PORT HEDLAND
PORT AUTHORITY
PILBARA PORTS

Lumsden Point General Cargo Facility

Ecosystem and Cumulative Impact Assessment

301012-01660 – 301012-01660-CIA-REP-01

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PROJECT 301012-01660 - LUMSDEN POINT GENERAL CARGO FACILITY

REV	DESCRIPTION	ORIG	REVIEW	WORLEY-PARSONS APPROVAL	DATE	CUSTOMER APPROVAL	DATE
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EXECUTIVE SUMMARY

The Port Hedland Port Authority (PHPA) plans to develop a General Cargo Facility at Lumsden Point. Two Handymax berths totalling 500 metres (m) in length will be developed. As part of this development, dredging of surface marine sediments to a depth of -13.5 m chart datum (CD) within the berth pocket and -12 m CD in the access channel will be undertaken. An area of land immediately behind the berths will also be cleared to make way for a landbacked wharf.

The dredging operations will directly affect benthic substrate within the proposed dredge footprint and may create a sediment plume that could have indirect effects on habitats near the dredging and disposal operations. In accordance with the *Environment Protection Act 1986* (EP Act), all proposals that may result in disturbance to or loss of marine benthic primary producer habitat (BPPH) should adhere to the principles and guidelines recommended within the Environmental Protection Authority (EPA) *Environmental Assessment Guidelines No. 3: Protection of benthic primary producer habitats in Western Australia's marine environment* (EAG3) (EPA 2009a).

The project has been assessed in accordance with the guidance principles presented in EAG3. This indicates the project is very unlikely to significantly affect the ecological function of the management unit and/or the wider Port Hedland area. On the balance of considerations, the project complies with the intent of EAG3.

ACRONYMS

BHPBIO	BHP Billiton Iron Ore
BPP	Benthic Primary Producer
BPPH	Benthic Primary Producer Habitat
CD	Chart Datum
CDOM	Coloured Dissolved Organic Matter
CSD	Cutter Suction Dredger
DEC	Department of Environment and Conservation
DMMA	Dredge Material Management Area
DOC	Dissolved Organic Carbon
DWT	Dead Weight Tonnes
EAG	Environmental Assessment Guideline
EPA	Environmental Protection Authority
LAU	Local Assessment Unit
PASS	Potential Acid Sulfate Soil
PHPA	Port Hedland Port Authority
SSC	Suspended Sediment Concentration
TSS	Total Suspended Sediment
WP	WorleyParsons
ZoHI	Zone of High Impact
ZoMI	Zone of Moderate Impact
ZoI	Zone of Influence

1. INTRODUCTION

1.1 Background

Port Hedland is located approximately 1,660 km north of Perth, within the Pilbara region of Western Australia. The Port of Port Hedland is defined as 'water within a radius of 10 nautical miles (nm) of Hunt Point Beacon (Beacon 47) (PHPA 2001) and is managed by the PHPA under the *Port Authorities Act 1999* (WA). The port consists of a 20 nm dredged channel leading (inshore) to a dredged basin between Nelson Point and Finucane Island, where several intertidal creeks converge. The harbour has been highly modified by dredging activities and development and operation of port-related industry.

The proposed Lumsden Point General Cargo Facility will be located opposite the existing inner harbour area of Port Hedland Port, at the junction of South Creek and South East Creek. The site has present seabed levels ranging from 0.0 m CD to over -6.0 m CD. The site is sheltered from swell, but has strong tidal currents as a result of the high tidal range experienced in the region.

The marine habitats found in Port Hedland are characteristic of those found along the arid coastlines of the Pilbara. Recent benthic habitat surveys have been undertaken in the inner harbour for BHP Billiton Iron Ore's (BHPBIO) RGP5 and RGP6 developments (SKM 2009; WorleyParsons 2011b), the PHPA's cyclone mooring facility at Stingray Creek (WorleyParsons 2011a) and the South West Creek Dredging and Reclamation Project (WorleyParsons 2012). These surveys identified five distinct mixed benthic primary producer (BPP) communities throughout Port Hedland harbour, which included coral colonies in South East Creek, South West Creek and Stingray Creek (WorleyParsons 2012).

1.2 Project overview

In line with expected growth in the iron ore export industry in the Pilbara region over the next few years, the PHPA has identified the need to develop a facility both to alleviate trade growth pressures on Port Hedland Port berths 1, 2 and 3 and to accommodate potential marine supply trades supporting the offshore oil and gas and other industries.

The proposed works for the Lumsden Point General Cargo Facility will include:

- two Handymax berths totalling a length of 500 m;
- dredging of up to -13.5 m CD for the berth pocket;
- dredging of up to -12 m CD for the access channel;
- an area of land immediately backing a wharf behind the two berth areas;
- causeway access along an existing land-based connection; and
- disposal of dredge spoil onshore to an approved Dredge Material Management Area (DMMA).

The proposed project will involve dredging approximately 2 million cubic metres (in-situ volume) of sand, clay and rock material from the dredge area. It is proposed that a cutter suction dredger (CSD) will be employed to dredge the material before it is transferred via a pipeline to an onshore DMMA. The program is expected to take approximately 20 weeks (4.6 months) to complete, inclusive of anticipated downtime.

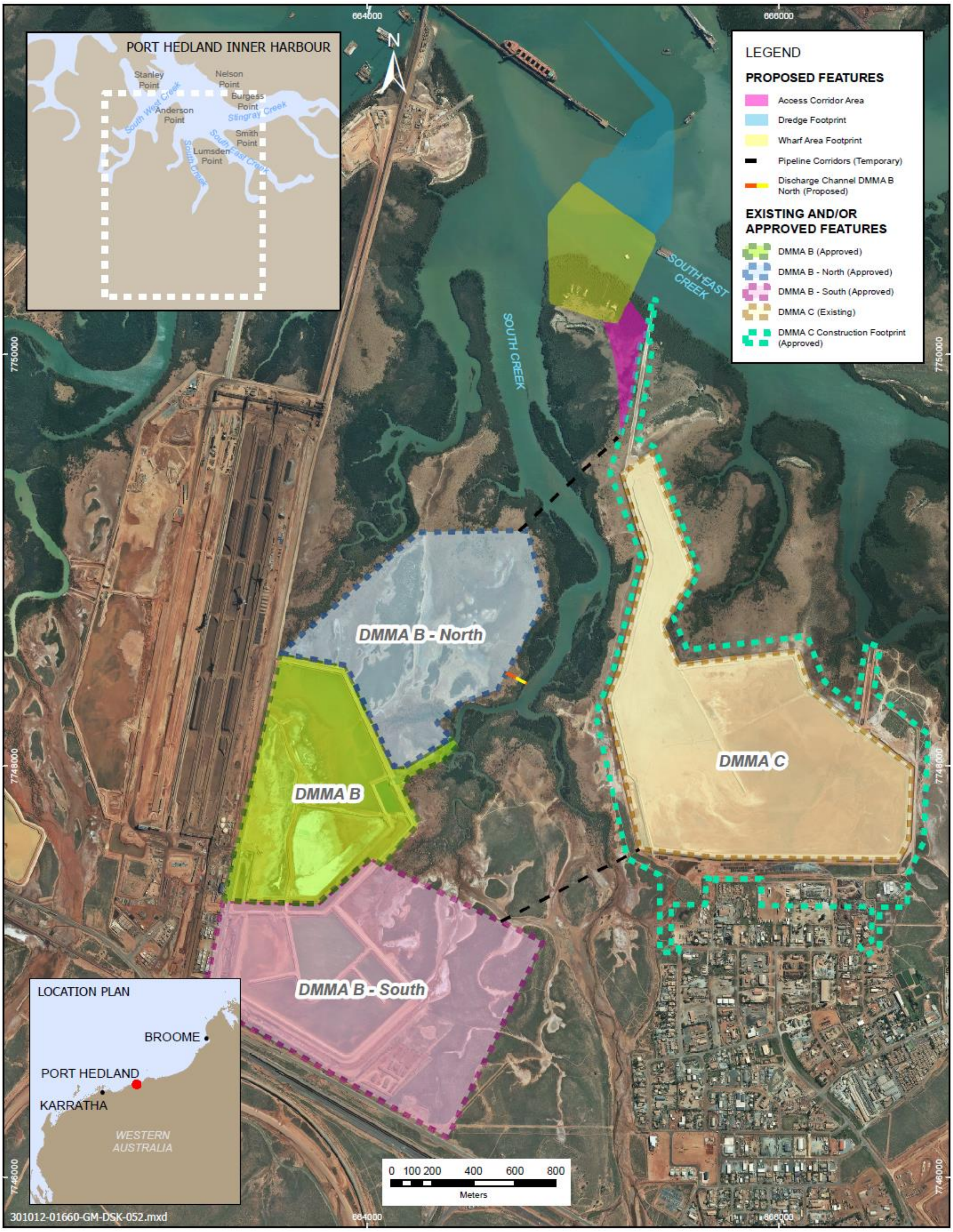

Figure 1: Proposed development footprint of the Lumsden Point General Cargo Facility

1.3 Environmental Assessment Guidelines

The EPA has published several guidelines for the protection and assessment of benthic primary producer habitat in the WA marine environment. These are outlined below.

1.3.1 Environmental Assessment Guideline No. 3

EAG3 looks at the protection of BPPHs in Western Australia's marine environment. The EAG defines BPPH as seabed communities within which algae (e.g. macroalgae, turf and benthic microalgae), seagrass, mangroves, corals or mixtures of these groups are prominent components (EPA 2009a). The EPA recognises the fundamental ecological importance of BPPHs and the potential consequences of their loss. It is also acknowledged that almost all marine development proposals will result in the loss of some of these important habitats (EPA 2009a).

For the purposes of this study, the following definitions were adopted:

- BPPs are primarily marine plants such as macroalgae, seagrasses, mangroves, turf algae and benthic microalgae, but also include the scleractinian corals (which gain a large proportion of their energy from internal symbiotic microalgae); and
- BPPHs are a combination of the BPPs and the substrata that can support them. BPPHs not only include areas of existing BPPs, but also areas that previously supported them or may be colonised by them in the future. Examples of BPPHs include coral reefs, seagrass meadows, mangrove forests, intertidal mud flats and seabed where macroalgal, coral or seagrass communities have grown and could grow.

Other benthic habitats such as those dominated by sessile organisms (e.g. soft corals, sponges and ascidians) are recognised as being important, but the loss of or damage to these habitats would be treated separately in the environmental impact assessment process.

The dredging and construction activities associated with the project will directly affect benthic substrate within the proposed dredge footprint and may create a sediment plume that causes indirect effects on habitats near the dredging and disposal operations. In accordance with the *Environment Protection Act 1986* (EP Act), all proposals that may result in disturbance to or loss of marine BPPH should adhere to the principles and guidelines recommended within EAG3 (EPA 2009a). Furthermore, the proposed land-based infrastructure accompanying the berths will result in a direct loss of mangrove habitat.

1.3.2 Environmental Assessment Guideline No. 7

The *Environmental Assessment Guideline for Marine Dredging Proposals* (EAG7) is 'designed to ensure that predicted extent, severity and duration of impacts to benthic habitats associated with significant dredging activities, which are subject to formal environmental impact assessment by the EPA, are presented in a clear and consistent manner' (EPA 2011a). EAG7 provides specific guidance on the layout and presentation of predicted impacts associated with dredging activities on benthic communities and habitats.

In particular, EAG7 focuses on direct loss of benthic habitats and communities by removal or burial, and indirect impacts on benthic habitats and communities from the effects of migration of sediment plumes by dredging. This guidance should be followed in conjunction with EAG3.

1.3.3 Environmental Protection Bulletin No. 14

The guidance for assessing BPPH in and around Port Hedland provides a set Local Assessment Unit (LAU) to aid proponents to comply with EAG3 for proposals in Port Hedland. Historically, LAUs have varied within the area according to different proponents, and application of EAG3 has been inconsistent. EP Bulletin No. 14 provides a clear definition of the LAU for proposals in Port Hedland, and all assessments within the area are expected to use this LAU for evaluating cumulative losses of BPPH from the date of issue in August 2011.

This guidance is used for best practice for proposals within Port Hedland and was used to assess the predicted impacts with the proposed Lumsden Point General Cargo Facility project.

1.4 Scope of work

A detailed BPP impact assessment was undertaken following completion of the BPPH survey and sediment plume modelling for the proposed development. The BPPH assessment was used to address the requirements of EAG3 (EPA 2009a) and to identify the potential direct and indirect impacts on BPPH associated with the proposed dredging program.

The objectives of the marine BPPH impact assessment were to:

- define the direct and indirect impacts related to the proposed development;
- predict the spatial extent of impacts to BPPH;
- calculate potential cumulative losses within the defined Port Hedland LAU (Figure 2);
- evaluate direct and indirect impacts against EAG3;
- consider the BPPH in a regional context to determine its ecological significance; and
- propose mitigation and management strategies to minimise potential impacts to BPPH.

Figure 2: The Port Hedland Local Assessment Unit (EPA 2011b)

2. APPROACH TO IMPACT ASSESSMENT

To accurately define impacts to BPPH associated with the Project, the impact assessment was conducted in accordance with EAG3, EAG7 and EP Bulletin No. 14. As described in EAG3, the impacts need to be defined, described spatially and compared with the larger Port Hedland LAU to determine the cumulative impact within the LAU.

2.1 Definitions of impacts

Several definitions are used to describe impacts on the benthic communities and habitats. EAG 7 provides a list of definitions, presented here in Table 1.

Table 1: Definitions for impact predictions

Word or phrase	Definition
Dredge spoil	Seabed substrate material after it has been excavated from the seabed.
Dredging	Involves excavation of the seabed from the upper intertidal zone to the subtidal zone. Dredging in the sense of the EAG7 means both dredging and dredge spoil activities.
Extent	The area over which an impact extends.
Functional groups	Groups of species (which are not necessarily related generically) that share similar important ecological characteristics and play equivalent roles in the functioning of the biological community.
Infrastructure	Shipping channels, turning basins, berth pockets, pipeline trenches, spoil disposal sites, sub-sea mine areas and land reclamations are some examples of infrastructure.
Irreversible	Lacking a capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less (also see reversible).
Near real-time	Refers to a system for monitoring and interpreting data where the time lag between collecting monitoring data and responding is sufficiently short to be considered as immediate as practicable.
Persistence	The period of time that an impact continues.
Prediction	A forecast of future outcomes.
Pressure threshold	Pressure thresholds signify a level of pressure (generally expressed in terms of intensity, frequency and duration) that equates to a pre-defined level of effect or impact to an organism or group of organisms of interest.
Recoverable	See reversible.
Reversible	A capacity to return or recover to a state resembling that prior to being impacted within a timeframe of five years or less.

Severity	The degree of harm caused. For example, the degree of harm or severity of impact to biota could range from sub-lethal effects to mortality or loss.
State coastal waters	State coastal waters extend three nautical miles seaward from the territorial sea baseline.
Uncertainty	In relation to prediction is doubt or concern about the reliability of achieving predicted outcomes.

2.2 Dredging impacts on BPPH

Impacts on BPPH due to the Project construction and dredging activities can be direct and indirect. According to EAG7, direct impacts occur within and immediately adjacent to the construction footprint where the dredging occurs. These typically cause an irreversible loss of benthic habitats and communities. Indirect impacts result from the dredging activities causing increased suspended sediments and generally extend over surrounding areas around the construction footprint. The indirect impacts can restrict or inhibit key ecological processes and can range in severity and duration from irreversible to readily reversible.

2.3 Definition of impact zones

EAG7 also describes a spatially-based zonation scheme to describe the predicted extent, severity and duration of the impacts associated with dredging. The three zones of impact are:

- Zone of High Impact (ZoHI): the area where impacts on benthic organisms are predicted to be irreversible. These areas would include the zones within and directly adjacent to the proposed dredge area.
- Zone of Moderate Impact (ZoMI): the area within which the predicted impact on benthic organisms are sub-lethal, and/or the impacts are recoverable. This zone would be located immediately outside of the ZoHI.
- Zone of Influence (ZoI): the area within which changes in environmental quality associated with dredge plumes are predicted and anticipated during the project, but where these changes would not result in a detectable impact on benthic biota.

In the ZoHI it is predicted that a 100% loss of the benthic communities due to the dredging activities will occur, either from the habitat being removed and disposed of, or due to chronic stress from turbidity or sedimentation.

In the ZoMI it is predicted that sub-lethal impacts to benthic communities will occur (e.g. reduced photosynthetic activity, increased mucous production).

In the ZoI the dredging activities may have some influence, however the impacts would not be sub-lethal and no detectable loss or impact would be present.

2.4 LAU boundary

Impacts on benthic communities and habitats are assessed spatially as defined in EAG3 (EPA 2009). An LAU is ‘a specific geographical area which provides the most effective boundaries for management of cumulative environmental impacts on marine habitats'. Unique to Port Hedland, the EPA has designated an LAU for the industrial area of Port Hedland, as shown in Figure 2. This area is 15,102.5 ha and is used for development related cumulative losses associated with the inner harbour, tidal creeks, barrier islands and the adjacent intertidal zone within the inner Port Hedland port area. The northern boundary has been based on existing coastline data and inshore mangrove extent, while taking into account the temporal variation of the soft erodible coastlines and the spoil ground located immediately east of the harbour entrance.

The LAU shown in Figure 2 forms the basis of the cumulative loss assessment for the Lumsden Point General Cargo Facility Project, as required by the EPA.

3. BENTHIC COMMUNITIES AND HABITATS

3.1 Benthic ecology in Port Hedland LAU

The BPPH ecology of the entire Port Hedland LAU was recently assessed as part of a cumulative loss assessment for a dredging project in South West Creek (WorleyParsons 2012). Data was collected through literature review and compilation of existing data including raw data collected from baseline investigations and ground truthing surveys, sonar surveys and satellite imagery analysis. Mangrove extent was adapted from the EPA report and recommendations for the Port Hedland Outer Harbour Development (EPA 2012).

Within the Port Hedland LAU, the dominant habitat was identified as bare sediment, which featured some small areas of turfing algae, corals and seagrasses. The BPPH observed is summarised in Table 2. Some habitat types significantly overlap, such as cyanobacterial mats and saltmarshes. An estimate of maximum possible BPPH (potential) and the BPPH surveyed (actual) for each is also presented.

Table 2: BPPH types within the Port Hedland LAU, May 2012

Habitat	Current (2012) total (ha)	% of LAU area
Coral	19	0.1
Macroalgae	23	0.2
Sandy (benthic microalgal) habitat	2097	14
Saltmarsh (potential)	1771	12
Saltmarsh (actual)	301	2
Cyanobacterial mats (potential)	2425	16
Cyanobacterial mats (actual)	170	1
Extent of mangroves	2333.9	15.1

3.2 Lumsden Point benthic habitat survey

WorleyParsons conducted two benthic habitat surveys within the Lumsden Point General Cargo Facility area in September 2011 and November 2012 and these were used to map the benthic habitat within the proposed disturbance footprint (WorleyParsons 2013a). A total of 150 points were surveyed using either still or video imagery within the disturbance footprint in areas where previous dredging had not occurred (Figure 3). These images were then classified by a marine scientist to record the key habitat types.

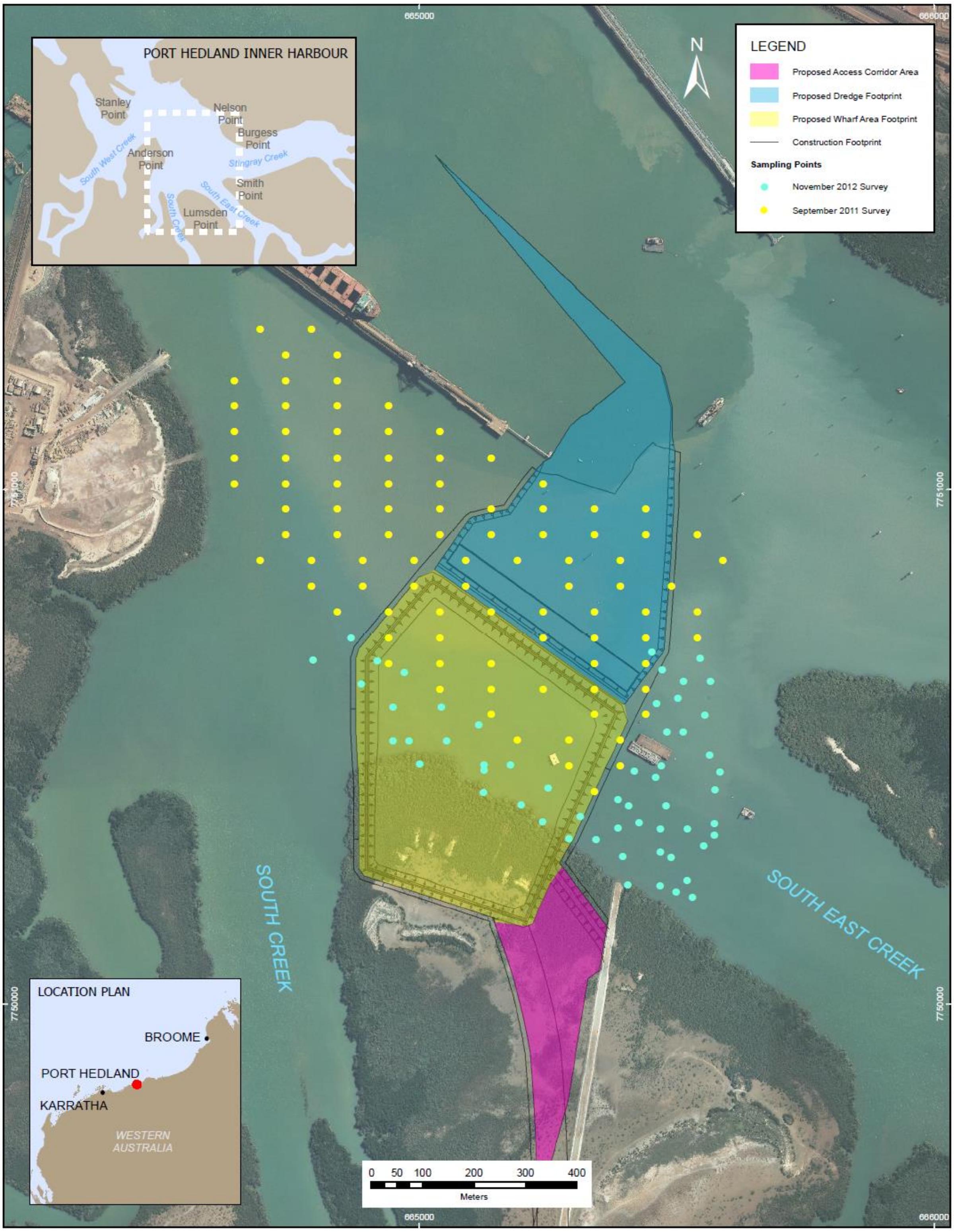

Figure 3: Benthic habitat mapping survey points

The supratidal zone (zone above high tide mark) in the infrastructure footprint was also surveyed by walking transects through representative areas of mangrove (Figure 4).

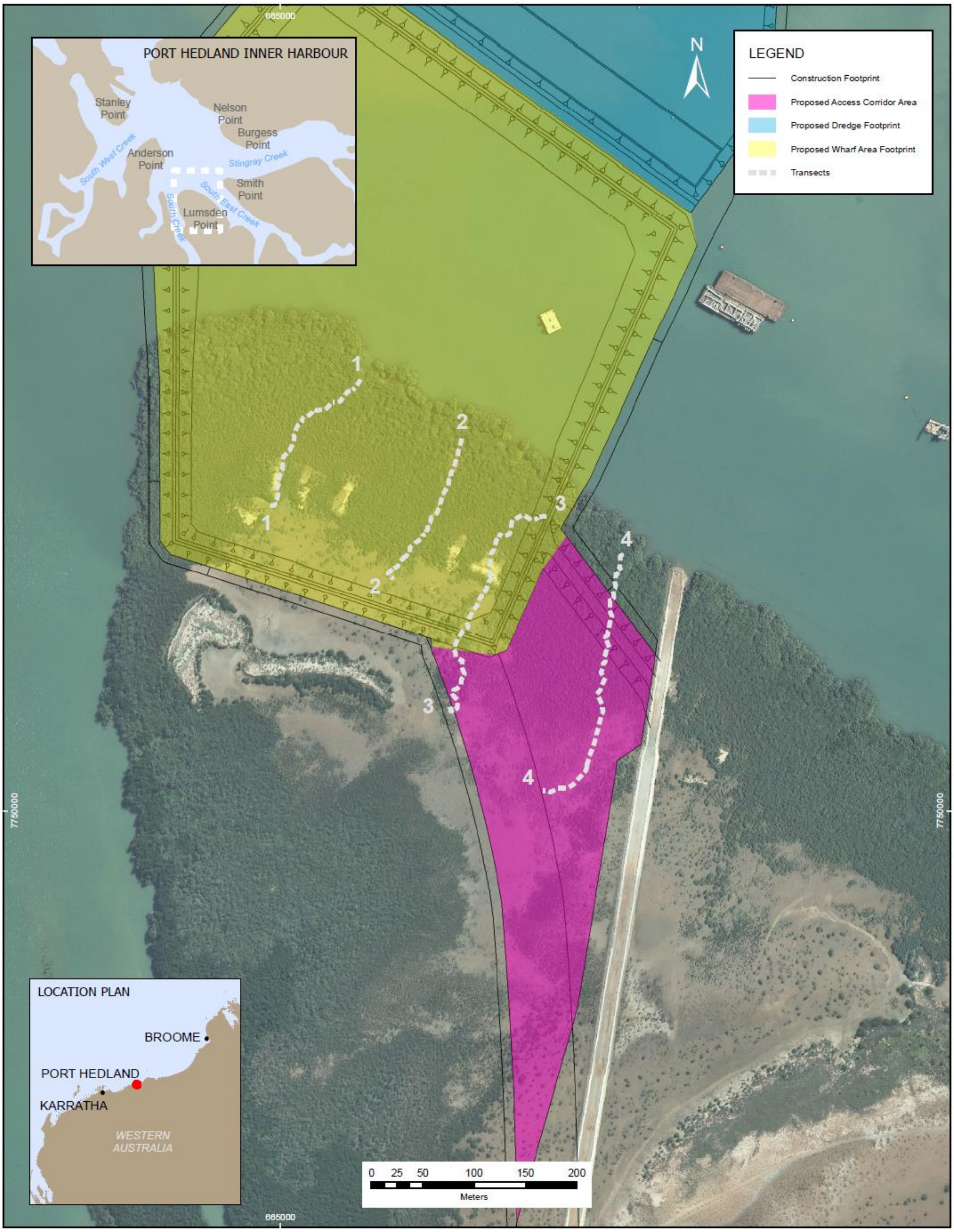

Figure 4: Mangrove habitat mapping transects

4. SEDIMENT DREDGE PLUME MODELLING

The dredging activities related to the Project will release sediment particles into the water column, creating a sediment plume that migrates away from the point of disturbance. The sediment plume's extent is influenced by a range of factors including dredge method, sediment characteristics, ambient current movement, depth of the water column and wind direction. An increase in sediment particles in the water column leads to an increase in turbidity and sedimentation in areas that promote sediment deposition as a consequence of changes in hydrodynamics and sediment particle size.

A sediment plume dispersion modelling study was undertaken to quantify the extent of sediment plume migration and sedimentation during construction dredging activities (WorleyParsons 2013b). The results of this modelling were then used to predict impacts to benthic communities and habitats.

4.1 Modelling approach

The sediment dispersion study involved using wave and three-dimensional hydrodynamic models within the oceanographic setting of a tide-dominated estuary (WorleyParsons 2013b). The Port Hedland inner harbour has a complex bathymetry, with tidal flats and inter-tidal regions dissected by deep channels that experience strong tidal currents. As such, the model needed to both resolve the complex bathymetry and be capable of representing the strong tidal currents in the deeper channel areas. Wetting and drying of the intertidal flats and current flow through fringing mangrove areas was also represented in the model.

Input data for the model included:

- wave and hydrodynamic data;
- detailed site-specific geotechnical data including particle-size distributions;
- tidal variation data;
- vessel and dredging method (alters the type of plume created);
- transport and disposal plans; and
- schedule of dredging and production rates.

4.2 Scenarios

As the start date of the dredging had not yet been defined at the time of the study, the model was designed to simulate the full proposed dredging process (20 weeks) over both a summer and winter scenario. This enabled seasonal effects present in the forcing dataset to be included in the model and hence allowed for a shift in the start date of the dredging operation. With the dredging program estimated to take 20 weeks, the summer scenario was predicted to begin in early September during the first year of operation and be completed by the end of January the following year. The winter dredging program was estimated to start in early April and be completed by late August the same year. Both scenarios were run for an additional week to ensure long-term migration and accumulation effects were captured.

4.3 Modelling results

4.3.1 Suspended sediment concentration

The summer scenario indicated that dredging over the summer season would result in a general plume migration near the project area within the inner harbour (Figure 5 and Figure 6). The sediment plume generated by the dredge is shown to be transported along South East Creek and the turning basin of Anderson Point Berth 3, with the plume then migrating throughout the inner harbour and Stingray Creek. Analysis of the winter scenario, shown in Figure 7 and Figure 8, also indicated a similar general plume migration.

The 50th summer and winter percentile plots (Figure 5 and Figure 7) show high concentrations (typically 40 to 50 mg/L and 40 to 100 mg/L respectively) within the dredging area and along South East Creek near the dredging area. Suspended sediment concentration (SSC) within the inner harbour outside of the dredging area is predicted to range between 5 and 40 mg/L. Within the immediate surrounds of the inner harbour, SSC is predicted to be less than 5 mg/L for both scenarios.

Elevated SSC observed from the 80th percentile output (Figure 6 and Figure 8) are the result of episodic re-suspension events of fine material during spring tides and energetic wave conditions. Immediately adjacent to the dredge area, maximum concentrations in the 80th percentile were between 50 and 100 mg/L in summer and between 50 and 200 mg/L in winter, decreasing to below 35 mg/L in summer and 50 mg/L in winter at distances greater than 1.0 km north-east of the project site. In addition, high SCC up to 55 mg/L and 50mg/L were also observed in Stingray Creek during the summer (Figure 6) and winter (Figure 8) scenarios respectively.

Overall, the sediment plume SSC near the dredge area in the winter scenario shows a higher SSC compared with the SSC in the summer scenario, because more of the plume is retained within the spill area and along South East Creek. This is due to the seasonal tidal flow rather than the seasonal wind conditions, as the dominant wind direction in the winter season is south-easterly (which will drive the plume north-west towards Utah Point). Therefore, winter conditions have been predicted to create a slightly higher SSC around the spill area and South East Creek compared with summer conditions.

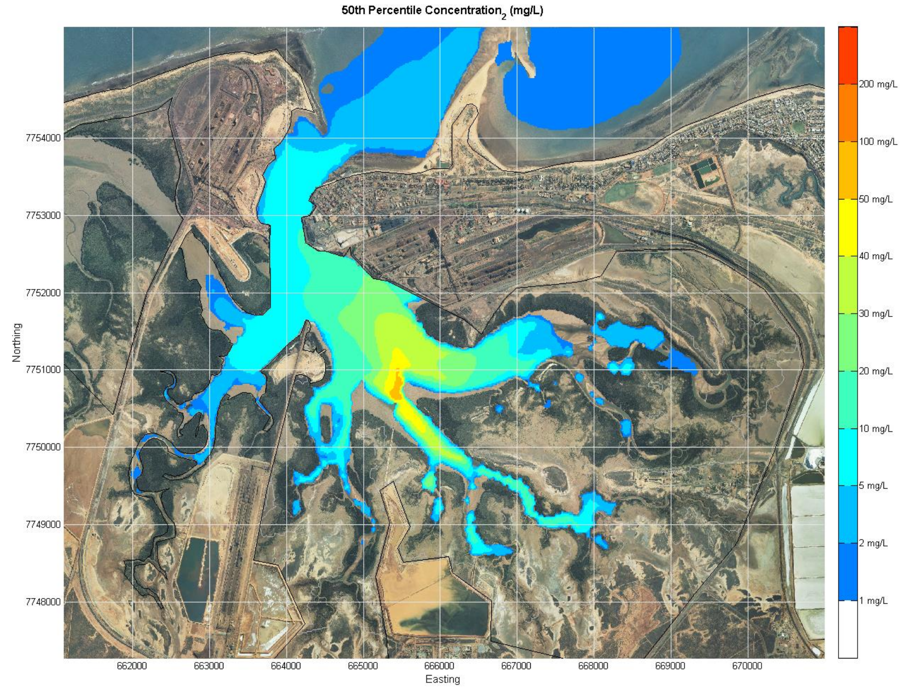

Figure 5: Predicted 50th percentile depth-averaged SSC in the inner harbour: summer scenario

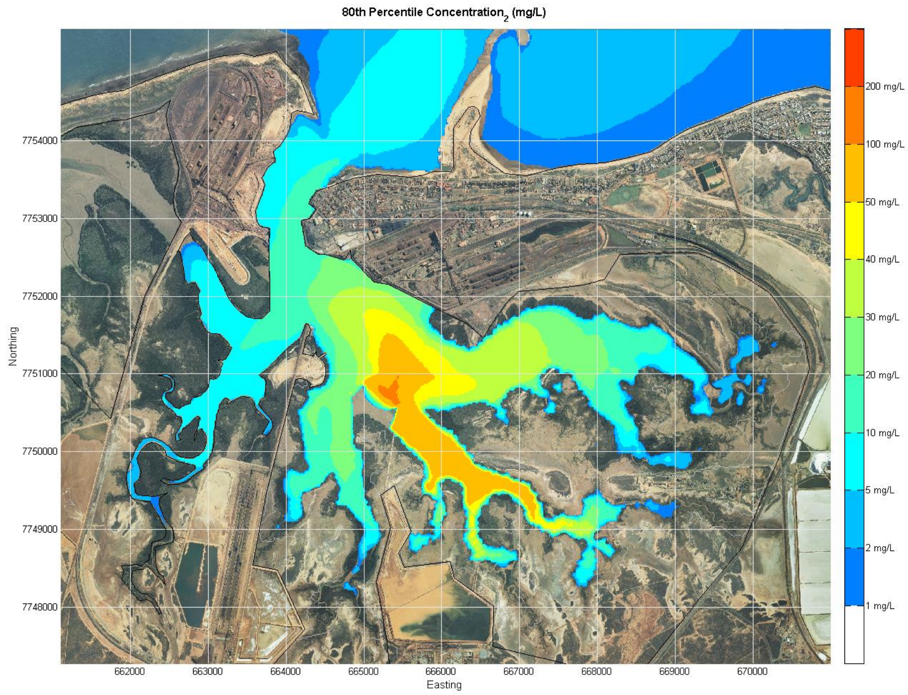

Figure 6: Predicted 80th percentile depth-averaged SSC in the inner harbour: summer scenario

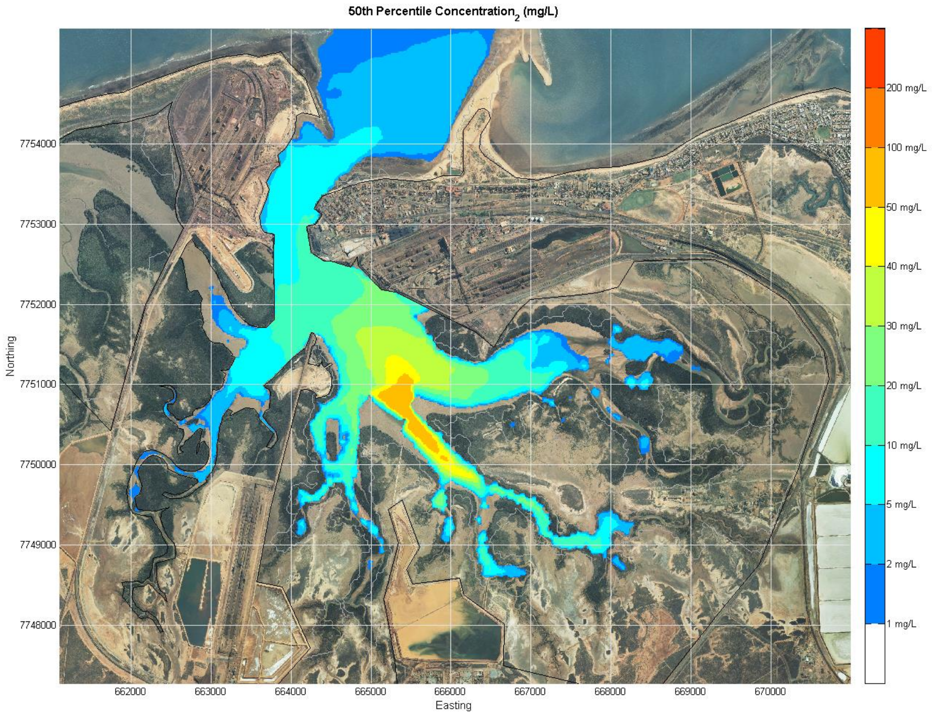

Figure 7: Predicted 50th percentile depth-averaged SSC in the inner harbour: winter scenario

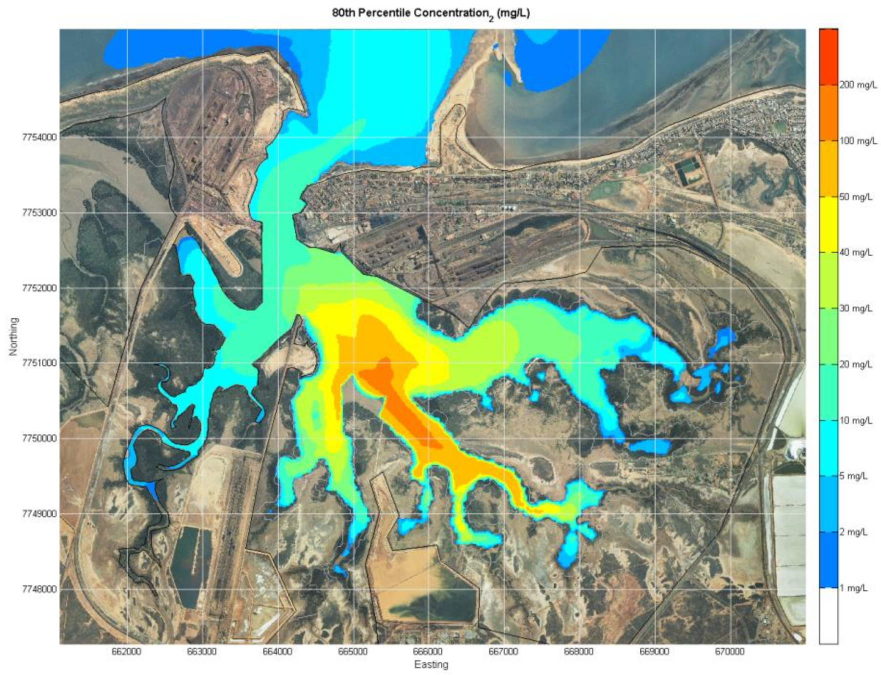

Figure 8: Predicted 80th percentile depth-averaged SSC in the inner harbour: winter scenario

4.3.2 Sedimentation

The resulting total seabed thickness change from the model is presented in Figure 9 and Figure 10 for the summer and winter scenarios. The highest levels of sedimentation, up to 200 mm, are expected within the dredge footprint itself due to deposition of sediments immediately following disturbance by the dredge.

Within the AP3 turning basin, sedimentation is expected to result in a 10 to 100 mm change in the seabed thickness. Greater than 1 km from the dredging area, the level of sedimentation is minimal (<10 mm).

Near the entrance of the inner harbour, sediment deposition thickness is generally less than 2 mm. Along the South East Creek, the deposition thickness varies from 2 to 20 mm, but along other creeks this sedimentation is restricted to below 5 mm.

Significant changes to bed thickness in mangrove zones are minimal, with most of the inner harbour mangroves expected to show less than 5 mm over the summer and winter scenarios apart from localised thickness changes of 5 to 20 mm in the mangroves immediately adjacent to the Smith Point along the South East Creek side.

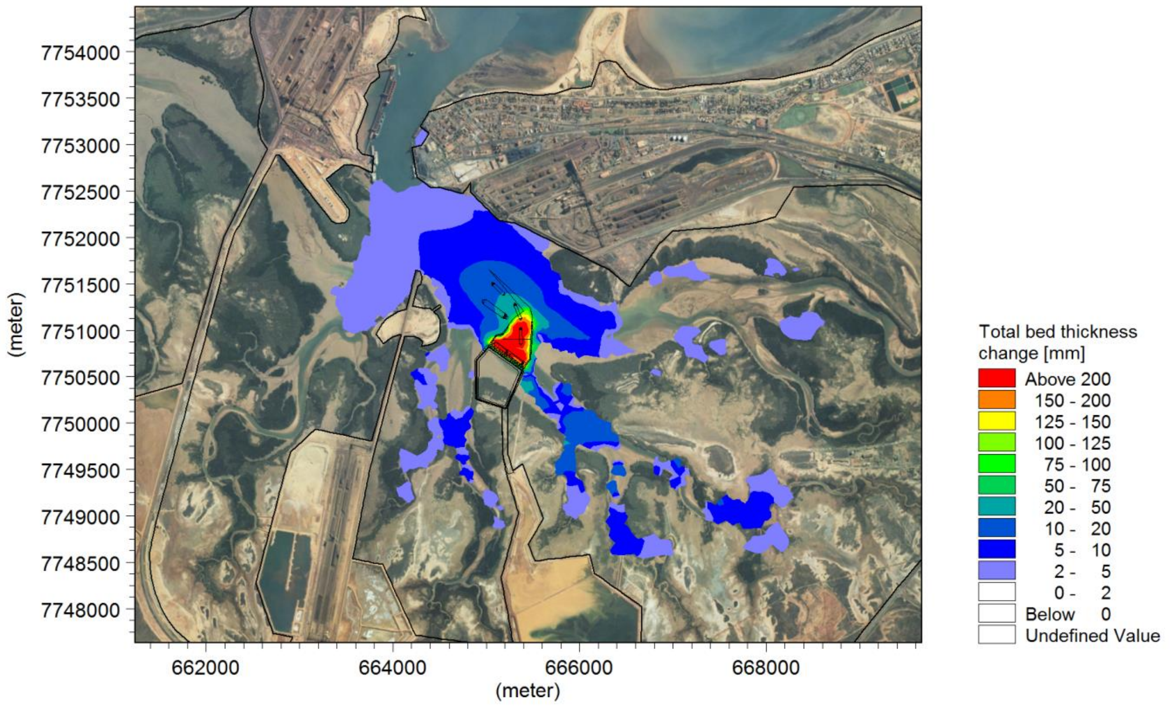

Figure 9: Total seabed thickness change after completion of dredging in the inner harbour: summer scenario

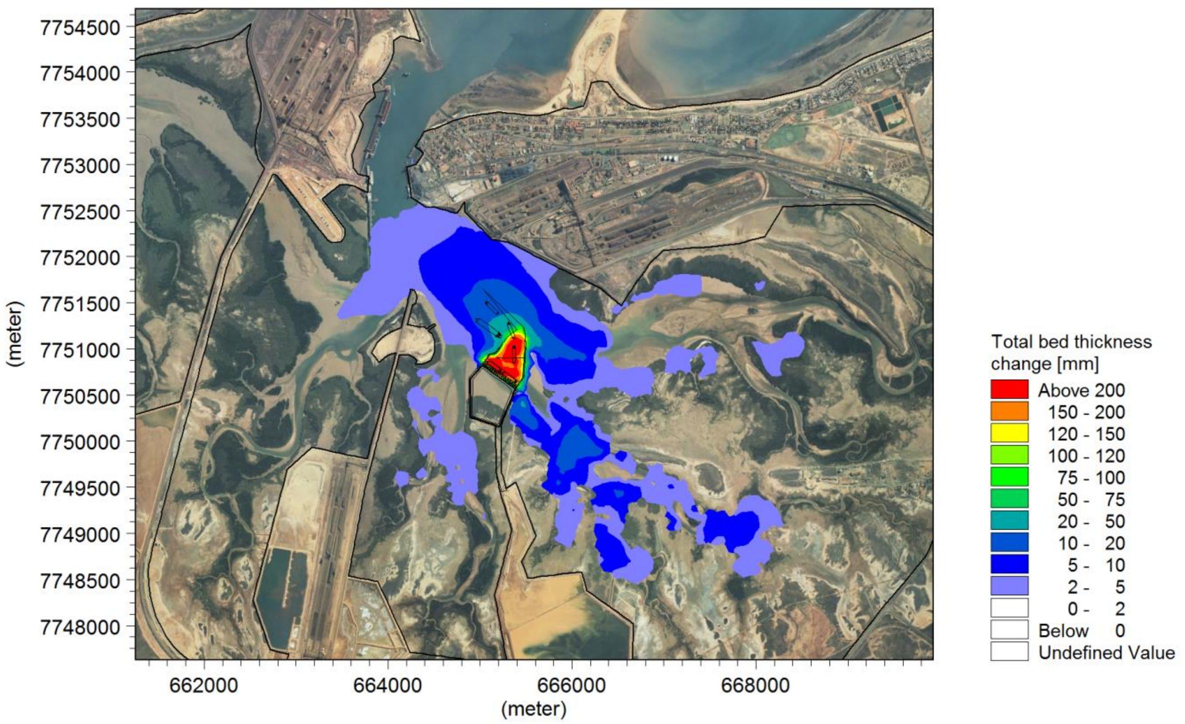

Figure 10: Total seabed thickness change after completion of dredging in the inner harbour: winter scenario

5. DIRECT IMPACTS

5.1 Historical loss of BPPH

BPP cumulative loss for the Port Hedland LAU up to the completion of dredging activities for the South West Creek Dredging and Reclamation Project was calculated in May 2012 for the PHPA (WorleyParsons 2012). The study investigated the historical loss of BPPH by comparing data from 1964 up to the time of the South West Creek Dredging and Reclamation project. Historic aerial photographs from 1964 were used to create a baseline of the area before major development and other anthropogenic activities.

Estimated BPPH loss since pre European settlement is summarised in Table 3. Habitat mapping was also undertaken, and a habitat map of the LAU is presented in Figure 11.

Table 3: Estimated cumulative BPPH loss from Port Hedland LAU (WorleyParsons 2012)

Habitat	Pre European BPPH total (ha)	Current (2012) total (ha)	Area lost	% Cumulative loss
Coral	19	19	0.1	0.7
Macroalgae	73	23	49	68
Sandy Habitat (potential MPB)	2349	2097	253	11
Saltmarsh (potential)	3394	1771	1623	48
Saltmarsh (actual)	628	301	327	52
Cyanobacterial mats (potential)	4274	2425	1849	43
Cyanobacterial mats (actual)	299	170	129	43

The cumulative loss of mangroves in presented in Table 4 and is based on the figures given by the EPA for the Outer Harbour Development proposal (EPA 2012). This table includes cumulative losses up to all projects conducted by proponents to the end of 2012 including the South West Creek and Roy Hill projects, and includes provision for the approved Outer Harbour Development Project which has not been constructed.

Table 4: Mangrove extent within the Port Hedland LAU (EPA 2012)

Benthic primary producer habitat (mangroves)	Coverage within Port Hedland LAU (ha)	Percentage impact (%)
Historical area of mangroves as defined by the EPA	2,676	
Estimated cumulative loss including projects during 2012 (up to 45 ha estimated in 2012)	342.1	12.8
Estimated cumulative loss including BHPBIO Outer Harbour Proposal (approved but not yet started)	376.1	14
Resulting extent of mangroves	2299.9	

Within EAG3, six categories of marine ecological protection are identified based on the area type; e.g. development areas or high protection areas. Associated with these are cumulative loss guidelines, which are tools to identify the risk to ecological integrity based on the cumulative loss within an area type.

The EPA have previously described the Port Hedland LAU as a Category F area (EPA 2009b), where cumulative loss guidelines have been significantly exceeded. However, a more recent assessment undertaken as part of the Outer Harbour Development proposal suggests that an overall level of mangrove loss from the PHLAU may be less than the 10% cumulative loss guideline (EPA 2012).

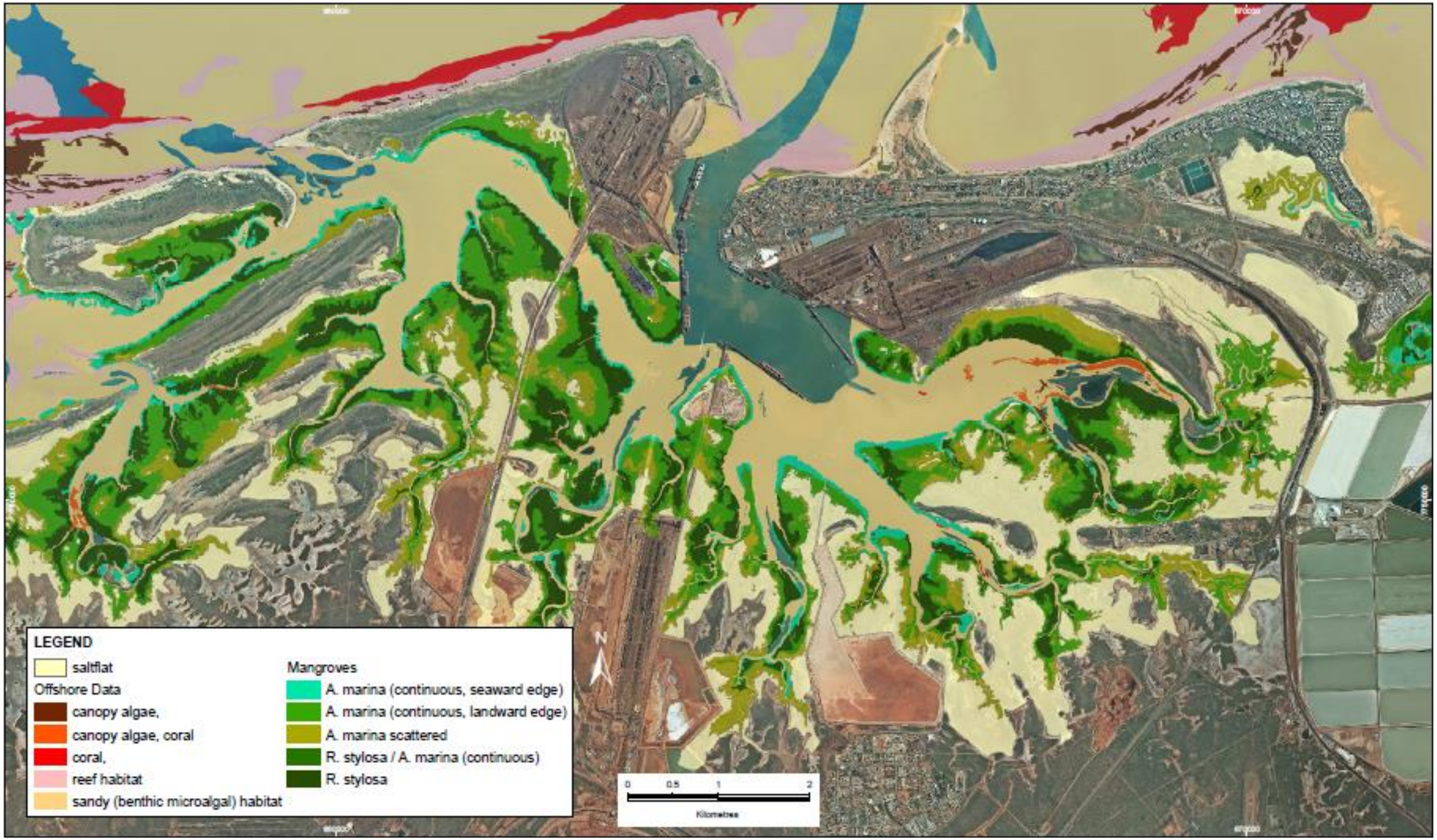

Figure 11: Benthic primary producer habitat of the Port Hedland LAU

5.2 Direct loss of BPPH

Direct loss of BPPH will occur within the ZoHI in the Project footprint due to the removal of substrate by dredging and construction, as well as the placement of material within the wharf and access corridor, and the use of pipelines and a discharge channel. The areas of BPPH estimated to be directly affected by these activities are presented in Figure 12, and summarised in Table 5 and Table 6.

The disturbance footprint includes mangrove habitat and bare substrate. Bare substrate already dredged due to previous projects has been assumed not to include BPPH and is not included in the calculations for this Project. Areas approved for disturbance for the PHPA Cyclone Mooring Project are also not included as they have already been accounted for as benthic habitat loss (WorleyParsons 2011a). Within the zones not previously approved for disturbance, mangroves (and associated pneumatophores) and bare substrate were the habitats identified. Bare substrate in the benthic zone covered 8.34 ha and is potential benthic microalgal habitat. This results in a loss of 0.36% of the benthic microalgal habitat present within the LAU, which leads to a cumulative loss of 11.36%. Mangrove habitat to be cleared has been proposed to be a maximum of 13.88 ha, or 0.52% of the mangrove habitat within the LAU and a cumulative loss of 14.57%.

Table 5: Maximum predicted BPPH loss within the Lumsden Point General Cargo Facility footprint

Habitat Type	Footprint (ha)					
	Wharf area	Access corridor	North pipeline corridor	South pipeline corridor	DMMA B-North discharge channel	Total
Mangroves	8.86	4.79	0.19	0	0.04	**13.88**
Bare Substrate	5.85	1.82	0.27	0.33	0.07	**8.34**
Total BPPH	**14.71**	**6.61**	**0.46**	**0.33**	**0.11**	**22.22**

Table 6: Estimated BPPH loss within Port Hedland LAU

Benthic habitat category	Benthic habitat area predicted loss due to project (ha)	Cumulative loss area of LAU from historic and proposed loss (ha)	Estimated percentage loss of habitat category within LAU due to proposal	Estimated cumulative loss within LAU (%) (current loss and proposed loss)
Bare substrate	8.34	261.34	0.36	11.36
Mangroves	13.88	389.98	0.52	14.57

It is predicted that only direct losses of BPPH and mangroves will occur in the primary footprint of construction.

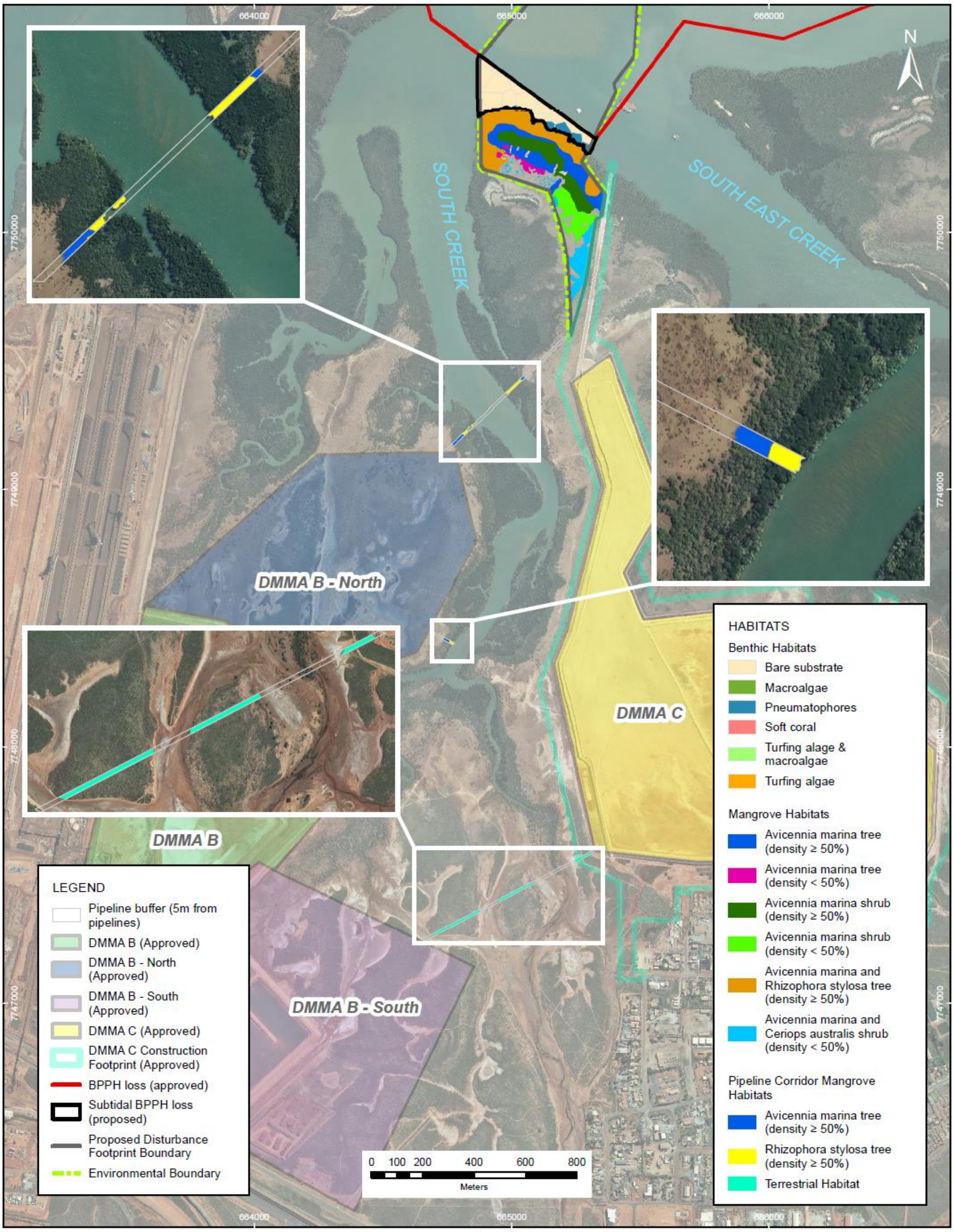

Figure 12: Proposed BPPH disturbance directly due to this proposal

5.3 Impacts from sedimentation

For mangrove species present in Port Hedland, previous projects have adopted 100 mm as a mortality threshold for indirect impacts from sediment deposition over the entire project (WorleyParsons 2010c). This was based on a review of scientific literature and of stressors from previous dredging projects. According to the sediment plume results, areas where possible sedimentation of 100 mm may occur are in the ZoHI – where direct loss will already occur (Figure 9 and Figure 10). Most of the inner harbour mangroves are expected to experience less than 2 mm of consolidated total seabed thickness change over the summer and winter scenarios, other than localised 5 to 10 mm changes in the mangroves immediately adjacent to the Harriet Point berths.

No indirect and irreversible loss of coastal intertidal BPPH is predicted to occur due to sedimentation. Any sub-lethal or recoverable impacts are discussed in Section 6.

6. INDIRECT IMPACTS TO BPPH

6.1 Impact Zonation

Suspended sediment concentrations are predicted to increase during dredging throughout the zones of high impact (ZoHI), zone of moderate impact (ZoMI) and zone of influence (ZoI) as shown in Figure 13. BPPH such as corals and algae communities present in the Port Hedland LAU depend on light reaching the seabed in order for photosynthesis to occur. Existing communities present in the Inner Harbour are known to be resilient and tolerant to high sediment loads.

In an attempt to understand light irradiance at the seabed and its effects on BPPH within the inner harbour, a mathematical model of light attenuation was undertaken using results from predictive modelling from previous projects (WorleyParsons 2010c) and the modelling undertaken for the current proposal (Section 4). While the impacts from dredging activities on water quality are derived from predictive modelling, the approach indicates how tolerant BPPs within the inner harbour are to increases in SSC from dredging activities.

The underwater light environment during the growing season is the most important period that determines the survival and productivity of BPPs (Moore, Wetzel et al. 1997; Batiuk, Bergstrom et al. 2000; Dixon 2000). The amount of light needed for growth and reproduction is the cumulative light received during the growth period of the BPPs' life history. Light levels below the minimum physiological requirement leads to the loss of BPPs dependent on physiological requirement[1].

The attenuation of light through the water column is the major water property that influences the underwater light climate experienced by BPPs (WorleyParsons 2010c). As light penetrates through the water column it is attenuated from the surface levels (I0) to the bottom at depth z (Iz). Factors that contribute to light attenuation or the light extinction coefficient include:

- total suspended sediment (TSS): particles absorb light quanta;
- chlorophyll-a (Chl-a): algae absorb light quanta and use the energy to fix inorganic carbon to organic forms; and
- coloured dissolved organic matter (CDOM): often measured as dissolved organic carbon (DOC) also effectively absorb light quanta in the water column (WorleyParsons 2010c).

Water quality monitoring undertaken within the inner harbour has determined SSC baseline values to be used in this assessment across all sites (WorleyParsons 2010b). Sites are illustrated in Figure 14 and represent the key BPPs established during the baseline survey (WorleyParsons 2010a).

[1] The physiological requirement for a number of the species present is not known. This assessment looks at baseline compared with modelled worst case scenarios.

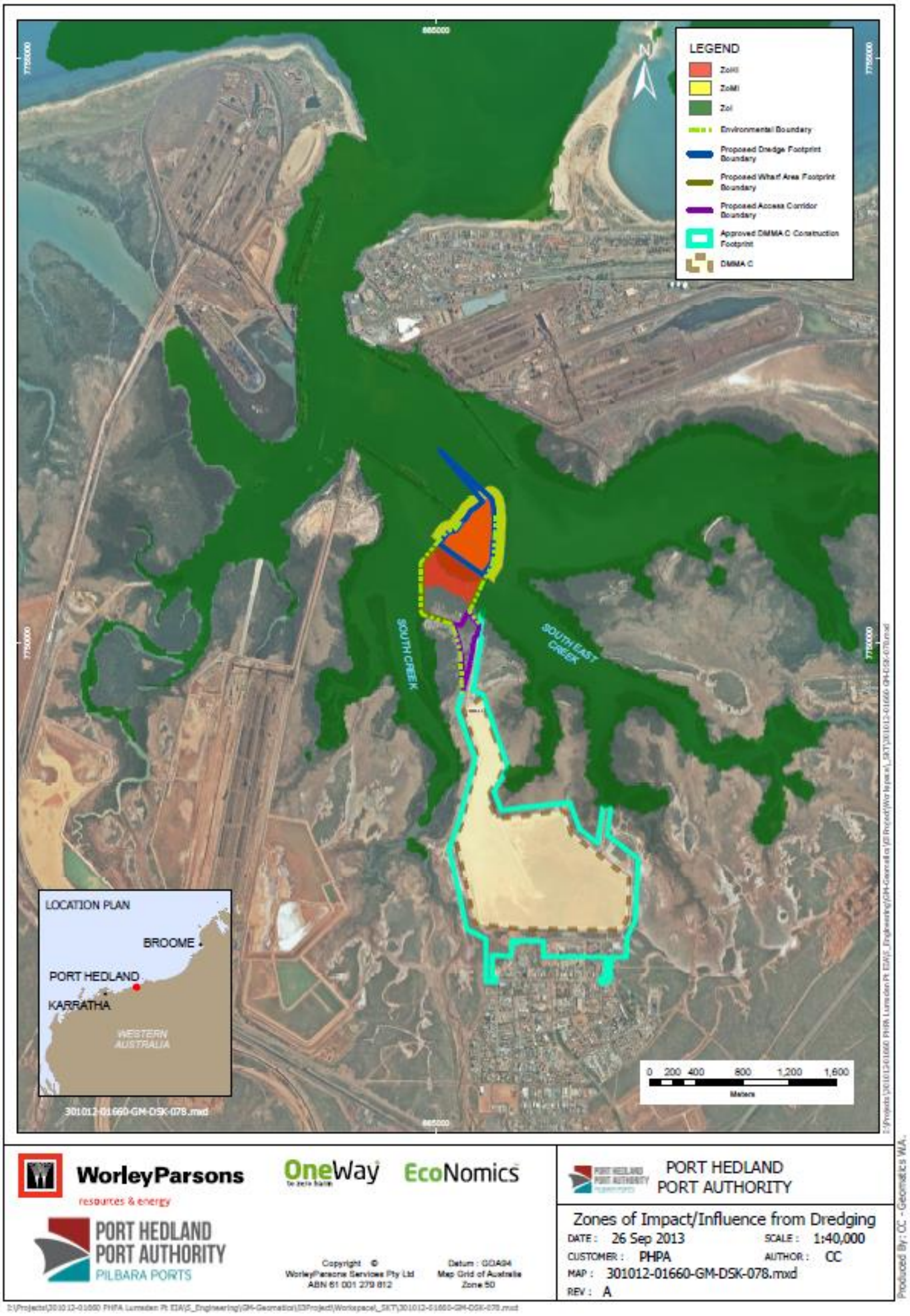

Figure 13 Zones of Impact/Influence from Proposed Dredging Program

The following inputs were adopted in the analysis of the underwater light environment experienced within the Port Hedland inner harbour:

- BPP distribution in the inner harbour is limited to 10 m HAT, so the maximum depth considered is 10 m (=zmax);
- the specific attenuation (or light extinction) coefficient (υChla) for Chl-a is 0.014 m^{-1} (µg Chl a/L)$^{-1}$ (Reynolds. C.S 1984); and
- the specific attenuation (or light extinction) coefficient (υTSS) for TSS is 0.047 m^{-1} (mg TSS/L^{-1}) (Verduin. J. 1982).

The Beer-Lambert relation has been used to estimate the light intensity over the different dredging programs at key BPPs and is represented as:

$$I_z = I_0 e^{-\eta z}$$

where IZ and I0 are the light intensities at depth (z) and at the surface, respectively, and η is the light extinction (or attenuation) coefficient. The light extinction coefficient can be readily calculated from the specific attenuation coefficients for TSS and Chl-a as:

$$\eta = \upsilon_{Chla} Chla + \upsilon_{TSS} TSS$$

where Chl-a is in units of µg/L, TSS is in unit of mg/L, and υTSS and υChla are the specific attenuation coefficients for TSS and Chl-a, respectively.

Rearranging the Beer-Lambert relation as:

$$\frac{I_z}{I_0} = e^{-\eta z}$$

allows the fraction of the incident light (I0) at depth z (I_z) to be readily calculated and has been undertaken in the analysis that follows.

Estimates of the light extinction coefficient from the median values of TSS and Chl-a at each of the BPP monitoring locations are given in Figure 15. Seasonal variations in TSS and Chl-a were not assessed because statistically they showed no significant differences (P<0.05) between seasons, as discussed in Section 4.3.1 (WorleyParsons 2010b).

Figure 14: Locations for light penetration assessments

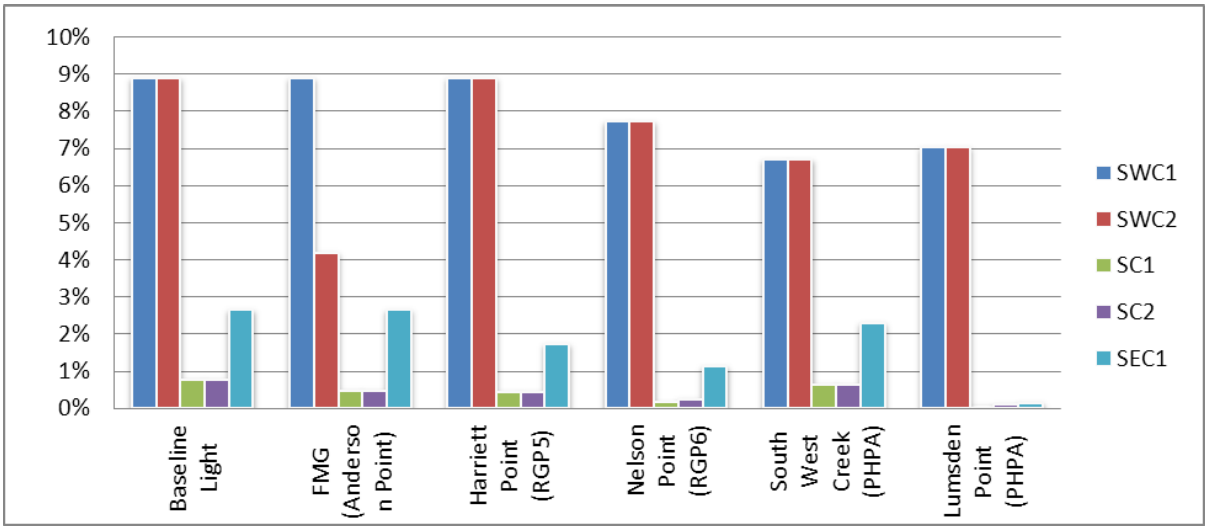

Figure 15: Percentage of surface irradiance at BPPH locations from predictive modelling from previous major dredging campaigns

As shown in Figure 15, changes in surface irradiance are low in relation to previously encountered light regimes (both natural and from previous dredging) and would be considered short and episodic, particularly at Sites SC1, SC2 and SEC1. At these sites, where light levels are already low, resident BPP communities have survived previous dredging campaigns and it can be reasonably assumed they will also survive/recover from disturbance associated with the current project, which will involve a much shorter construction campaign than the others shown in Figure 15.

6.2 Summary of BPPH impacts

The proposed dredging is likely to result in increased rates of sedimentation over benthic communities within the ZoMI, however frequent tidal movement will likely cause resuspension and redistribution of sediments as seen in the modeled sedimentation plots (WorleyParsons 2013b). None of the modeled sedimentation within the ZoMI exceeds the adopted threshold for mangrove mortality.

The increase in TSS will not result in a significant decrease in light levels compared with baseline or previous dredging projects and therefore no indirect impacts are predicted to occur on any of the benthic primary producer species.

Due to this frequent movement of sediments within the ZoMI and the existing tolerance levels of the resident BPPH communities, it is predicted that indirect losses of BPPs will not occur in this zone. Sub-lethal impacts may occur but will be reversible.

7. PREDICTED FUTURE BPPH LOSS

Additional projects that are currently under consideration include:

- Common User Facility at Lumsden Point (separate to this project) which will involve clearing of up to 20 ha of land including mangrove habitat (GHD 2012)
- Pilbara Ports Outer Harbour project (FMG), which has an estimated mangrove loss of up to 15 ha.

In accordance with best practice, these projects will also be taken into account in the overall cumulative loss assessments and the predicted extent of mangroves following this proposal (see Table 7).

Table 7: Predicted cumulative loss due to future Common User Facility and FMG proposals including Lumsden Point General Cargo Facility proposal

Benthic primary producer habitat (mangroves)	Coverage within Port Hedland Industrial Area LAU (ha)	Percentage impact (%)
Estimated cumulative loss including Common User Facility and Pilbara Ports Outer Harbour	Up to 424.98	Up to 15.88

8. BENTHIC HABITAT LOSS ASSESSMENT SUMMARY

8.1 Irreversible BPPH losses

The areas of BPPH estimated to be directly affected by these activities are summarised in Table 8.

Table 8: Summary of estimated BPPH loss within Port Hedland LAU

Benthic habitat category	% loss of habitat category within LAU due to proposal	Estimated cumulative loss within LAU (%)
Bare substrate (benthic microalgal) habitat	0.36	11.36
Mangroves	0.52	14.57 (up to 15.88 including future proposals)

No other direct or indirect losses are expected to be associated with this Project.

8.2 Predicted impacts on BPPH

Predicted impacts in the ZoMI and ZoI were analysed by using sediment plume modelling and previous project impacts to understand the effects of suspended sediment and sedimentation.

Impacts related to increased suspended sediment were investigated by comparing light levels on the bottom environment that might affect BPPs. Light attenuation at the seabed during baseline, other dredging projects and the modelled TSS levels were compared for different sites within the ZoMI and ZoI. TSS concentrations predicted through the sediment plume modelling did not significantly change light levels from those of baseline or previous projects. Given the BPPs at each site have survived these levels of turbidity, it can be reasonably assumed they will also survive/recover from the TSS concentrations predicted for this Project.

Sedimentation was also compared with previous projects and also adopted a chronic trigger level of 100 mm to determine indirect impacts (WorleyParsons 2010c). The sediment plume modelling predicts that sedimentation levels of 100 mm will only occur in the disturbance footprint, and shows no indirect losses to mangroves.

Therefore it is predicted that no irreversible impacts will occur outside of the disturbance footprint.

8.3 Ecological significance of losses

From the data collected during the recent benthic habitat mapping in the Project disturbance footprint, no unusual, unique or highly significant habitat complexes were identified in the disturbance footprint.

The direct losses of coastal intertidal BPPH due to the dredging and construction activities for this project also represent a very small fraction of the total BPPH found in Port Hedland. Therefore the ecological significance of estimated benthic community losses can be considered minimal.

Consistent with the intent of the protection of BPPH in port operational areas within EAG 3, the PHPA remains committed to protecting and maintaining the ecological integrity of the mangroves within Port Hedland through continued implementation of its mangrove rehabilitation program with the intent to lower cumulative loss.

The PHLAU in general terms is accreting and if net loss was used rather than gross loss it would represent around 5% mangrove loss instead (WorleyParsons 2010d). This indicates a far lower ecological impact to ecosystems in a like for like biosphere.

A detailed construction and dredging management plan has been developed for this Project which will manage and mitigate potential impacts to the marine environment.

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