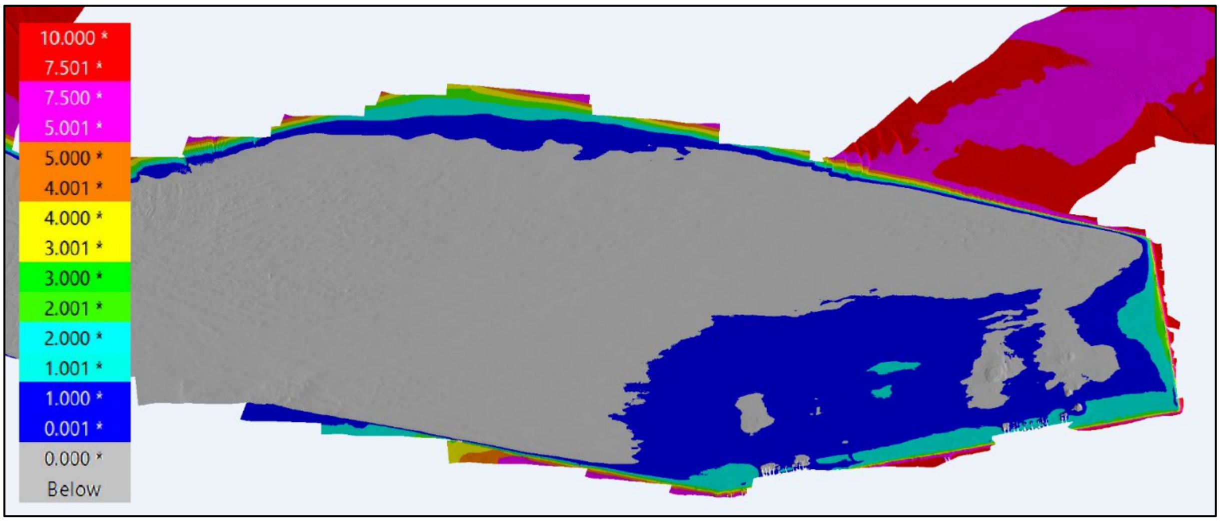


Figure 8-3: Location and depth of sediment above (i.e. shallower) -13.5 m LAT based on 2021 hydrographic survey (depths greater than -13.5 m LAT are greyed out).

APPENDIX D: PRE-REFERRAL STAKEHOLDER ENGAGEMENT

A summary of the stakeholders engaged during the pre-referral stage including the information provided/requested to/from each stakeholder, as relevant to their functions and interests, is provided in Section D.1.

To ensure the dissemination of information was consistent and accurate INPEX prepared an email template and an activity fact sheet. The fact sheet provided to relevant stakeholders included important details of the maintenance dredging activity, as follows:

- description of the activity, including location and map
- schedule
- methodology (i.e. how the activity will be undertaken, as well as general logistics and safety information)
- environmental management approach
- enquiries and feedback information.

A copy of the fact sheet and the email templates sent to key stakeholders during the engagement is provided in sections D.2.1 and D.2.2.

As part of the pre-referral engagement both broad and targeted (key aspects/issues) engagement was undertaken. Targeted engagement was undertaken in relation to the following aspects/issues:

- sediment sampling
- heritage management
- biosecurity management
- protected marine megafauna management
- cumulative impact assessment (i.e. request for details of other planned dredging programs).

Where targeted engagement was undertaken with a stakeholder, additional information or specific requests for information were included in the cover email, in addition to the factsheet.

D.1 Stakeholder engagement register

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
ATSI Community	INPEX Larrakia Advisory Committee	• Briefing provided to the Committee • Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
ATSI Community	Larrakia Development Corporation	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
ATSI Community	Larrakia Nation Aboriginal Corporation	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Cwlth Australian Border Force (ABF), Darwin Office	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Office of the Chief Minister	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Authorities	Department of Agriculture, Water and the Environment (DAWE - Environment) – Biosecurity	• Cover email and Fact Sheet • Extract of the proposed controls to manage biofouling risks.	• General request for feedback on the proposed activity. • Specific request on the appropriateness of proposed biofouling controls to be adopted.	Yes. Refer to Referral Report Section 7.2, Table 7-1.
Authorities	Cwlth Department of Agriculture, Water and the Environment (DAWE - Environment) - Ichthys LNG - Project Officer	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Darwin City Council	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Darwin Harbour Advisory Committee	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Environment Minister NT	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Authorities	Litchfield Council	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Minister for Planning NT	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Minister for Resources NT	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Northern Land Council	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Authorities	NT Department of Environment, Parks and Water Security - Environmental Assessment Division	Cover email and Sediment and Analysis Plan Exemption Justification Paper.	Specific request seeking advice, and if in agreeance of on the acceptability, endorsement of the INPEX justification that further sediment sampling is not required to inform its future maintenance dredging referral and approval, based on the information provided.	Yes. Refer to Referral Report Section 7.2, Table 7-1.
Authorities	NT Department of Environment, Parks and Water Security - Environmental Division	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	NT Department of Environment, Parks and Water Security - Flora and Fauna Division	• Cover email and Fact Sheet • Extract of the proposed controls to manage interactions with protected marine fauna.	• General request for feedback on the proposed activity. • Specific request on the appropriateness of proposed controls to be adopted to manage interactions with protected marine fauna.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	NT Department of Environment, Parks and Water Security - NT WildWatch	• Cover email and Fact Sheet	• General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
		• Extract of the proposed controls to manage interactions with protected marine fauna.	• Specific request on the appropriateness of proposed controls to be adopted to manage interactions with protected marine fauna. • Request for confirmation on reporting requirements relating to deceased, injured or entrained megafauna in Darwin Harbour.	
Authorities	NT Department of Industry, Tourism and Trade (DITT) - Agribusiness and Aquaculture	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	NT Department of Industry, Tourism and Trade (DITT) - Aquatic Biosecurity	• Cover email and Fact Sheet • Extract of the proposed controls to manage biofouling risks.	• General request for feedback on the proposed activity. • Specific request on the appropriateness of proposed biofouling controls to be adopted.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Authorities	NT Department of Industry, Tourism and Trade (DITT) - Fisheries	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	NT Department of Infrastructure Planning and Logistics - Regional Harbour Master	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	NT Department of Chief Minister and Cabinet - Shiplift Project	Cover email and Fact Sheet	Request for information from stakeholder to inform the cumulative impact assessment presented in the Maintenance DSDMP. Information requested: • If any dredging (maintenance or capital) is planned to be undertaken by your Company/Department at any time during 2023-2027?	Yes. Refer to Referral Report Section 7.2, Table 7-1.

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
			• If a campaign is planned, is your Company/Department willing to share details with INPEX (i.e. timeframes, dredge volumes, disposal options and method) to help inform our cumulative impact assessment?	
Authorities	NT Department of Infrastructure Planning and Logistics - Darwin Harbour Infrastructure Projects	Cover email and Fact Sheet	Request for information from stakeholder to inform the cumulative impact assessment presented in the Maintenance DSDMP. Information requested: • If any dredging (maintenance or capital) is planned to be undertaken by your Company/Department at any time during 2023-2027?	Yes. Refer to Referral Report Section 7.2, Table 7-1.

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
			• If a campaign is planned, is your Company/Department willing to share details with INPEX (i.e. timeframes, dredge volumes, disposal options and method) to help inform our cumulative impact assessment?	
Authorities	NT Department of Territory Families, Housing and Communities - Heritage branch	• Cover email and Fact Sheet • Extract of the proposed controls to manage heritage chance finds during maintenance dredging.	• General request for feedback on the proposed activity. • Specific request on the appropriateness of proposed biofouling controls to be adopted.	Yes. Refer to Referral Report Section 7.2, Table 7-1.
Authorities	NT EPA	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Authorities	Tourism NT	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Authorities	Department of Defence - NT Division	Cover email and Fact Sheet	Request for information from stakeholder to inform the cumulative impact assessment presented in the Maintenance DSDMP. Information requested: • If any dredging (maintenance or capital) is planned to be undertaken by your Company/Department at any time during 2023-2027? • If a campaign is planned, is your Company/Department willing to share details with INPEX (i.e. timeframes, dredge volumes, disposal options and method) to help inform our cumulative impact assessment?	Yes. Refer to Referral Report Section 7.2, Table 7-1.
Business	Cullen Bay Marina	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Business	Darwin Port - Landbridge	Cover email and Fact Sheet	Request for information from stakeholder to inform the cumulative impact assessment presented in the Maintenance DSDMP. Information requested: • If any dredging (maintenance or capital) is planned to be undertaken by your Company/Department at any time during 2023-2027? • If a campaign is planned, is your Company/Department willing to share details with INPEX (i.e. timeframes, dredge volumes, disposal options and method) to help inform our cumulative impact assessment?	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Business	NT Seafood Council	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Business	SANTOS - Darwin LNG	Cover email and Fact Sheet	Request for information from stakeholder to inform the cumulative impact assessment presented in the Maintenance DSDMP. Information requested: • If any dredging (maintenance or capital) is planned to be undertaken by your Company/Department at any time during 2023-2027? • If a campaign is planned, is your Company/Department willing to share details with INPEX (i.e. timeframes, dredge volumes, disposal options and method) to help inform our cumulative impact assessment?	Yes. Refer to Referral Report Section 7.2, Table 7-1.
Business	Sea Link NT (Mandorah ferry and Tiwi Islands ferry)Toll Marine Logistics Group	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Business	Tourism Top End (Fishing and harbour charter operators)	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Business	Svitzer - Harbour towage provider	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Business	ASCO - Darwin Marine supply base	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Business	Sun Cable	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).
Civil society	Amateur Fishermen's Association, Northern Territory	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

Sub-category	Stakeholder	Information provided	Specific INPEX requests for information/feedback	Material stakeholder feedback received (Yes/No)
Civil society	Palmerston Fishing Club	Cover email and Fact Sheet	General request for feedback on the proposed activity.	No. Ongoing engagement in the event of planned campaign refer to Stakeholder Engagement Plan (Appendix E).

D.2 Engagement materials

D.2.1 Maintenance dredging fact sheet

Maintenance Dredging Activities Darwin Harbour

INPEX Operations Australia Pty Ltd (INPEX), on behalf of the Ichthys Joint Venture, is currently in the process of renewing its environmental approvals for maintenance dredging in East Arm, Darwin Harbour; as required under the Northern Territory *Environment Protection Act 2019* and *Waste Management Pollution Control Act 1998*, and INPEX's Commonwealth approval (EPBC 2008/4208).

Background

To support the construction and development of the Ichthys Liquified Natural Gas (LNG) onshore processing facilities at Bladin Point in Darwin Harbour, capital dredging works were carried out within Darwin Harbour's East Arm between 2012 and 2014. During these works, approximately 16.1 million cubic metres of material was dredged, transported and disposed at a designated dredge spoil disposal area (DSDA) within the Beagle Gulf, approximately 45 kilometres north from East Arm and around 12 kilometres north-west of Lee Point.

Over time, some sediment will naturally accumulate within areas of the existing dredged footprint, having the potential to impact on the operability of Ichthys LNG, in terms of tidally restricting product carriers.

Consequently, periodic maintenance dredging within the dredge area may be required. Additional contingency dredging may also be required in the event of extreme weather events such as cyclones and flooding.

INPEX has previously obtained all relevant environmental approvals to undertake maintenance dredging over a five-year period within the existing dredge footprint; however, these are due to expire in early 2023[1]. As such, INPEX is currently in the process of renewing/obtaining new approvals to allow for future maintenance dredging activities.

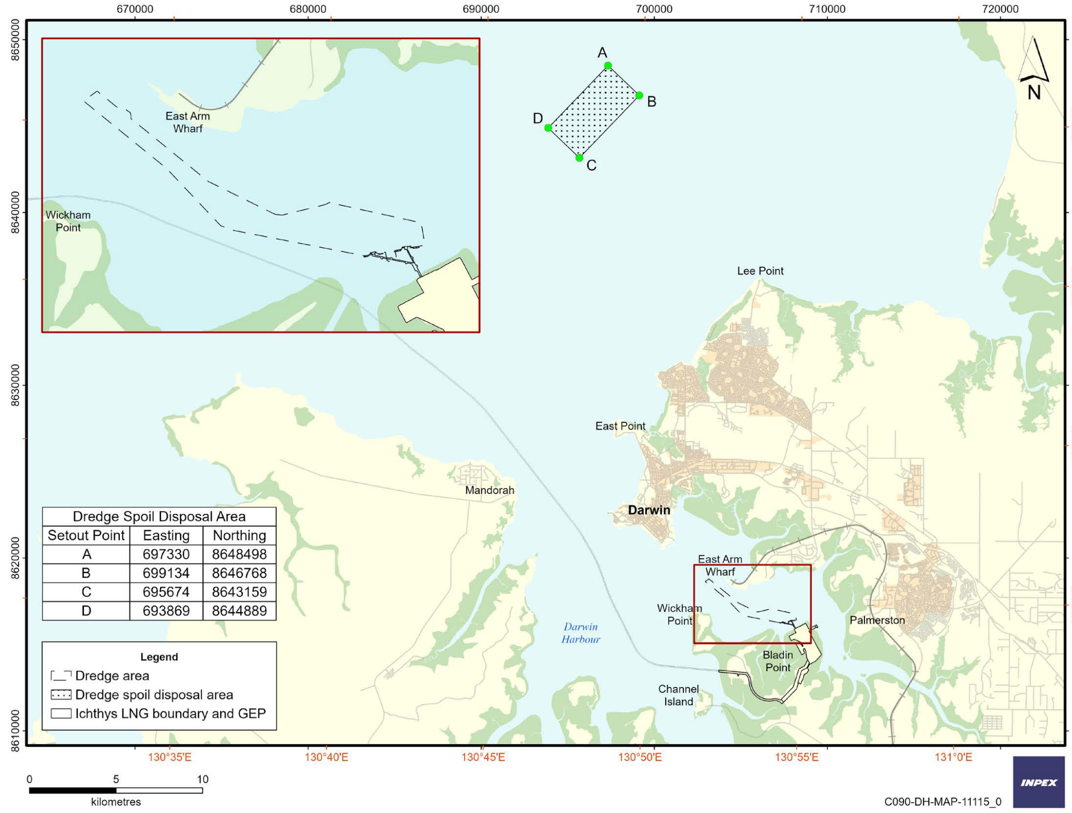
To date no maintenance dredging has been undertaken.

1 INPEX's current Maintenance DSDMP and approvals can be viewed at Ichthys **LNG Pty Ltd / INPEX Operations Australia Pty Ltd | NTEPA**

Description of activity

INPEX is proposing to obtain a five-year maintenance dredging approval consisting of one planned and up to four contingency campaigns. These campaigns may be undertaken at any time within the five-year period. A maximum of 1.5 million cubic metres of spoil could be removed across the five years, with no single campaign to exceed 0.75 million cubic metres.

As with the capital dredging campaign, maintenance dredging spoil would be disposed at the DSDA in the Beagle Gulf. The planned dredge and dredge spoil areas are shown in Figure 1.



Dredge Spoil Disposal Area		
Setout Point	Easting	Northing
A	697330	8648498
B	699134	8646768
C	695674	8643159
D	693869	8644889

Figure 1: *Location of dredge footprint and dredge spoil disposal area.*

Methodology

It is proposed that maintenance dredging will be carried out by a trailing suction hopper dredger (TSHD) – a self-propelled hydraulic dredge typically used for dredging sand, silts and soft clays (an example shown in Figure 2). The dredged material is stored in its cargo hold ('hopper') and transported to the DSDA for disposal (Figure 1).

Timeframe and duration

The duration of a maintenance dredging campaign would be influenced by aspects such as the size of the TSHD, the actual volume to be dredged, the sediment type and any concurrent activities that influence dredge production.

During a campaign, dredging will be intermittent as the TSHD travels to and from the DSDA.

Based on the use of a medium TSHD, a maximum campaign volume of 0.75 million cubic metres and in the scenario where dredge access is not restricted, the duration is modelled to be approximately six weeks.

Figure 2: Trailing suction hopper dredge.

Timeframe and duration (cont.)

No decision has been made in regard to timing of the first maintenance dredging campaign. Hydrographic surveys, which monitor accretion and erosion of sediment within the dredge area, are routinely undertaken to inform the timing of a maintenance dredging campaign. In addition, the timing of maintenance dredging campaigns will need to account for other aspects including, but not limited to, the availability of dredge vessels, planned shutdown periods for maintenance and the operational schedule of Ichthys LNG.

Maintenance Dredging and Spoil Disposal Management Plan

To support relevant Northern Territory and Commonwealth Government's approval processes, INPEX is preparing a Maintenance Dredging and Spoil Disposal Management Plan (Maintenance DSDMP) in consultation with external expert reviewers.

The Maintenance DSDMP will demonstrate all reasonable and practicable measures have been taken to manage the risks and potential environmental and social impacts arising from proposed maintenance dredging and spoil disposal activities.

Key controls that will be included in the Maintenance DSDMP to mitigate potential impacts to environmental sensitivities and other marine users are described in Table 1. Additional controls may be identified during engagement with key stakeholders.

Table 1: Maintenance DSDMP key controls

Aspect	Management controls
Marine notices and safety zones	INPEX will ensure harbour users are kept informed about proposed maintenance dredging activities, and will notify Darwin Port so advice can be issued to vessels working in the harbour. A Notice to Mariners will be issued ahead of each maintenance dredging campaign. In addition, during each campaign, a safety zone will be established around the TSHD.
Water quality monitoring and adaptive management	Monitoring of water quality for potential sediment-related impacts, will be undertaken throughout the maintenance dredging campaign. This monitoring will also inform the adaptive management processes used to manage sediment-related impacts (if any) on sensitive receptors.
Marine megafauna (dolphins, turtles and dugongs) management	During dredging and spoil disposal activities observation and exclusion zones for protected marine megafauna will be implemented and monitored by a marine megafauna observer.
Heritage management	During dredging, vessel "no anchor" and/or "exclusion zones" will be established around heritage sites (eg Catalina flying-boats) and sacred sites in proximity to the dredge footprint.
Biosecurity management	Invasive marine species from biofouling and ballast risks will be managed in accordance with the recommendations listed in the relevant International Maritime Organisation guidelines and the Department of Agriculture, Water and the Environment (Commonwealth) requirements.
Unplanned discharges	Vessels will have tested shipboard oil pollution emergency plans in place in the unlikely event of any unplanned discharge. Oil spill contingency planning for the activity will be managed in accordance with Darwin Port, Northern Territory Government and Australian Maritime Safety Authority requirements.
Ongoing stakeholder consultation	INPEX believes effective stakeholder engagement is essential in maximising the safety of all Company personnel and the community; and in establishing, building and maintaining community support, receiving feedback and trust. In the event of a maintenance dredging campaign various mechanisms of engagement will be undertaken to inform stakeholders.

Further information and feedback

INPEX welcomes your feedback on the proposed maintenance dredging activities. To provide feedback or to request additional information, please see the 'Comments and enquiries' section below. All communications will be logged, assessed and acknowledged with a response.

How is your feedback used?

Feedback received will be used to inform relevant Northern Territory Government approval applications required for maintenance dredging and the management framework of the final Maintenance DSDMP.

A summary of the feedback received from stakeholders and how INPEX has addressed this feedback will be provided to the Northern Territory Environment Protection Authority.

Comments and enquiries

If you would like to provide comment or seek further information, or if you do not wish to receive future communications about the maintenance dredging activities, please contact:

Contact
John Williams
INPEX Manager - Government Affairs and Approvals

Subject
INPEX Maintenance Dredging

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enquiries@inpex.com.au

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D.2.2 Email templates

Maintenance dredging – General

To Whom It May Concern

I am writing to advise you that INPEX is currently in the process of renewing its environmental approvals to allow for maintenance dredging in East Arm, Darwin Harbour (refer to attached fact sheet). INPEX currently holds all relevant environmental approvals to undertake maintenance dredging in East Arm, Darwin Harbour; however these are due to expire in early-2023. As such, INPEX will be submitting a new referral under the Northern Territory Environment Protection Act. As with the previous approval, INPEX will be seeking a five year approval to conduct maintenance dredging in the turning basin covering:

- *One planned maintenance dredging campaign and up to four contingency campaigns (such as in the event of severe weather conditions)*
- *An upper limit of 0.75 million cubic metres (Mm^3) of material to be removed per campaign up to a maximum of 1.5 Mm^3 across the five year period. This compares to the 16.1 Mm^3 of material removed in the capital dredging campaign.*

No decision has been made in regard to timing of the first maintenance dredging campaign; however, hydrographic surveys are routinely undertaken to inform this. To date no maintenance dredging activities have been required to be undertaken since the cessation of the capital dredging program in 2014.

To support the approval process INPEX is preparing a Maintenance Dredging and Spoil Disposal Management Plan (Maintenance DSDMP) which will describe the environmental management and water quality monitoring activities that are intended to be implemented during maintenance dredging.

INPEX welcomes any feedback you may have on the proposed maintenance dredging activity. INPEX kindly request that any feedback be provided via enquiries@inpex.com.au by 06 May 2022.

Kind regards

[INPEX Sign-off]

Attachments: Maintenance dredging fact sheet

Maintenance dredging – Protected marine megafauna management

To Whom It May Concern

I am writing to advise you that INPEX is currently in the process of renewing its environmental approvals to allow for maintenance dredging in East Arm, Darwin Harbour (refer to attached fact sheet). INPEX currently holds all relevant environmental approvals to undertake maintenance dredging in East Arm, Darwin Harbour; however these are due to expire in early-2023. As such, INPEX will be submitting a new referral under the Environment Protection Act. As with the previous approval, INPEX will be seeking a five year approval to conduct maintenance dredging in the turning basin covering:

- *One planned maintenance dredging campaign and up to four contingency campaigns (such as in the event of severe weather conditions)*
- *An upper limit of 0.75 million cubic metres (Mm^3) of material to be removed per campaign up to a maximum of 1.5 Mm^3 across the five year period. This compares to the 16.1 Mm^3 of material removed in the capital dredging campaign.*

No decision has been made in regard to timing of the first maintenance dredging campaign; however, hydrographic surveys are routinely undertaken to inform this. To date no maintenance dredging activities have been required to be undertaken since the cessation of the capital dredging program in 2014.

To support approvals, INPEX is in the process of preparing a Maintenance Dredging and Spoil Disposal Management Plan (Maintenance DSDMP) which will describe the environmental management and water quality monitoring activities that are intended to be implemented during maintenance dredging. To assist in the preparation of the Maintenance DSDMP and supporting risk assessment, INPEX is seeking advice from your Department with regards to the proposed controls to manage protected marine megafauna interactions and entrainment.

For ease I have extracted the relevant sections of the Maintenance DSMDP for your consideration and feedback. Note, these are based on the controls which currently form part of the existing approval and Maintenance DSDMP. Included in these controls is the reporting of deceased, injured or entrained megafauna to NT WildWatch; INPEX would like to confirm that NT WildWatch are still the correct contact for deceased, injured or entrained megafauna?

INPEX looks forward to your response and welcomes any additional feedback you may have on the proposed maintenance dredging activity. INPEX kindly request that any feedback be provided via enquiries@inpex.com.au by 6 May 2022.

Kind regards

[INPEX Sign-off]

Attachments:

- *Maintenance dredging fact sheet*
- *Maintenance DSDMP extract of proposed controls to manage interactions with protected marine megafauna*

Maintenance dredging – Biosecurity management

To Whom It May Concern

I am writing to advise you that INPEX is currently in the process of renewing its environmental approvals to allow for maintenance dredging in East Arm, Darwin Harbour (refer to attached fact sheet). INPEX currently holds all relevant environmental approvals to undertake maintenance dredging in East Arm, Darwin Harbour; however these are due to expire in early-2023. As such, INPEX will be submitting a new referral under the Environment Protection Act. As with the previous approval, INPEX will be seeking a five year approval to conduct maintenance dredging in the turning basin covering:

- *One planned maintenance dredging campaign and up to four contingency campaigns (such as in the event of severe weather conditions)*
- *An upper limit of 0.75 million cubic metres (Mm^3) of material to be removed per campaign up to a maximum of 1.5 Mm^3 across the five year period. This compares to the 16.1 Mm^3 of material removed in the capital dredging campaign.*

No decision has been made in regard to timing of the first maintenance dredging campaign; however, hydrographic surveys are routinely undertaken to inform this. To date no maintenance dredging activities have been required to be undertaken since the cessation of the capital dredging program in 2014.

To support approvals, INPEX is in the process of preparing a Maintenance Dredging and Spoil Disposal Management Plan (Maintenance DSDMP) which will describe the environmental management and water quality monitoring activities that are intended to be implemented during maintenance dredging. To assist in the preparation of the Maintenance DSDMP and supporting risk assessment, INPEX is seeking advice from your Department with regards to the proposed controls to manage biosecurity risks.

For ease I have extracted the relevant sections of the Maintenance DSMDP for your consideration and feedback. Note, these are based on the controls which currently form a part of the existing approval and Maintenance DSDMP.

INPEX looks forward to your response and welcomes any additional feedback you may have on the proposed maintenance dredging activity. INPEX kindly request that any feedback be provided via enquiries@inpex.com.au by 06 May 2022.

Kind regards

[INPEX Sign-off]

Attachments:

- *Maintenance dredging fact sheet*
- *Maintenance DSDMP extract of proposed controls to manage biosecurity risks*

Maintenance dredging – Heritage management

To Whom It May Concern

I am writing to advise you that INPEX is currently in the process of renewing its environmental approvals to allow for maintenance dredging in East Arm, Darwin Harbour (refer to attached fact sheet). INPEX currently holds all relevant environmental approvals to undertake maintenance dredging in East Arm, Darwin Harbour; however these are due to expire in early-2023. As such, INPEX will be submitting a new referral under the Environment Protection Act. As with the previous approval, INPEX will be seeking a five year approval to conduct maintenance dredging in the turning basin covering:

- *One planned maintenance dredging campaign and up to four contingency campaigns (such as in the event of severe weather conditions)*
- *An upper limit of 0.75 million cubic metres (Mm^3) of material to be removed per campaign up to a maximum of 1.5 Mm^3 across the five year period. This compares to the 16.1 Mm^3 of material removed in the capital dredging campaign.*

No decision has been made in regard to timing of the first maintenance dredging campaign; however, hydrographic surveys are routinely undertaken to inform this. To date no maintenance dredging activities have been required to be undertaken since the cessation of the capital dredging program in 2014.

To support approvals, INPEX is in the process of preparing a Maintenance Dredging and Spoil Disposal Management Plan (Maintenance DSDMP) which will describe the environmental management and water quality monitoring activities that are intended to be implemented during maintenance dredging. To assist in the preparation of the Maintenance DSDMP and supporting risk assessment, INPEX is seeking advice from your Department with regards to the proposed controls to manage chance finds for heritage and heritage protection zones.

For ease I have extracted the relevant sections of the Maintenance DSMDP for your consideration and feedback. Note, these are based on the controls previously agreed with your Department as part of the current approval and Maintenance DSDMP.

INPEX looks forward to your response and welcomes any additional feedback you may have on the proposed maintenance dredging activity. INPEX kindly request that any feedback be provided via enquiries@inpex.com.au by 06 May 2022.

Kind regards

[INPEX Sign-off]

Attachments:

- *Maintenance dredging fact sheet*
- *Maintenance DSDMP extract of proposed controls to manage heritage aspects*

Maintenance dredging – Cumulative impact assessment

To Whom It May Concern

I am writing to advise you that INPEX is currently in the process of renewing its environmental approvals to allow for maintenance dredging in East Arm, Darwin Harbour (refer to attached fact sheet). INPEX currently holds all relevant environmental approvals to undertake maintenance dredging in East Arm, Darwin Harbour; however these are due to expire in early-2023. As such, INPEX will be submitting a new referral under the Environment Protection Act. As with the previous approval, INPEX will be seeking a five year approval to conduct maintenance dredging in the turning basin covering:

- *One planned maintenance dredging campaign and up to four contingency campaigns (such as in the event of severe weather conditions)*
- *An upper limit of 0.75 million cubic metres (Mm^3) of material to be removed per campaign up to a maximum of 1.5 Mm^3 across the five year period. This compares to the 16.1 Mm^3 of material removed in the capital dredging campaign.*

No decision has been made in regard to timing of the first maintenance dredging campaign; however, hydrographic surveys are routinely undertaken to inform this. To date no maintenance dredging activities have been required to be undertaken since the cessation of the capital dredging program in 2014.

To support approvals, INPEX is in the process of preparing a Maintenance Dredging and Spoil Disposal Management Plan (Maintenance DSDMP) which will describe the environmental management and water quality monitoring activities that are intended to be implemented during maintenance dredging. To assist in the preparation of the Maintenance DSDMP and supporting risk assessment, INPEX is seeking assistance from your Company/Department with regards to information on other dredging campaigns (capital or maintenance), which may occur during the same timeframe. Specifically:

- *If any dredging (maintenance or capital) is planned to be undertaken by your Company/Department at any time during 2023-2027?*
- *If a campaign is planned, is your Company/Department willing to share details with INPEX (i.e. timeframes, dredge volumes, disposal options and method) to help inform our cumulative impact assessment?*

INPEX looks forward to your response and welcomes any additional feedback you may have on the proposed maintenance dredging activity. INPEX kindly request that any feedback be provided via enquiries@inpex.com.au by 06 May 2022.

Kind regards

[INPEX Sign-off]

Attachments:

- *Maintenance dredging fact sheet*

APPENDIX E: ICHTHYS LNG MAINTENANCE DREDGING STAKEHOLDER ENGAGEMENT PLAN

Appendix E is provided as a separate document.