Appendix A Subtidal Field Assessment Notes

Site	Start		Finish		Time Start-Finish	Depth	Description
	Latitude	Longitude	Latitude	Longitude			
23	21 37.9798 S	115 07.1359 E	21 37.9798 S	115 07.1359 E	12:15-12:20 pm	5.0 m	Flat brown silt substrate heavily bioturbated with infauna holes (i.e. crabs). Benthic epifauna rare (<1%). Visibility was very bad.
25	21 37.9552 S	115 07.7437 E	21 37.9305 S	115 07.7474 E	12:31-12:35 pm	4.8 m	Flat brown silt substrate. Sparse bioturbation. Isolated rubble/shell pieces with turf algae attached and rare small areas of rubble with occasional filter feeders (bryozoans) and macroalgae (Phaeophyceae) (<1%)
27	21 38.0331 S	115 08.2871 E	21 37.9546 S	115 08.3291 E	12:46-12:50 pm	5 m	Flat brown silt substrate with occasional patches of shells, rubble and exposed small rock boulders (e.g. <30cm). Sparse bioturbation in silty sand. Diverse epifauna on the rubble/rock patches including fauna filter feeders (sponges, bryozoans, octocorals) & turf algae, macroalgae and some seagrass (*Halophila*) and hard coral (small *Turbinaria*). Generally, very low total biotic cover (1-3%)
29	21 38.0344 S	115 08.8738 E	21 38.0344 S	115 08.8738 E	12:59-13:05 pm	4.5 m	Flat brown rippled silty sand and occasional isolated rubble with rare patches of limestone pavement overlain by a thin veneer of silt. Very sparse bioturbation. Occasional filter feeders (octocorals) and macroalgae (*Halimeda*, *Caulerpa* & *Udotea*) with one small dense patch (10%) of filter feeders, macroalgae (*Dictyota*, *Padina*, *Asparagopsis*) and seagrass (*Halophila*). Total biotic cover 1-3%.
52	21 37.4806 S	115 07.1448 E	21 37.4806 S	115 07.1448 E	13:47-13:52 pm	7 m	Flat brown sandy substrate with rubble and broken shells and occasional patches of limestone pavement overlain by thin veneer of sand or low-profile reef. No bioturbation. Benthic filter feeder invertebrates (i.e. bryozoans, ascidians, octocorals) and turf algae predominate, with rare macroalgae (small isolated red, green & brown plants) and patches of low cover seagrass (*Halophila*). Total biotic cover (1-3%)
54	21 37.4941 S	115 07.7216 E	21 37.4941 S	115 07.7216 E	13:37-13:42 pm	6 m	Flat brown rubbly substrate with broken shells and patches of silty sand. Occasional patches of limestone pavement overlain by thin veneer of sand or low-profile reef. No bioturbation. Benthic filter feeder invertebrates (i.e. bryozoans, ascidians, octocorals) and macroalgae (i.e. *Sargassum*) and rare patches of low cover seagrass (*Halophila*). Total biotic cover (1-3%)
56	21 37.4949 S	115 08.3249 E	21 37.4790 S	115 08.3236 E	13:24-13:29 pm	5 m	Flat brown silty sand substrate with broken shells and rubble. No bioturbation. Turf algae growing on rubble and occasional filter feeders (i.e. octocorals). Small areas of higher density (5-10%) filter feeders, seagrass (*Halophila*), macroalgae (chlorophyceae), hard coral (*Porites*, *Turbinaria*) patches on presumably occasional limestone pavement overlain by thin veneer of silty sand. Total biotic cover (1-3%).

Site	Start		Finish		Time Start-Finish	Depth	Description
	Latitude	Longitude	Latitude	Longitude			
58	21 37.4873 S	115 08.8915 E	21 37.4873 S	115 08.8915 E	13:13-13:18 pm	5 m	Flat brown sandy substrate with rubble, broken shell and exposed small rocks (i.e. <30 cm). No bioturbation. Filter feeders (i.e. octocorals, sponges & bryozoans) most common with occasional patches of seagrass (*Halophila*). Total biotic cover (3-10%).
88	21 36.9294 S	115 07.1553 E	21 36.9294 S	115 07.1553 E	13.58-14:03 pm	8.5 m	Flat brown silty sand substrate with rubble, broken shell and exposed small rocks (i.e. <30 cm). No bioturbation. Filter feeders (i.e. octocorals, sponges & bryozoans) most common with occasional turf algae and macroalgae. Total biotic cover (1-3%).
90	21 36.9278 S	115 07.7913 E	21 36.9091 S	115 07.8330 E	14:11-14:16 pm	7 m	Flat brown silty sand substrate with rubble, broken shell. No bioturbation. Occasional turf algae, small macroalgae and filterfeeders. Total biotic cover (<1%).
92	21 36.9238 S	115 08.3245 E	21 36.9238 S	115 08.3245 E	14:21-14:26 pm	6.5 m	Relatively flat low-profile reef/ limestone pavement overlain by rubble and turf algae with occasional small rocky outcrops (5 m^2). Dense cover of filter feeders (sponges, octocorals, hydroids, bryozoans & ascidians) & some hard corals (*Turbinaria*, Faviidae, *Porites*) on rocky outcrops with greater relief (50-80%). Lower cover (5-25%) composed of seagrass (*Halophila*), filter feeders, including Echinoderms and Tunicates. All three-common species *H. ovalis, H. spinulosa* & *H. decipiens* recorded. Total biotic cover (>25%).
94	21 36.9730 S	115 08.8815 E	21 36.9730 S	115 08.8815 E	14:32-14:37	6 m	Flat brown sandy substrate with occasional rubble and broken shells. No bioturbation. Occasional small macroalgae (phaeophyceae and rhodophyseae) and filter feeders (sponges, bryozoans). Total biotic cover (<1%).
96	21 36.9606 S	115 09.4739 E	21 36.9606 S	115 09.4739 E	14:40-14:45 pm	5.5 m	Flat brown rippled sand and occasional isolated rubble. Sparse bioturbation. Few small macroalgae plants (common nearshore brown & red algae) and filter feeders attached to occasional rubble. Very low total biotic cover (<1%).
130	21 36.4084 S	115 08.2758 E	21 36.3707 S	115 08.2542 E	15:28-15:34 pm	8 m	Flat brown sandy substrate with rubble, broken shell. No bioturbation. Turf algae growing on rubble and shell as well as occasional macroalgae (common nearshore brown & red algae). Very low total biotic cover (<1%).
132	21 36.4199 S	115 08.8488 E	21 36.4199 S	115 08.8488 E	15:19 pm-15:24 pm	7 m	Flat brown sandy substrate with rubble, broken shell. No bioturbation. Turf algae growing on rubble and shell as well as occasional macroalgae (common nearshore brown & red algae & *Halimeda*). Very low total biotic cover (<1%).

Site	Start		Finish		Time Start-Finish	Depth	Description
	Latitude	Longitude	Latitude	Longitude			
134	21 36.4261 S	115 09.4644 E	21 36.4162 S	115 09.4366 E	15:11-15:16 pm	6 m	Flat brown sandy substrate with rubble, broken shell. No bioturbation. Turf algae growing on rubble and shell as well as occasional macroalgae (common nearshore brown & red algae) & rare seagrass (*Halophila*). Very low total biotic cover (<1%).
136	21 37.9798 S	115 07.1359 E	21 37.9798 S	115 07.1359 E	15:03-15:08 pm	5.5 m	Flat brown rippled sand, broken shell and rare isolated rubble. Sparse bioturbation. Few small macroalgae plants (common nearshore brown & red algae) and filter feeders (octocorals, sponges). Very low total biotic cover (<1%).
138	21 36.4348 S	115 10.6516 E	21 36.4348 S	115 10.6516 E	14:53-14:57 pm	5.5 m	Flat brown sand substrate with rubble, broken shell and occasional patches of limestone pavement overlain by thin veneer of sand or small rock outcrop. No bioturbation. Turf algae on rubble and occasional patches of macroalgae (common nearshore brown, red & green algae), filter feeders (sponges, octocorals & bryozoans) and seagrass. Total biotic cover (<1%) although greater than sites 132-136.
154	21 35.8588 S	115 08.9297 E	21 35.8588 S	115 08.9297 E	15:39-15:44 pm	8 m	Flat brown sand substrate with rubble, broken shell and occasional patches of limestone pavement overlain by thin veneer of sand or small rock outcrop. No bioturbation. Turf algae on rubble and occasional patches of macroalgae (common nearshore brown, red algae), filter feeders (sponges, octocorals & bryozoans) and seagrass. Total biotic cover (<1%) similar .to 138.
156	21 35.9019 S	115 09.5210 E	21 35.9124 S	115 09.5349 E	15:48-15:53 pm	7.5 m	Flat brown sand substrate with rubble, broken shell and occasional patches of limestone pavement overlain by thin veneer of sand or small rock outcrop. No bioturbation. Turf algae on rubble and occasional patches of macroalgae (common nearshore brown, red algae), filter feeders (sponges, octocorals & bryozoans) and seagrass. Total biotic cover (<1%) similar .to 154.
158	21 35.8757 S	115 10.0872 E	21 37.9798 S	115 07.1359 E	15:58-16:04 pm	6.5 m	Flat coarse brown sand substrate with occasional rubble/broken shell and rare patches of small rock outcrop (1 m^2). No bioturbation. Turf algae & macroalgae (common nearshore brown, red & green algae) on rubble. Dense patches of, filter feeders (sponges, octocorals & bryozoans) and rare hard corals on rock outcrops and rare seagrass (*Halophila*) on sand. Total biotic cover (<1%).
160	21 35.8967 S	115 10.6495 E	21 35.8967 S	115 10.6495 E	16:09-16:14 pm	4.5 m	Low to moderate profile reef with undulating relief and high benthic cover. The cover is typically interspersed and diverse with thick macroalgae (*Sargassum*), filter feeders (sponges, octocorals, hydroids) & hard corals (*Turbinaria*, *Acropora*, Faviidae). Total biotic cover (80%).

Site	Start		Finish		Time Start-Finish	Depth	Description
	Latitude	Longitude	Latitude	Longitude			
162	21 35.9027 S	115 11.2387 E	21 35.9027 S	115 11.2387 E	16:20-16:25 pm	5 m	Relatively flat low-profile reef/ limestone pavement overlain by a thin veneer of sand and rubble with occasional undulating reef relief. Dense cover of filter feeders (sponges, octocorals, hydroids, bryozoans & ascidians) & some hard corals (*Turbinaria*) on rocky outcrops with greater relief (50-80%). Lower cover (5-10%) composed of turf algae, macroalgae, seagrass (*Halophila*), filter feeders on flat relief. Total biotic cover (15-25%).
184	21 35.3318 S	115 10.0544 E	21 35.3318 S	115 10.0544 E	17:09-17:13 pm	7.5 m	Flat brown sand substrate with rubble, broken shell and occasional patches of limestone pavement overlain by thin veneer of sand or small rock outcrop. No bioturbation. Turf algae on rubble and occasional patches of macroalgae (common nearshore brown, red algae) & filter feeders (sponges, octocorals & bryozoans). Total biotic cover (<1%).
186	21 35.3610 S	115 10.6509 E	21 37.9798 S	115 07.1359 E	16:58-17:03 pm	6 m	Flat coarse brown/white sand substrate with occasional rubble/broken shell and patches of limestone pavement overlain by thin veneer of sand or undulating rock outcrop. Relatively high cover of filter feeders (sponges, octocorals, hydroids) & some hard corals (*Turbinaria*) on patchy rocky outcrops with greater relief (25-50%). Patchy areas of lower cover of filter feeders and macroalgae on turf covered rubbles & limestone pavement (5-25%) interspersed with sand patches with low cover (0-5%). Total biotic cover 25%.
188	21 35.3762 S	115 11.2507 E	21 35.3762 S	115 11.2507 E	16:51-16:55 pm	5.5 m	Flat coarse white sand substrate with occasional rubble/broken shell and patches of limestone pavement overlain by thin veneer of sand or low-profile rock outcrop. Patchy areas of relatively high cover (25%) of filter feeders (octocorals, sponges) and macroalgae (*Sargassum*). Total biotic cover 10%.
190	21 35.3697 S	115 11.7901 E	21 37.9798 S	115 07.1359 E	16:41-16:46 pm	6 m	Flat coarse white sand substrate, sparse bioturbation. Sporadic patches of conspicuous stands of macroalgae (*Sargassum*). Total biotic cover 10%.
192	21 35.3575 S	115 12.4044 E	21 35.3575 S	115 12.4044 E	16:33-16:37	4 m	Flat coarse white sand substrate, sparse bioturbation. Patchy low cover of sparse brown macroalgae and some seagrass (*H. ovalis & H. spinulosa*). Total biotic cover <1%.

Appendix B Dredge Plume Impact Assessment

Technical Memorandum

DATE:	02 August 2017	**REFERENCE:**	17WAU-0008/T1702024
TO:	Andrew Natta	**EMAIL:**	andrew.natta@omsb.com.au
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SUBJECT: **OMSB Project Stage 2 Capital Dredging: Dredge Plume Impact Assessment**

1. Introduction

1.1. Project Description

Onslow Marine Support Base Pty Ltd (OMSB) is planning to modify and extend the harbour approach channel, turning circle and berth pocket as part of Stage 2 of the Onslow Marine Support Base Project (herein the OMSB Project). The proposed capital dredging will enable offshore supply vessels to access the newly-constructed OMSB land-backed wharf infrastructure within the Beadon Creek Maritime Facility.

Capital dredging proposed includes a turning basin and channel to a declared depth of - 6.0 m CD and a berth pocket to -8.0m CD (**Figure 1**). The total volume of dredging is anticipated to be 930,000 cubic metres and it is expected that dredging will be undertaken using a medium-sized cutter suction dredge over a period of approximately eight (8) months. The current schedule has operations planned to commence in November 2017, subject to planning and approvals.

Dredge material is proposed to be disposed of onshore within surplus land owned freehold by the Shire of Ashburton (SoA) adjacent to the Onslow Airport (**Figure 1**). During dredging, the dredge spoil area will be dewatered to the intertidal flats between the disposal site and the western tributary of Beadon Creek.

1.2. Background

Historical capital and maintenance dredging has been undertaken within Beadon Creek since established as a harbour in 1964 (Oceanica 2015). Dredging for Stage 1 of the OMSB Project was recently completed in March 2017 which involved removal of ~55,000 m^3 of material from Beadon Creek with the material reclaimed to create the OMSB land-backed wharf in the previously undeveloped northern end of the Beadon Creek Maritime Facility. Previous surveys undertaken by Oceanica (2015) determined the substrate of Beadon Creek is entirely composed of bare sand with no BCH present.

Chevron Australia recently completed construction of the Wheatstone Project, a multi-train liquified natural gas (LNG) facility and domestic gas plant, located in the Ashburton North Strategic Industrial Area (ANSIA) approximately 14 km south-west of the Beadon Creek Maritime Facilities. Construction of the nearshore facilities involved dredging up to 45 million cubic metres (Mm^3) of material to develop key marine infrastructure to develop a Materials Offloading Facility (MOF) with an approach channel, turning circle, berth pocket and tug harbour area, a Product Loading Facility (PLF) with turning basins and berth pockets, and a 16 km approach channel. The Wheatstone Project was assessed through an Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) assessment process under the WA Environmental Protection Act (EP Act) and the Commonwealth Environmental Protection and Biodiversity Conservation Act 1999 (EPBC Act). Approvals were granted in August and September 2011, respectively.

Figure 1 OMSB Stage 2 project area, including proposed capital dredging area and spoil disposal location

1.3. Objectives

This technical memorandum presents the prediction of the extent, severity and duration of impacts to nearshore BCH associated with dredging activities within the outer channel for the OMSB Project. The impacts have been assessed in accordance with Technical Guidance for the Environmental Impact Assessment of Marine Dredging Proposals prepared by the Environmental Protection Authority (EPA 2016).

The impact assessment approach applies previously calibrated, validated and approved modelling outputs of the predicted plumes and sedimentation rates generated by dredging activities prepared for the Wheatstone Project by DHI (2010a, 2010b), and transfers those outputs to the proposed Beadon Creek harbour approach channel to develop an impact zonation scheme for the OMSB Project. The approach was considered appropriate due to similarities shared in the oceanographic conditions (i.e. waves, currents, water depths) and sediment properties (see O2 Marine 2017). For example, the OMSB Project and predicted impact zones occur within the modelled extent of the plumes from the Wheatstone Project.

A dredge plume impact assessment has been undertaken by O2 Marine to:

- Provide brief overview of the dredge spoil modelling methodology and inputs from the Wheatstone Project;
- Compare the selected dredge scenario from the Wheatstone Project with the proposed OMSB Project proposal to allow evaluation of the suitability of adopting the model outputs;
- Describe the methods used to establish the impact zonation scheme for the OMSB Project using model outputs from the Wheatstone Project;
- Present the impact zonation scheme proposed for the OMSB Project to inform predictions of the extent, intensity and persistence of dredge-generated sediment plumes, and the extent, severity and duration of resultant impacts on benthic habitats; and
- Provide a brief description of the dredge spoil modelling results and potential impact on benthic habitats

2. Methods

Detailed methods for the comprehensive dredge spoil modelling undertaken for the Wheatstone Project are provided in Appendix Q1 Dredge Spoil Modelling (DHI 2010a) and Appendix N2 Dredge Plume Impact Assessment (DHI 2010b) of the Draft EIS/ERMP. A summary of the dredge spoil modelling methods is provided below. For a more detailed review of dredge spoil modelling undertaken for the Wheatstone Project, copies of these documents are publicly available from https://www.chevronaustralia.com/our-businesses/wheatstone/environmental-approvals.

The strategy adopted for the Wheatstone Project dredge spoil modelling follows recommendations by the World Association for Waterborne Transport Infrastructure (PIANC) and involves modelling of the dredging program using combinations of short-term climatic scenarios, dredge scenarios and spill rates to ensure that the bounds of the range of plausible conditions are adequately assessed. Thus, the adopted scenario approach for the modelling of the transport and fate dredge sediment are sufficiently flexible to be adapted and used for the OMSB Project.

2.1. Modelling Tools

The Wheatstone Project dredge spoil modelling uses a Eulerian, coupled, sediment transport and two-dimensional depth averaged hydrodynamic model. The following suite of modelling tools were utilised:

- Hydrodynamic model (2D) – MIKE 21 HD
- Wave model – MIKE 21 SW
- Sediment transport model – MIKE 21 MT

A nested rectangular grid approach has been adopted involving four grids with resolutions of 3,645 m, 1,215 m, 405 m and 135 m. DHI (2010a) reviewed all available data available at the time of the model setup and calibration phases of the assessment and evaluated the suitability for the purposes of calibrating the model parameters and validating model outputs.

2.2. Characterisation of Sediments

The soil properties vary along the channel and for different depths, and corresponding variations in spill rates will therefore be experienced. The assumed particle size distributions for the material to be disposed in the model was based on analysis carried out on geotechnical samples taken within the Wheatstone dredge area showing the silt and clay fractions of the sandy material are highly variable. Silt fractions varied been 20% and 60% while the corresponding clay fractions in samples could range between 10% and 30%. The assumed particle size for the model indicates only 16% is coarser than 0.2 mm, indicating that more than 80% of the material on average will be mobilised based on Shield stability criterion. This criterion provides a simple estimate of a stable sediment grain size from the critical shield parameter formulation for initiation of movement of sand particles (DHI 2010a).

According to sediment sampling undertaken for the OMSB Project (O2 Marine 2017), **Table 1** presents there is generally a higher proportion of fines modelled (38%) than recorded within samples collected from the OMSB outer channel (max = 18%). The higher content of fines from the Wheatstone model were generally replaced by a higher content of sand and gravel fractions in samples collected to a depth of 1 m from the OMSB outer channel. These sand and gravel fractions were typically coarser than 0.2 mm, indicating these sediments are unlikely to be mobilised.

The proportion of silt/clay fractions in deeper sediment layers may vary and it is highly probable a higher content of fines may be found in deeper sediments. Analysis of eight geotechnical boreholes to -13 m CD depth collected from within Beadon Creek (CH2MHILL 2014). The engineering model identified three geological units to a depth of -6.0 m CD (i.e. proposed depths of the outer channel):

- Marine/Estuarine Deposits: Typically, loose dark grey or yellow brown silty sand/ gravelly silty sand/ sandy gravel or soft to firm low plasticity silty clay. The depth of these materials varied significantly ranging from -2.9 m to -6.9 m CD and typically between 2 m and 6.5 m thick.
- Tantabiddi Member: A layer of cap rock comprised of yellow/brown low to high strength calcarenite/limestone found along the southern end of the wharf line from a depth ranging from -1 m to -1.6 m CD up to 2.4 m thick.
- Upper Onslow Red Beds: Described as medium dense to dense, orange brown silt sand/ sandy silt with gravel of authigenic nodules of siltstone/ sandstone (cemented silt/ sand) or very stiff orange brown high plasticity silty clay with authigenic nodules of siltstone/ sandstone. The top of the horizon varies between a depth of -1 m to -4 m CD and is typically between 3 m to 6 m thick.

The particle size distribution of samples tested from the geotechnical survey of Beadon Creek indicates that an assumed 84% of material less than 0.2 mm provides a conservative estimate of the typical composition of sediment material to be dredged throughout the outer channel that is likely to be mobilised.

Table 1 Particle size comparison of modelled sediments from the Wheatstone Project (DHI 2010a) and sediments sampled from the OMSB Outer Channel (O2 Marine 2010) and from geotechnical boreholes from Beadon Creek (CH2MHILL 2014)

Size	Wheatstone Model	OMSB Outer Channel Surficial Samples (<-1.0 m)		Beadon Creek Geotechnical Boreholes (<-6.5 m)	
		Min	Max	Min	Max
Clay/Silt (<60 um)	38%	0%	18%	3%	71%
Sand (0.06-2 mm)	66%	65%	99%	9%	95%
Gravel (>2 mm)	0%	1%	25%	0%	39%

2.3. Climatic Selection

The OMSB Project area is exposed to dominant summer and winter conditions with wind-driven net currents that cause the sediment plumes to travel in predominant easterly and westerly directions, respectively. Therefore, numerous scenarios covering both representative and strong conditions were required to develop an envelope of possible impacts. These scenarios are presented in **Table 2**.

The Draft EIS/ERMP for the Wheatstone Project includes two full sets of dredge spoil modelling climatic scenarios, applying both the Onslow winds and MesoLAPS winds. Modelling demonstrated that the simulated wind and pressure maps of the MesoLAPS data provided the best wind representation during winter with off-shore directed winds that increase in strength when transiting from land to ocean. Measured winds from Onslow would tend to underestimate wind speeds over the ocean. The MesoLAPS wind fields, however, do not fully resolve the sea breezes which can be an important component in the near-shore area, particularly during the summer months. Wind measurements from Onslow provide a better direct resolution of the sea breezes. The MesoLAPS winds therefore tend to be slightly non-conservative for the near-shore area for summer conditions, while the Onslow winds tend to be slightly non-conservative for winter conditions. During the transitional period, the winds are generally weaker and more variable, which seems to be captured well by the MesoLAPS winds which better account for the spatial variability. To maintain consistency with the EIS/ERMP approach of adopting the most conservative of the two wind fields, model outputs using the MesoLAPS winds have been applied for the winter and transitional climatic scenarios, while the model outputs for Onslow wind has been applied for the summer climatic scenarios.

Table 2 Climatic scenarios used in dredge spoil modelling for the Wheatstone Project (DHI 2010a,2010b)

Condition Period	Period
Summer A	January 2007
Summer B	February 2007
Winter A	June 2007
Winter B	July 2007
Transitional A	April 2007
Transitional B	May 2007

2.4. Spill Rates

Typical measured spill rates based on the continuous cycle of 19 kg/s have been adopted for interpretation of the model outputs. These spill rates were produced by Lanier-Wallingford International using their Dredging Research dredger simulation models, which are designed to replicate the operations of the dredger type and site conditions for the proposed scenario described from the Wheatstone Project. These typical measured spill rates are defined for dredging of sandy sediment material (Section 2.2) using a large Cutter Suction Dredge (CSD) dredge equipment for the described dredging scenario in Section 2.5. The spill rates represent the median spill simulated in the dredger simulation model. The Wheatstone Project also presented model outputs for higher spill rates based on the continuous cycle of 34 kg/s, or the 90th percentile of spill rates, to represent the “worst-case” of the proposed dredge equipment. DHI (2010a, 2010b) considered it was overly conservative (i.e. unrealistic) to apply the worst-case rate constantly for the entire 14-day simulation period and the “realistic” spill rates were subsequently used to predict the potential impacts for the Project. The predicted “best case” and “worst-case” impact zonation scheme for the OMSB Project is therefore based on production rates of the CSD, which is described further in Section 2.10. Only the “realistic” case spill rate model outputs from DHI (2010a,2010b) were used to predict the suspended sediment plume and sedimentation generated by dredging activities for the OMSB Project.

2.5. Dredging Scenario

Dredging Scenario 1 modelled in DHI (2010a, 2010b) closely resembles the proposed dredging for Stage 2 of the OMSB Project, with the exception that the size of the dredge for the OMSB Project is smaller and therefore the provided results represent a very conservative "worst case" estimate of the predicted impacts (**Table 3**).

Dredging Scenario 1 was simulated to represent a large CSD (4,000 kW) operating in the nearshore area (~1 km offshore) to dredge an access channel to the temporary Materials Offloading Facility (MOF) of 75 m width to -6 m LAT. Dredging was required to provide temporary access for the barges to the MOF. The scenario included direct pumping to placement site A using a near bed diffuser. The production rates used in the model for the large CSD was 155,000 m^3/week in sand.

Capital dredging for the OMSP Project is planning to use a medium CSD (950-1300 kW) operating in the nearshore area (between ~0.4-2.0 km offshore) to dredge the proposed approach channel of 55 m width to a declared depth of - 6.0 m CD. As the dredged material for the OMSB Project will be pumped directly onshore, sediment plumes generated from disposal of the dredged material at placement site A has been omitted for the evaluation of the impact zonation scheme for the OMSB Project. The proposed dredge equipment will have weekly production rates of about 40-50,000 m^3 in sand.

Table 3 Comparison of the Wheatstone modelled scenario 1 and OMSB dredge channel

Details	Modelled Scenario 1 (Wheatstone)	OMSB Outer Channel 1
Dredge	Large CSD (4,000 kW)	Medium CSD (950-1300 kW)
Disposal	Hydraulic Pumping to Placement Site A	Hydraulic pumping to Onshore Disposal Site
Channel Depth	-6 m (LAT)	-6 m CD
Channel Width	75 m	55 m
Location	Nearshore (~1 km offshore)	Nearshore (~0.4-2.0 km offshore)
Production Rates	155,000 m^3/week	40-50,000 m^3/week

2.6. Impact Zonation Scheme

The impacts have been classified in accordance with the Technical Guidance for the Environmental Impact Assessment of Dredging Proposals (EPA 2016). This uses a spatially-based zonation scheme to describe the predicted extent, severity and duration of impacts associated with the OMSB Project. The scheme consists of three (3) zones that represent different levels of impact:

- **Zone of High Impact (ZoHI)** area where impacts on benthic communities or habitats are predicted to be 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).
- **Zone of Moderate Impact (ZoMI)** is the area within which predicted impacts on benthic organisms are recoverable within a period of five years following completion of the dredging activities.
- **Zone of Influence (ZoI)** is the area within which changes in environmental quality associated with dredge plumes are predicted and anticipated during the dredging operations, but where these changes would not result in a detectible impact on benthic biota.

2.7. Tolerance Limits

A detailed literature review of the turbidity and sedimentation concentrations which affect benthic communities and habitats was undertaken by DHI to develop tolerance limits for the Wheatstone Project (DHI 2010a). MScience (2009) also undertook a review of background water quality conditions of the project area, using a combined approach of field measurements and remote sensing using four years of MODIS optical satellite images. The conclusions of the reviews are summarised below.

The turbidity and sedimentation in the nearshore area (within the 5 m isobath) is relatively high and variable when compared to waters further offshore during summer and winter (typically 10-12 mg/L & 10 mg/cm^2/day) due to strong winds and wave action causing re-suspension in these shallow nearshore areas. The area also experiences occasional cyclones and heavy rainfall events during the summer period, as well as strong spring tide currents and strong wind and wave activity during both the summer and winter periods which cause elevated and variable turbidity (>100 mg/L) and sedimentation rates. Therefore, benthic habitat and communities present are exposed to periodic elevated turbidity and sedimentation levels, sometimes lasting for several weeks. The tolerance limits within the nearshore area during summer and winter has been established to consider elevated and variable background turbidity and sedimentation experienced in shallow nearshore areas during these periods. However, tolerance limits are based on above background suspended sediment concentrations (SSC) or rates of sedimentation generated by dredging which if benthic habitats and communities were exposed to for an extended period (several months) would likely result in the predicted levels of impact. The limits are based on the most sensitive species for coral and seagrass to ensure the levels of impact predicted are conservative.

The SSC and sedimentation tolerance limits for corals and seagrass are presented in **Table 4**. The limits are based on a concentration over a given proportion of time within the short-term scenario model outputs (14-day period to represent at least one full tidal cycle).

Table 4 Impact zones and tolerance limits for corals and seagrass during the transitional and summer/winter seasons applied to DHI modelling (DHI 2010b)

Zone	Transitional		Summer/Winter	
	Coral	Seagrass	Coral	Seagrass
Suspended Sediment				
ZoHI	>25 mg/L for >10%; or >10 mg/L for >25%.	>25 mg/L for >25%; or >10 mg/L for >50%.	>20 mg/L for >20%.	>20 mg/L for >50%.
ZoMI	>25 mg/L for 2.5-10%; or >10 mg/L for 10-25%; or >5 mg/L >25%.	>25 mg/L for 2.5-25%; or >10 mg/L for 10-50%; or >5 mg/L >25%.	>25 mg/L for 5-20%; or >10 mg/L for >20%; or >5 mg/L>50%.	>25 mg/L for 5-50%; or >10 mg/L for >20%.
ZoI	>25 mg/L for 0.5-2.5%; or >10 mg/L for 0.5-10%; or >5 mg/L 2.5-25%.	>25 mg/L for 0.5-2.5%; or >10 mg/L for 0.5-10%; or >5 mg/L 2.5-25%.	>25 mg/L for 1-5%; or >10 mg/L for 1-20%; or >5 mg/L 5-50%.	>25 mg/L for 1-5%; or >10 mg/L for 1-20%; or >5 mg/L >5%.
Sedimentation				
ZoHI	>0.2 kg/m^2/day	>0.7 kg/m^2/day	>0.5 kg/m^2/day	>1 kg/m^2/day
ZoMI	0.05-0.2 kg/m^2/day	0.2-0.7 kg/m^2/day	0.1-0.5 kg/m^2/day	>0.3-1 kg/m^2/day
ZoI	0.01-0.05 kg/m^2/day	0.03-0.2 kg/m^2/day	0.025-0.1 kg/m^2/day	>0.04-0.3 kg/m^2/day

2.8. Defining the Impact Zonation Scheme

DHI (2010a,2010b) evaluated each grid cell from the modelled area using an algorithm developed from the tolerance limits provided in **Table 4** to determine an impact classification for that cell. Impact classifications are shown in the modelling outputs as “Total Mortality”, “Partial Mortality” and “Zone of Influence”. These classifications correlate to the ZoHI, ZoMI and ZoI used for the impact zonation scheme, respectively. The highest level of impact is applied where multiple tolerance criteria were exceeded. The tolerance limits for suspended sediments and sedimentation, for both for corals and seagrass, were assessed and are presented separately. The dredge spoil suspended sediments and sedimentation “realistic case” model outputs for Dredge Scenario 1 for each seasonal scenario and for both corals and seagrass from DHI (2010a, 2010b) are presented in **Appendix C**.

These plume model results presented in **Appendix C** were imported into ArcGIS and boundaries were created around the SSC and sedimentation plumes which represent the areas for the ZoHI (i.e. total mortality), ZoMI (i.e. partial mortality) and ZoI (**Figure 1**). This process was repeated for both coral and seagrass modelling outputs for each season (summer, winter, transitional). The impact zonation scheme for Dredge Scenario 1 on the Wheatstone Project dredge area was prepared by overlaying the results from all the seasonal scenarios together, and using the highest impact zone out of each of the individual scenarios for each given location. Therefore, the outputs are intended to represent the maximum spatial extent for each of the zones. Plumes associated with the disposal activities at Placement Site A in the model simulation were excluded from the impact zonation scheme due to onshore disposal proposed for the OMSB Project.

This step provided four composite plots (i.e. SSC/sedimentation, coral/seagrass) presenting the impact zonation scheme for Dredge Scenario 1 (minus disposal at Placement Site A) operating nearshore in the Wheatstone Project area using a large CSD with production rates of 155,000 m^3/week.

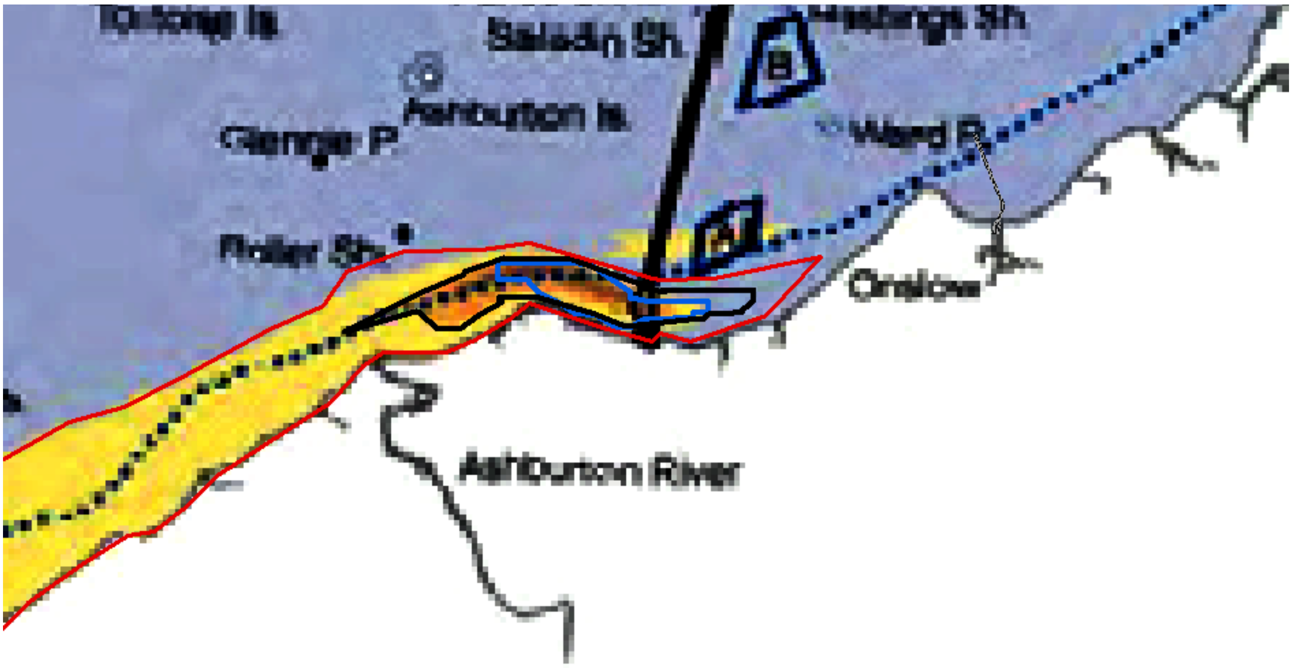


Figure 2 Example of tracing boundaries around the SSC plume model outputs from Dredge Scenario 1 (DHI 2010a, 2010b)

2.9. Transferring Results to OMSB Channel

The dredging source point of all four combined plots (i.e. coral/seagrass, SSC/sedimentation) was then repositioned (i.e. dragged) at the seaward extent of the proposed OMSB Project harbour approach channel approximately 2 km offshore (**Figure 3** and **Figure 4**). Given the model represents a dredge working in one location along the channel, the plots needed expanding to present the impact zonation scheme simulating the dredge scenario occurring along the entire channel. The maximum east/west point of each zone was extended to the to the shoreline using the north-north-west orientation of the OMSB Project approach channel. The coastline provided the southern boundary for each plot. The differences in the coastline between the Wheatstone Project area and OMSB Project area also had to be accounted for to create the northern boundary of each plot to allow for geographical features specific to the OMSB Project (i.e. Beadon Point). This was achieved by measuring the difference between the dredging source point and the northern boundary as well as the coastline to the dredge source point at multiple locations along the predicted zones.

This step provided four composite plots (i.e. SSC/sedimentation, coral/seagrass) presenting the impact zonation scheme for Dredge Scenario 1 (minus Placement Site A) operating throughout the proposed OMSB Project approach channel simultaneously using a large CSD with production rates of 155,000 m^3/week (i.e. Wheatstone Project dredge plant).

Figure 3 Example of final plume model output for all seasons

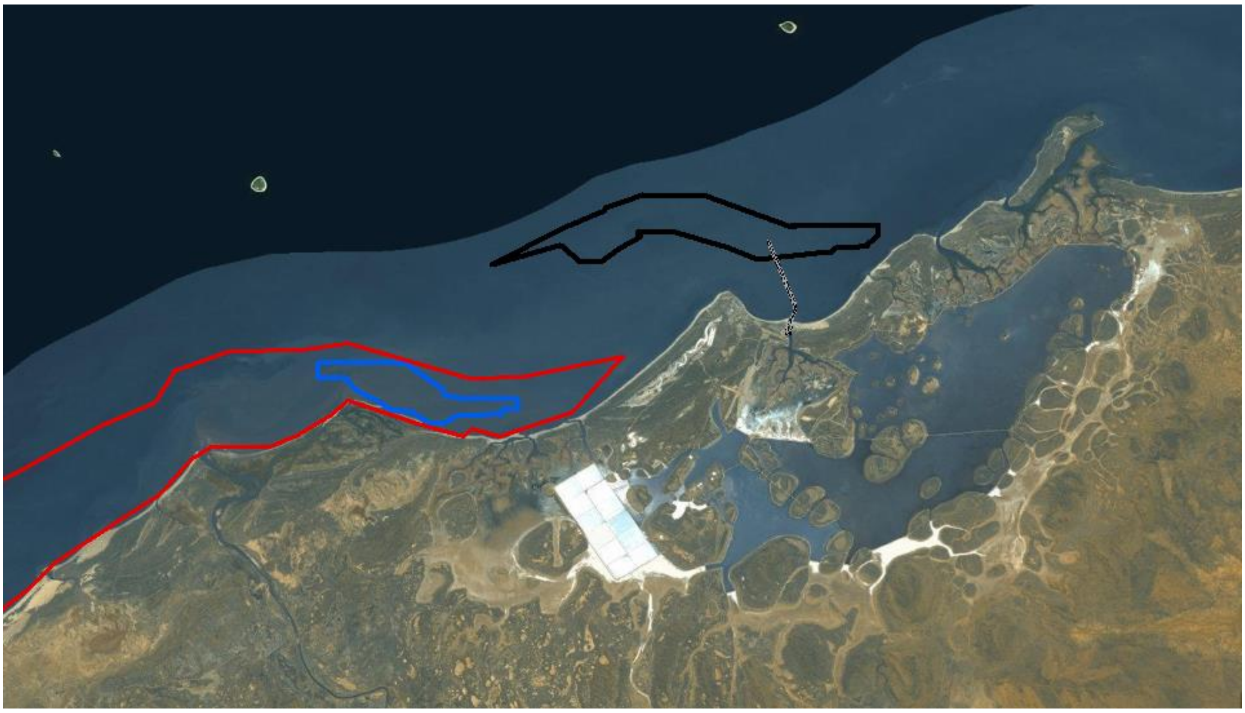


Figure 4 Example of repositioning the sediment plume

2.10. Best and Worst-case Scenarios

To develop “best case” and “worst-case” spatially based zonation schemes for the OMSB Project, it has been assumed that the spill rate generated from a cutter head is proportional to the rate of production (i.e. production is expressed as a percentage of the total amount of material dredged). The “best case” and “worst-case” estimates of the predicted impacts are based on one quarter and one third of the extent of suspended sediment concentrations and sedimentation plumes generated from the Wheatstone Project “realistic” dredge spoil modelling outputs, respectively. One quarter of the extent assumes a production rate of 38,750 m^3/week as the “best case”, and a production rate of 51,667 m^3/week is represented as the “worst-case”. These assumptions are made in the absence of cutter head specifications and operating parameters for either CSDs for each project, although dredging will be undertaken on similar sediment material and in similar ambient hydrodynamic conditions. However, there is always a level of uncertainty in estimating spill rates and production rates assumed from the type of dredging equipment used and the local sediment characteristics in dredge spoil modelling. Rationalisation of this approach as described in Mills and Kemps (2016) is explained further below.

CSDs use a rotating cutter head equipped with blades and teeth to break and excavate sediment. The blades guide the material into the cutter head where it is mixed with sea water and hydraulically removed through the suction line and centrifugal pumps. The source of sediment release is from the cutter head action (Mills & Kemps 2016). However, when the production capacity in the local sediment is known, this can be translated into a production to be cut by the cutter head. This cutter production is considerably higher than the dredged production because not all the material that has been cut enters the suction mouth. Typically, in the order of 20 to 30 percent of material cut by the cutter head is not drawn into the suction pipe in soft sediments (Dekker et al. 2003, Den Burger et al. 2005, Vlasblom 2005; Mills & Kemps 2016). When the material type, particle size distribution and settling characteristics of the sediment to be dredged is known, the primary factors controlling the amount of cut material that avoids the suction intake is the cutter head specifications and operating parameters (Lorenz & Henriksen 2010). Given these factors are almost always assumed in dredge spoil modelling, application of the proportional approach to the production rates to describe the lower and upper ends of the likely range of impacts, using an existing validated model which has been demonstrated to perform well during the Wheatstone Project, is considered to offer a similar or lower level of uncertainty than re-running simpler less complex and robust model (which would inevitably occur due to the scale of the proposal in comparison to the Wheatstone Project).

This step resulted in a total of eight composite plots:

- Four plots (i.e. SSC/sedimentation, coral/seagrass) presenting the “best case” impact zonation scheme is shown in **Appendix A**. These plots are based on a medium CSD operating throughout the proposed OMSB Project approach channel simultaneously at production rates of 38,750 m^3/week.
- Four plots (i.e. SSC/sedimentation, coral/seagrass) presenting the “worst-case” impact zonation scheme is shown in **Appendix B**. These plots are based on a medium CSD operating throughout the proposed OMSB Project approach channel simultaneously at production rates of 51,667 m^3/week.

3. Results and Discussion

3.1. DHI Dredge Spoil Modelling Results

The “realistic” DHI (2010a, 2010b) dredge spoil modelling plots for Dredge Scenario 1 for each climatic scenario are presented in **Appendix C**. These plots are provided for both the coral and seagrass tolerance limits simulated using a large CSD working in the Wheatstone Project area.

Results for the two summer climate scenarios are associated with plumes that extend eastward, driven by the predominantly easterly flow from the strong westerly sea breezes during this period. The two winter climate scenarios are generally associated with plumes that extend westward from easterly winds. The transitional periods are associated with plumes with a limited degree excursion away from the source region, so the zones are more centralised around the dredging area. These periods of relative “calm” are associated with elevated levels of localised sedimentation. This is because the introduced material experiences less dispersion under these ambient conditions, but may still be kept in suspension by relatively high tidal current velocities during spring tides. The results indicate the directional variability of the currents observed in the nearshore region which generally flows parallel to the shoreline with limited excursion of the plumes towards a northerly direction further offshore.

The CSD releases a relatively narrow plume of suspended sediments over an extended period (resulting in relatively high impacts within the narrow zone of the plume) that extends a considerable distance from the dredging location. However, it should be noted that elevated concentrations are known to occur naturally in these nearshore areas due to strong spring tide currents in combination with strong and persistent winds, which lead to resuspension of fine material in the shallow coastal waters east of the channel during summer and west during winter.

3.2. OMSB Project Impact Zonation Scheme

The maps presenting the spatially-based zonation schemes representing predicted dredging related impacts on BCH are presented in **Appendix A** and **Appendix B**. The predicted ZoHI is represented by the red boundary, orange represents the ZoMI and yellow represents the ZoI. The zonation schemes have been overlaid onto maps showing the distribution of relevant BCH derived from O2 Marine (2017). The likely range of the ZoHI and ZoMI boundaries in the dredge spoil model predictions are presented as the “best case” (**Appendix A**) and “worst case” (**Appendix B**) impact zonation schemes based on the production rates of the dredge. These production rates represent the lower (38,750 m^3/week) and upper (51,667 m^3/week) range that could reasonably be expected for a medium CSD dredging sand material. It is noted that weak rock that may be encountered in the nearshore area within the dredge footprint which may result in higher spillage (i.e. ~50%) from the cutter head (Mills & Kemps, 2016), although production rates for dredging this material would be significantly reduced (i.e. ~15% productivity of sand) and is generally considered to result in plumes well within the predicted boundaries.

Plots are presented to enable evaluation of the two primary ecological threats to BCH from dredge generated sediments:

- Suspended sediment concentration: Shading or increased light attenuation caused by sediments suspended in the water column, and
- Sedimentation: smothering of benthic habitats and organisms caused by the deposition of these sediments.

To assess the impacts of the proposed dredging program on the marine environment, the tolerance levels for both two key BCH types (corals and seagrass) were selected to derive impact zonation boundaries based on their sensitivity to dredging generated sediments. Therefore, four plots are presented for each “best case” (**Appendix A**) and “worst case” (**Appendix B**) impact zonation scheme in the following sequence:

1. Suspended sediment impact zones for coral.
2. Suspended sediment impact zones for seagrass.
3. Sedimentation impact zones for coral.
4. Sedimentation impact zones for seagrass.

The schedule for the proposed dredging activities will be subject to the time required to gain external approvals for the OMSB Project. Therefore, although the duration of dredging for the outer channel is only anticipated to last 13 weeks (3-4 months), the dredge spoil modelling has allowed flexibility for the dredging program to be undertaken during all seasons of the year. The maximum predicted spatial extent of the plumes from two representative historical climatic scenarios for the region within each season (summer, winter, transitional) were used to derive each impact zonation scheme plot. The plots depict the maximum extent of the plume for dredging operations undertaken throughout the year. As described in Section 3.1, the current patterns within the OMSB Project area are strongly seasonal with dominant easterly flows during summer, the stronger westerlies during winter, and the relatively equally weighted reduced strength east and west flows during the transitional period. Once the OMSB Project schedule for dredging activities has been confirmed, the impact zonation schemes may be refined to reflect the representative climatic conditions for the seasonal timing of the proposed dredging activities and will result in significantly reducing the spatial area of each zone.

Suspended Sediment Plumes

The “worst-case” suspended sediment plumes above background concentrations (i.e. the ZoI) are predicted to extend approximately 15 km east (beyond Coolgra Point) and 17 km west (Ashburton delta) from the OMSB Project approach channel. The broad plume extent is largely due to the conservative approach applied to the modelling omitting any consolidation effects of sediments and allowing particles to be re-suspend throughout the model area (DHI 2010a, 2010b). The “best case” ZoI boundary extent is reduced by approximately 3 km east and 4 km west, resulting in predicted “best case” predictions for above background concentrations at Coolgra Point and the Ashburton North Strategic Industrial Area. The difference in tolerance limits for corals and seagrass has little influence over the extent of the predicted ZoI between plots.

The predicted “worst-case” ZoMI extends approximately 3.5 km east and west beyond Second Creek and Beadon Point, respectively. The “best case” ZoMI boundary extent is reduced by approximately 1 km to the east and 0.8 km west. Distinct tolerance limits for corals and seagrass create slight discrepancy in the ZoMI boundaries, with coral zones extending slightly further west and seagrass zones extending slightly further east.

Tolerance limits for corals and seagrass also create discrepancies for the extent of the ZoHI. The predicted “worst-case” ZoHI for corals extends approximately 2 km east and west, whilst the seagrass ZoHI extends only about 1.2 km in either direction. The “best case” ZoHI for corals and seagrass extends approximately 1.5 km and 0.8 km either direction, respectively.

Sedimentation

The sedimentation impact zone schemes for corals are generally broader than seagrass due to more conservative tolerance limits and greater sensitivity to sediment deposition. The “worst-case” sedimentation plumes above background concentrations (i.e. the ZoI) for corals are predicted to extend approximately 5.5 km east near 3rd Creek and 1 km west from the OMSB Project approach channel. The “best case” ZoI extends 3.7 km east and 0.5 km west. Comparably, the “worst-case” ZoI for seagrass extends 3 km east and 0.5 km west, whilst the “best case” extends 2 km east and <0.3 km west.

The extent of the ZoMI and ZoHI for both coral and seagrass is limited to the area immediately adjacent to the west of the OMSB outer channel. However, the zones extend further east. The “worst-case” ZoMI for corals and seagrass extends 3 km and 1.3 km east, respectively. The “worst-case” ZoHI for corals and seagrass extends 2 km and 1 km east, respectively. The best-case zones are more conservative and generally limited in predicted extent.

3.3. Impact on Benthic Habitats and Communities

Visualisation of the estimated impact on benthic habitat and communities within each zone based on the processed modelling results is presented for the ‘best case’ and ‘worst-case’ spill rates in **Appendix A** and **Appendix B**, respectively.

It should be noted that the model outputs represent the total distribution of seasonal effects, with sediment plumes tracking easterly during summer, westerly during winter and are typically more localised and uniformly spread during transitional periods. This is a conservative approach providing flexibility in planning dredging activity and provision for delays to the schedule. The proposed dredging activities of the outer channel will be undertaken over a period of approximately 13 weeks.

The benthic habitat and communities which occur within the OMSB Project area are described and mapped in O2 Marine (2017). While the ZoI overlaps extensive coral and seagrass areas, the definition of this zone is that it is not predicted to result in any material and/or measurable effect. The conservative approach taken by not including any consolidation of the dredged material for these short-term scenarios has resulted in fine dredged material repeatedly settling and then being re-suspended and carried further and further from the dredging area in the model due to the strong spring tide currents and strong and persistent wind conditions, particularly during summer and winter. Cohesive forces occur relatively rapidly, and can take place between the spring tides which tend to re-suspend the material. This consolidation would reduce the amount of re-suspension that would occur, compared to what is predicted in the model, and would therefore be expected to reduce the spatial extent of above background concentrations. The benthic communities and habitat within the ZoI are commonly exposed to periodic elevated turbidity throughout the year, particularly during summer due to strong tides and persistent south-westerly winds causing re-suspension and transport of fine seabed material in the nearshore area.

The “best case” and “worst-case” ZoHI and ZoMI for SSC plumes generated from proposed dredging activities are predominantly located over benthic habitat presented in the seagrass plots described as ‘Moderate cover of seagrass/macroalgae/filter feeders’, which occur nearshore between Sunset Beach (i.e. Onslow back beach) and Third Creek (**Appendix A** and **Appendix B**). These plumes also cover a small nearshore area to the west of the OMSB channel mapped as ‘Low cover macroalgae and filter feeder’ habitat (**Appendix A** and **Appendix B**). No areas mapped as coral habitat occur within the ZoHI or ZoMI for “best-case” or “worst-case” model outputs. The impact zones for sedimentation impacts on corals and seagrass are more localised than for SSC.

The predicted area in hectares and proportion of BCH types that occur in each nearshore Loss Assessment Unit (LAU) for the predicted “best case” and “worst case” SSC and sedimentation model outputs for the OMSB Project are presented in **Table 5**. No coral habitats are predicted to occur within the zones of impact. The zones of impact are limited to two Loss Assessment Units: LAU 1C and LAU 1G. The Seagrass/Macroalgae/Filter Feeder in LAU 1G comprises the largest area of BCH within the zones of impact for all model outputs. The sedimentation model outputs predict only the Seagrass/Macroalgae/Filter Feeder BCH in LAU 1G occurs within the zones of impact. The predicted areas occurring within the impact zones for BCH from both SSC and sedimentation models is marginally lower for the “best case” compared to the “worst case” model outputs in LAU 1G. However, areas of BCH occurring within the impact zones in LAU 1C from “best case” model outputs are notably lower than “worst case”. The proportion of BCH predicted to be impacted for all results remains less than 10% of that habitat within either LAU 1G or LAU 1C.

Table 5 The area in hectares and proportion of BCH types that occur in each nearshore Loss Assessment Unit for the predicted "best case" and "worst case" SSC and sedimentation model outputs

LAU	BCH	Original Extent (ha)	ZoMI				ZoHI			
			Best Case		Worst Case		Best Case		Worst Case	
			(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)	(%)
Suspended Sediment Concentration (SSC)										
LAU 1C	Seagrass, Macroalgae, Filter Feeder	6,000 ha	157 ha	2.6%	236 ha	3.9%	5 ha	0.1%	18.5 ha	0.3%
	Macroalgae, Filter Feeder	3,240 ha	46 ha	1.4%	102 ha	3.2%	-	-	-	-
LAU 1G	Seagrass, Macroalgae, Filter Feeder	10,228 ha	838 ha	8.2%	975 ha	9.5%	391 ha	3.8%	459 ha	4.5%
	Macroalgae, Filter Feeder	1,309 ha	109 ha	8.3%	71 ha	5.4%	58 ha	4.4%	96 ha	7.3%
Sedimentation										
LAU 1G	Seagrass, Macroalgae, Filter Feeder	10,228 ha	192 ha	1.9%	220 ha	2.2%	122 ha	1.2%	168 ha	1.6%

4. References

DHI (2010a). *Wheatstone Project Dredge Spoil Modelling*. Draft Environmental Impact Statement/ Environmental Review and Management Programme for the Proposed Wheatstone Project. Appendix Q1

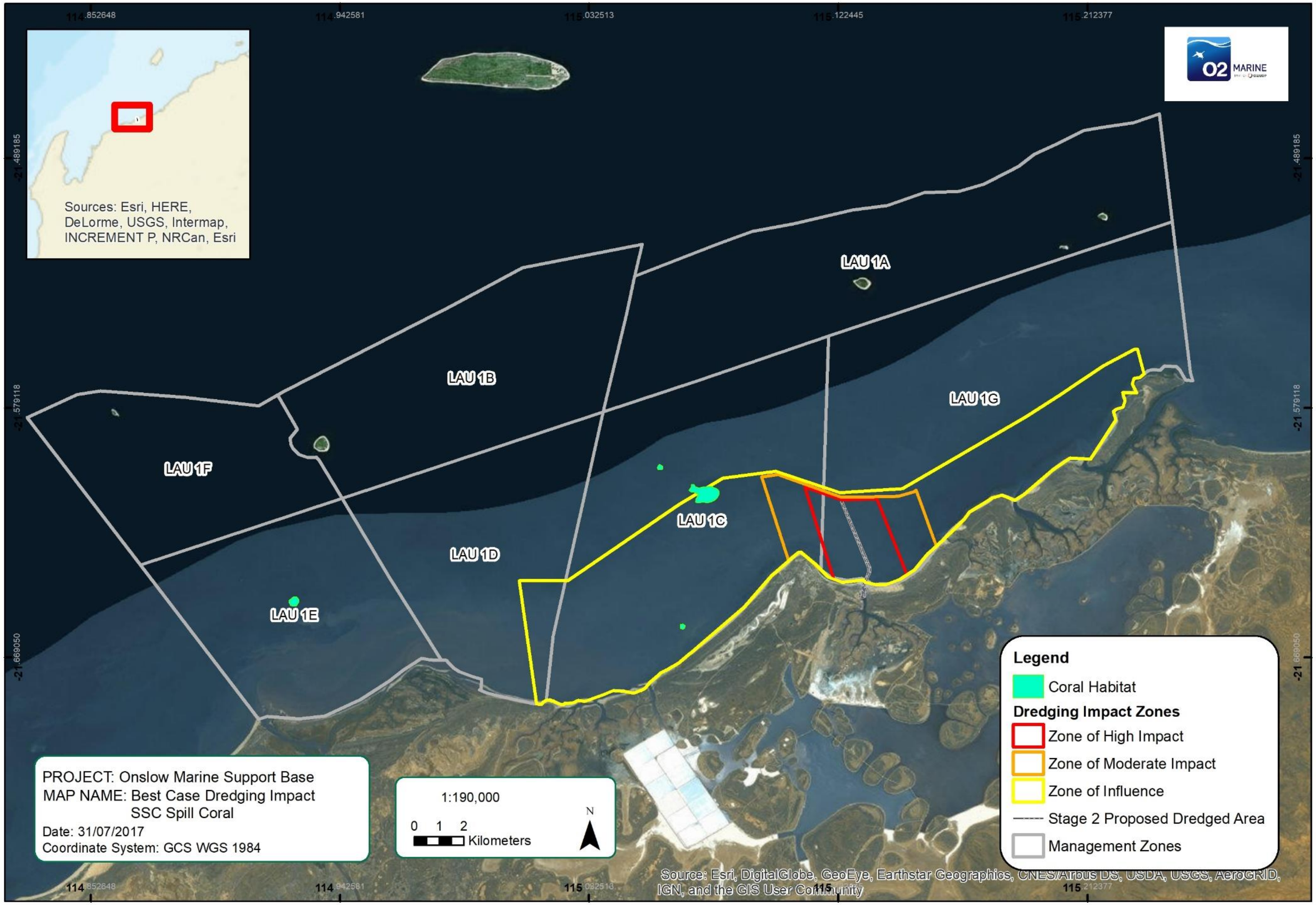
DHI (2010b). Wheatstone Project Dredge Plume Impact Assessment. Draft Environmental Impact Statement/ Environmental Review and Management Programme for the Proposed Wheatstone Project. Appendix N2

Mills, D., Kemps, H. (2016). Generation and release of sediments by hydraulic dredging: a review. Report of Theme 2 - Project 2.1 prepared for the Dredging Science Node, Western Australian Marine Science Institution, Perth, Western Australia. 97 pp.

O2 Marine (2017a). Onslow Marine Support Base Stage 2 Capital Dredging: Ecological Site Investigation. Report prepared for OMSB Pty Ltd: No. 1702005

O2 Marine (2017b). Onslow Marine Support Base Stage 2 Capital Dredging: Ecological Site Investigation. Report prepared for OMSB Pty Ltd: No. 1702005

Appendix A Realistic Case Dredge Plume Predictions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115.122445
115.212377
-21.489185
-21.579118
-21.669050
Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri
O2 MARINE
LAU 1A
LAU 1B
LAU 1F
LAU 1G
LAU 1C
LAU 1D
LAU 1E
Legend
Coral Habitat
Dredging Impact Zones
Zone of High Impact
Zone of Moderate Impact
Zone of Influence
Stage 2 Proposed Dredged Area
Management Zones
PROJECT: Onslow Marine Support Base
MAP NAME: Best Case Dredging Impact SSC Spill Coral
Date: 31/07/2017
Coordinate System: GCS WGS 1984
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Kilometers
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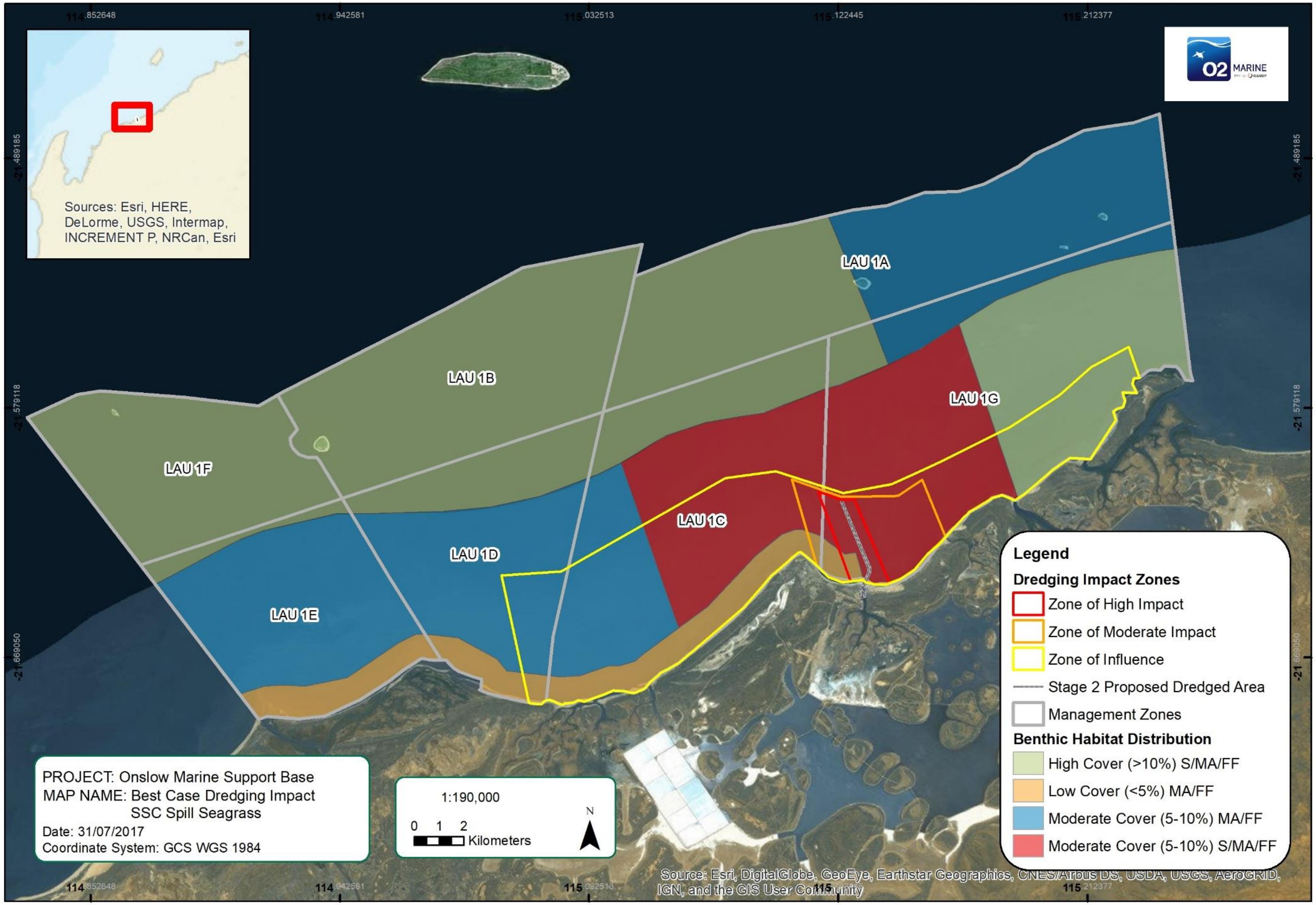
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community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O2 MARINE
LAU 1A
LAU 1B
LAU 1G
LAU 1F
LAU 1C
LAU 1D
LAU 1E
Legend
Dredging Impact Zones
Zone of High Impact
Zone of Moderate Impact
Zone of Influence
Stage 2 Proposed Dredged Area
Management Zones
Benthic Habitat Distribution
High Cover (>10%) S/MA/FF
Low Cover (<5%) MA/FF
Moderate Cover (5-10%) MA/FF
Moderate Cover (5-10%) S/MA/FF
PROJECT: Onslow Marine Support Base
MAP NAME: Best Case Dredging Impact SSC Spill Seagrass
Date: 31/07/2017
Coordinate System: GCS WGS 1984
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Kilometers
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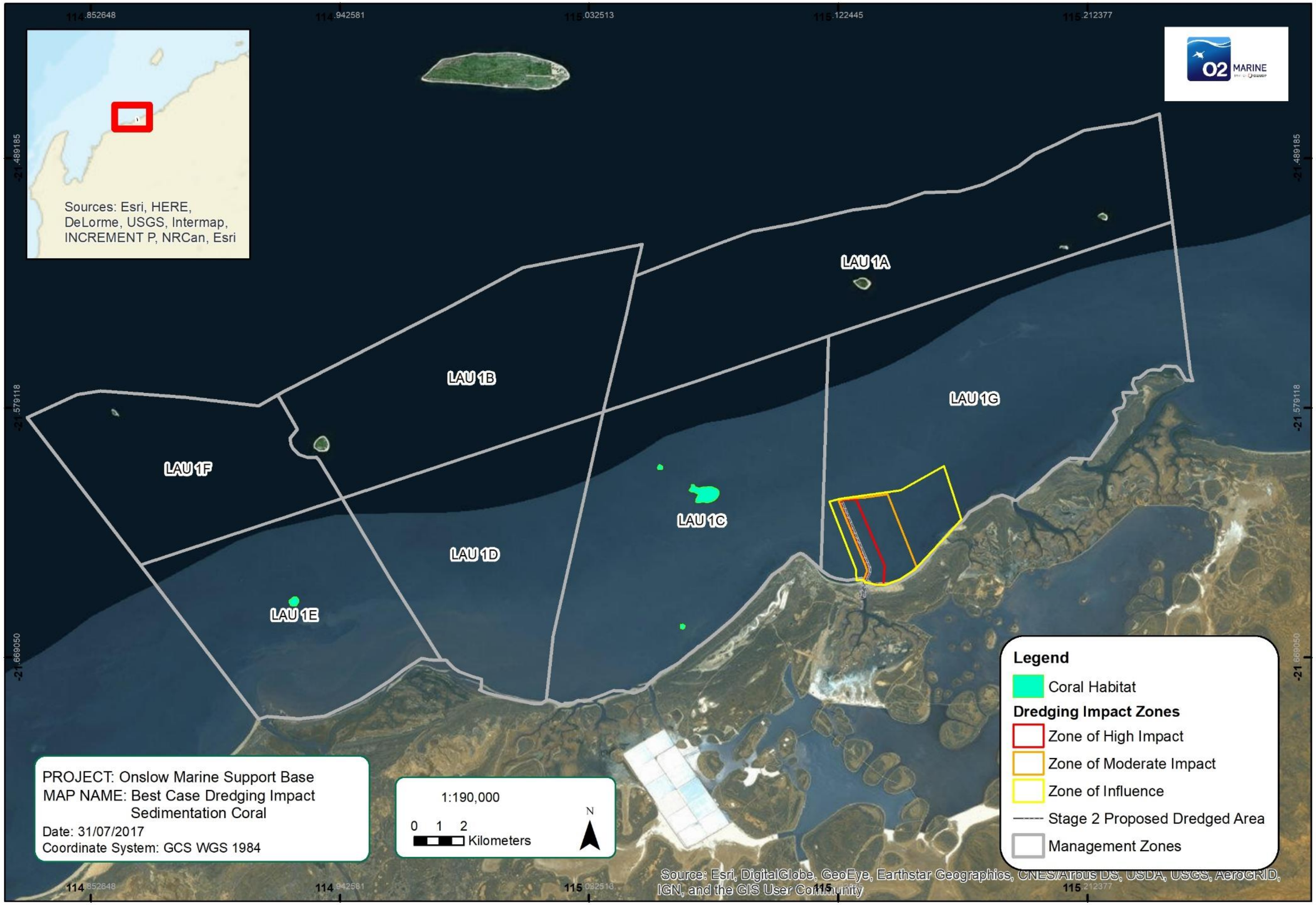
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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Zone of High Impact
Zone of Moderate Impact
Zone of Influence
Stage 2 Proposed Dredged Area
Management Zones
PROJECT: Onslow Marine Support Base
MAP NAME: Best Case Dredging Impact Sedimentation Coral
Date: 31/07/2017
Coordinate System: GCS WGS 1984
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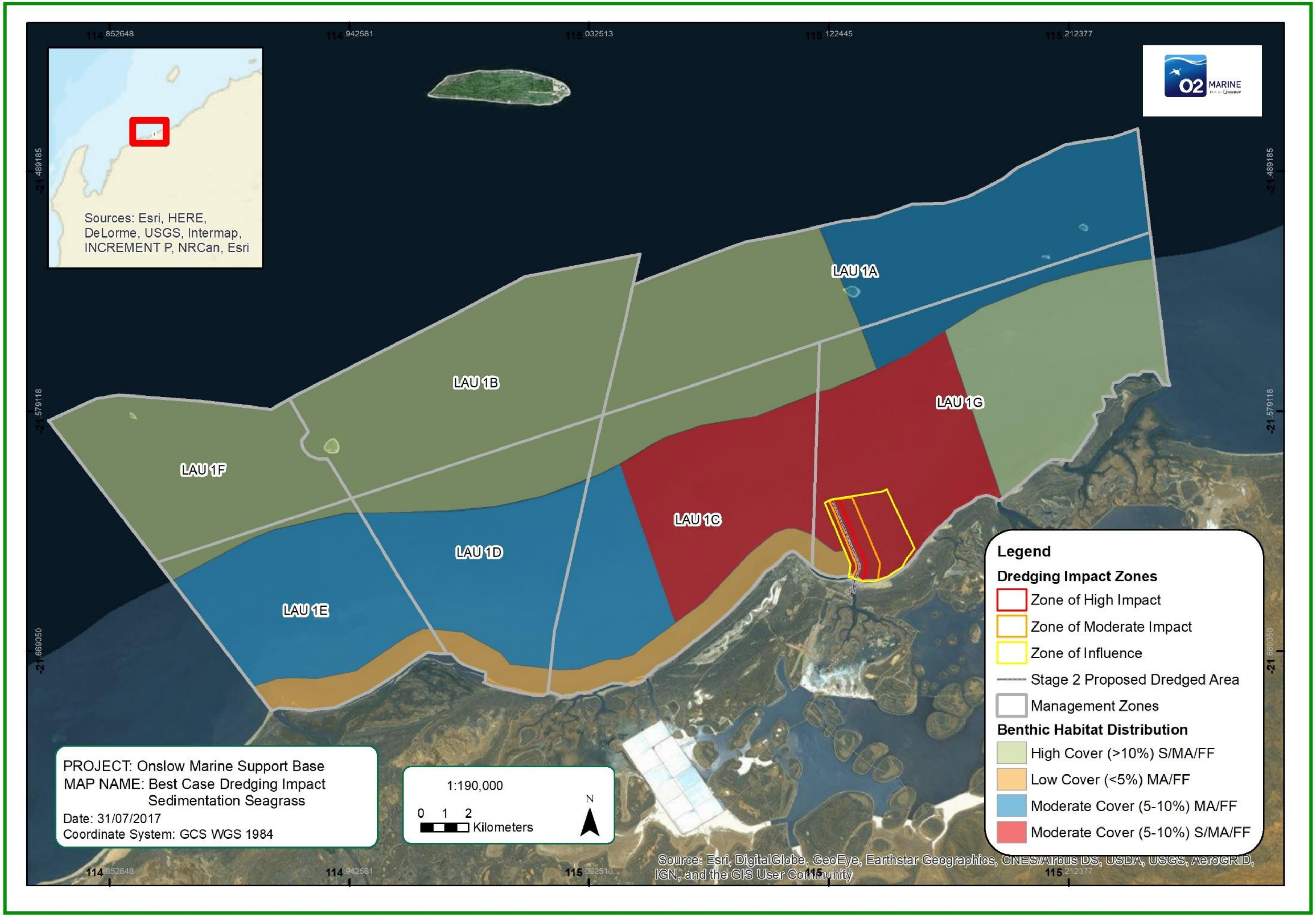
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



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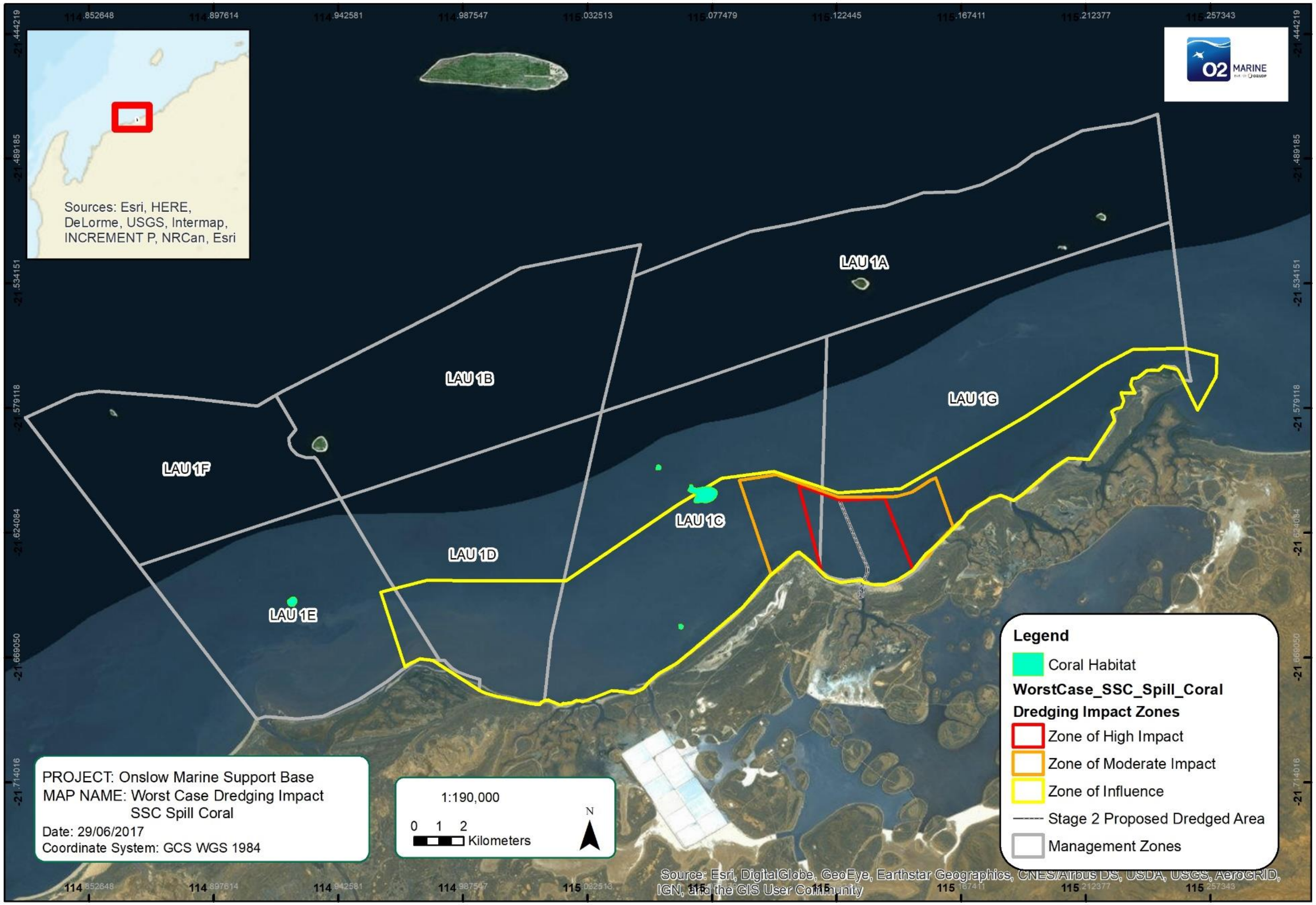
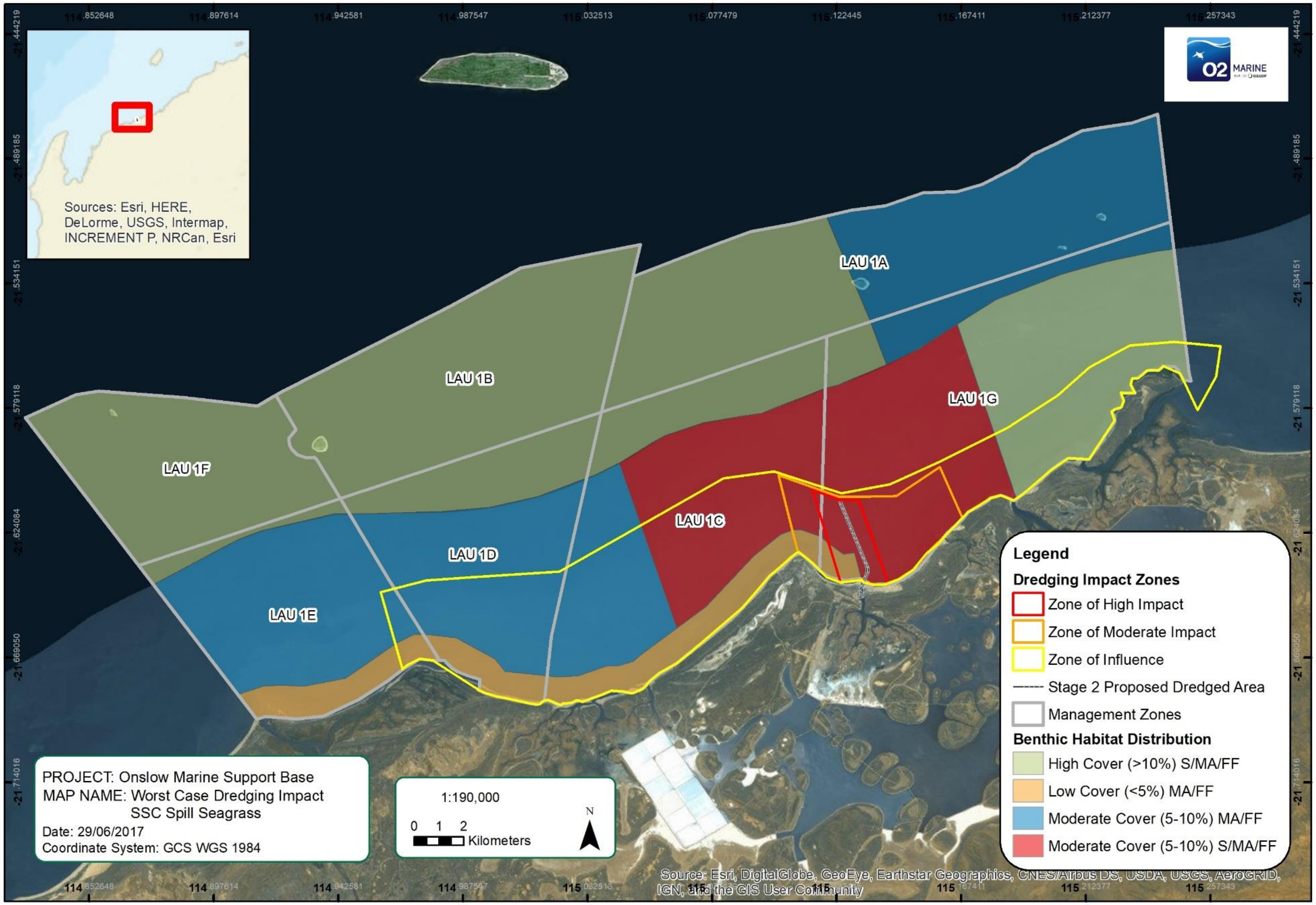
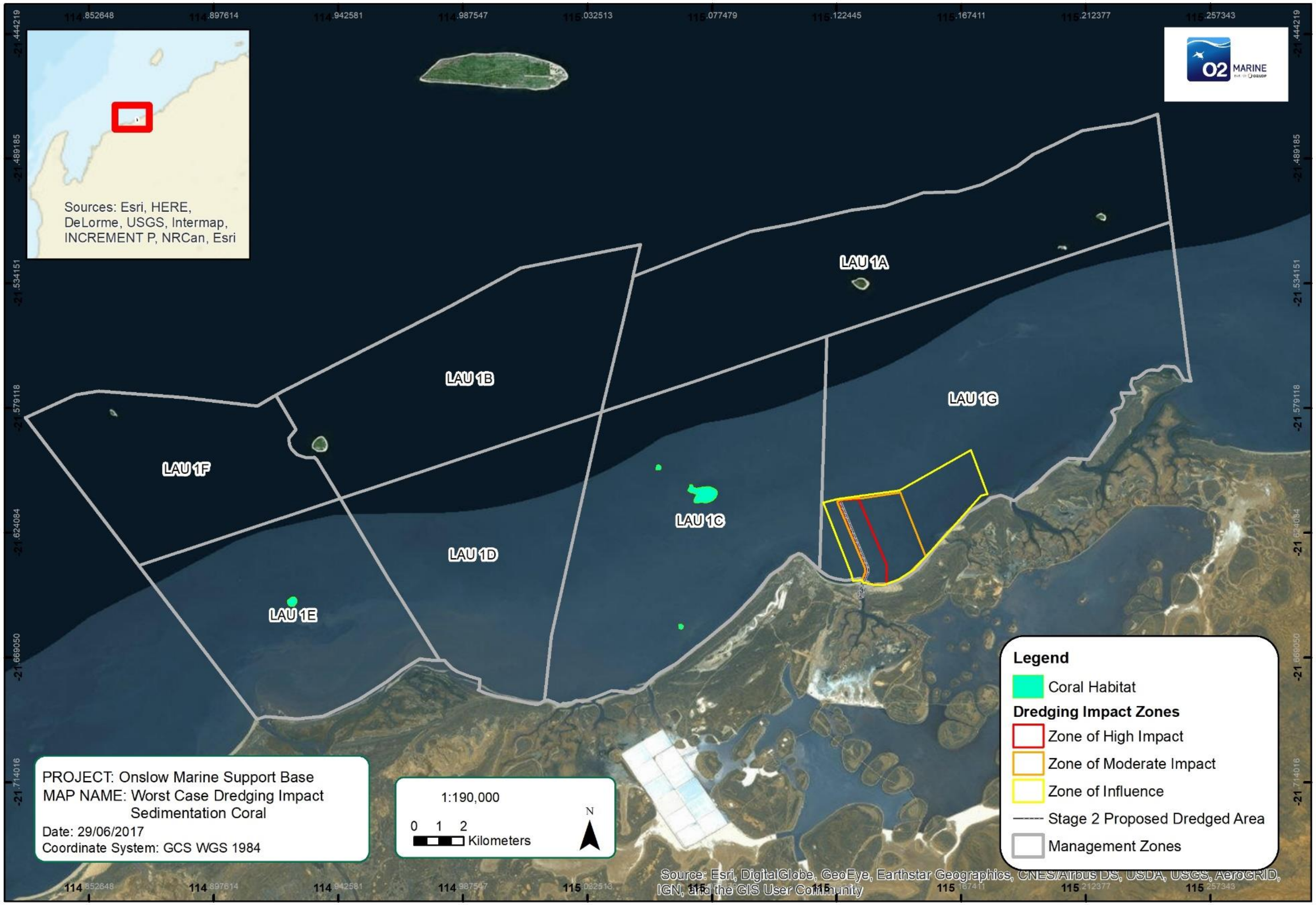
Dredging Impact Zones
Zone of High Impact
Zone of Moderate Impact
Zone of Influence
Stage 2 Proposed Dredged Area
Management Zones
Benthic Habitat Distribution
High Cover (>10%) S/MA/FF
Low Cover (<5%) MA/FF
Moderate Cover (5-10%) MA/FF
Moderate Cover (5-10%) S/MA/FF
PROJECT: Onslow Marine Support Base
MAP NAME: Best Case Dredging Impact Sedimentation Seagrass
Date: 31/07/2017
Coordinate System: GCS WGS 1984
1:190,000
0 1 2
Kilometers
N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

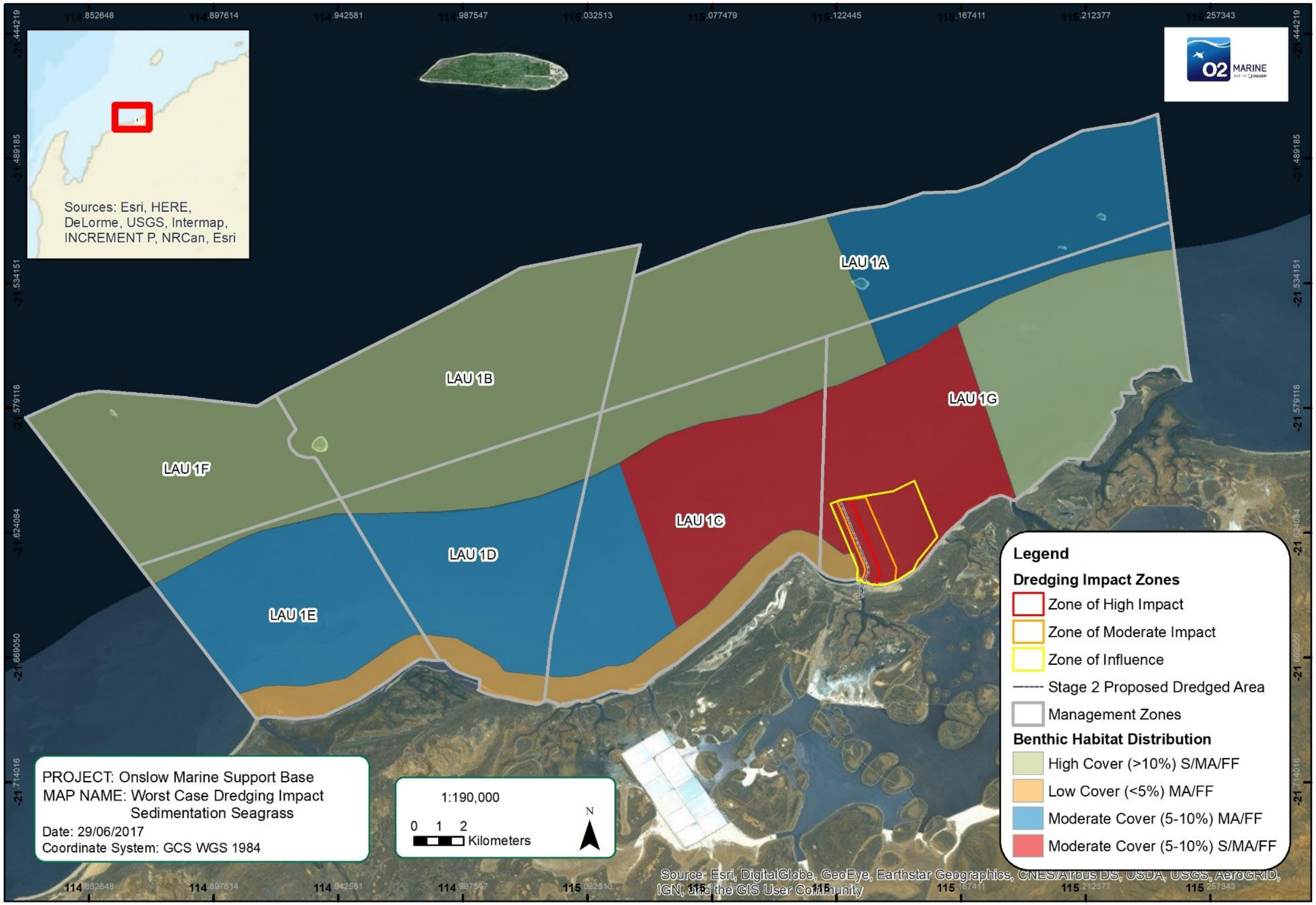
Appendix B Worst Case Dredge Plume Predictions



Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri
O2 MARINE
LAU 1A
LAU 1B
LAU 1C
LAU 1D
LAU 1E
LAU 1F
LAU 1G
Legend
Coral Habitat
WorstCase_SSC_Spill_Coral
Dredging Impact Zones
Zone of High Impact
Zone of Moderate Impact
Zone of Influence
Stage 2 Proposed Dredged Area
Management Zones
PROJECT: Onslow Marine Support Base
MAP NAME: Worst Case Dredging Impact SSC Spill Coral
Date: 29/06/2017
Coordinate System: GCS WGS 1984
1:190,000
0 1 2
Kilometers
N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri
LAU 1A
LAU 1B
LAU 1C
LAU 1D
LAU 1E
LAU 1F
LAU 1G
Legend
Dredging Impact Zones
Zone of High Impact
Zone of Moderate Impact
Zone of Influence
Stage 2 Proposed Dredged Area
Management Zones
Benthic Habitat Distribution
High Cover (>10%) S/MA/FF
Low Cover (<5%) MA/FF
Moderate Cover (5-10%) MA/FF
Moderate Cover (5-10%) S/MA/FF
PROJECT: Onslow Marine Support Base
MAP NAME: Worst Case Dredging Impact SSC Spill Seagrass
Date: 29/06/2017
Coordinate System: GCS WGS 1984
1:190,000
0 1 2
Kilometers
N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community


LAU 1A
LAU 1B
LAU 1C
LAU 1D
LAU 1E
LAU 1F
LAU 1G
O2 MARINE
Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri
PROJECT: Onslow Marine Support Base
MAP NAME: Worst Case Dredging Impact Sedimentation Coral
Date: 29/06/2017
Coordinate System: GCS WGS 1984
1:190,000
0 1 2
Kilometers
N
Legend
Coral Habitat
Dredging Impact Zones
Zone of High Impact
Zone of Moderate Impact
Zone of Influence
Stage 2 Proposed Dredged Area
Management Zones
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community



Sources: Esri, HERE, DeLorme, USGS, Intermap, INCREMENT P, NRCan, Esri
O2 MARINE
LAU 1A
LAU 1B
LAU 1C
LAU 1D
LAU 1E
LAU 1F
LAU 1G
Legend
Dredging Impact Zones
Zone of High Impact
Zone of Moderate Impact
Zone of Influence
Stage 2 Proposed Dredged Area
Management Zones
Benthic Habitat Distribution
High Cover (>10%) S/MA/FF
Low Cover (<5%) MA/FF
Moderate Cover (5-10%) MA/FF
Moderate Cover (5-10%) S/MA/FF
PROJECT: Onslow Marine Support Base
MAP NAME: Worst Case Dredging Impact Sedimentation Seagrass
Date: 29/06/2017
Coordinate System: GCS WGS 1984
1:190,000
0 1 2 Kilometers
N
Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AeroGRID, IGN, and the GIS User Community

Appendix C Wheatstone Project Model Outputs Dredge Scenario 1 (DHI 2010a, 2010b)

B.1 Dredging Scenario 1

B.1.1 Summer-A, Realistic Spill Scenario

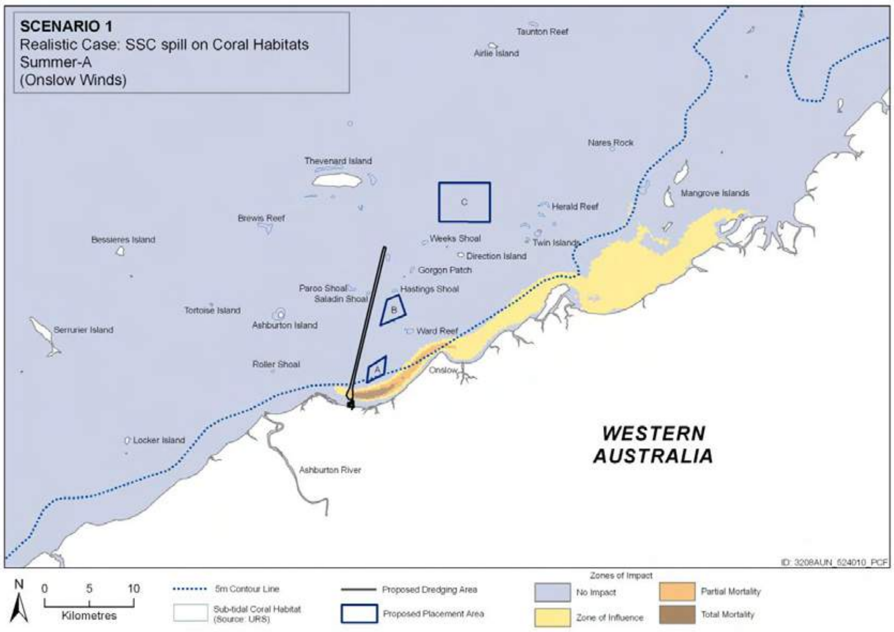


Figure B.1 Scenario 1, Summer-A, Realistic: SSC Zones of Impact for Corals during Summer Conditions with Realistic Spill based on Onslow winds

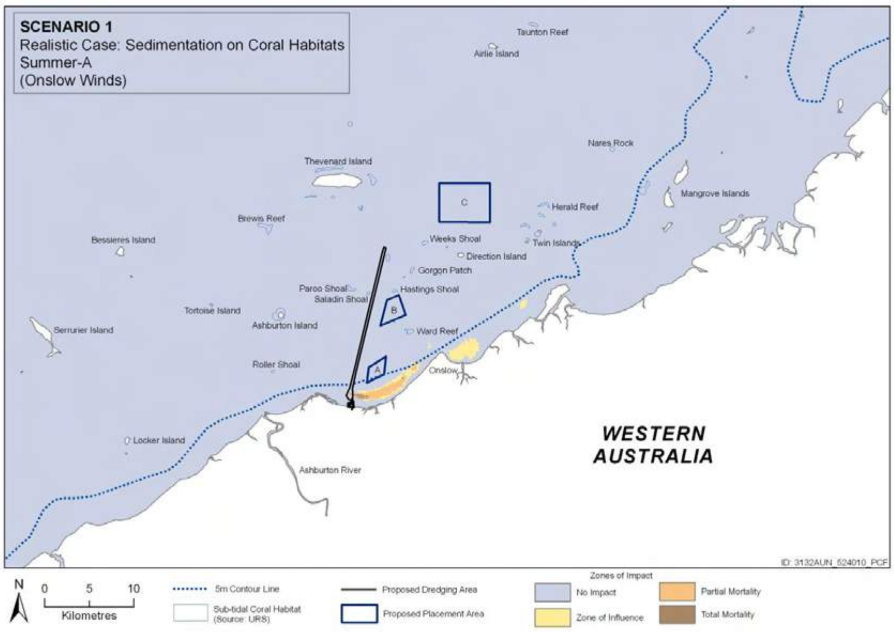


Figure B.2 Scenario 1, Summer-A, Realistic: Sedimentation Zones of Impact for Corals, during Summer Conditions with Realistic Spill based on Onslow winds

B-3

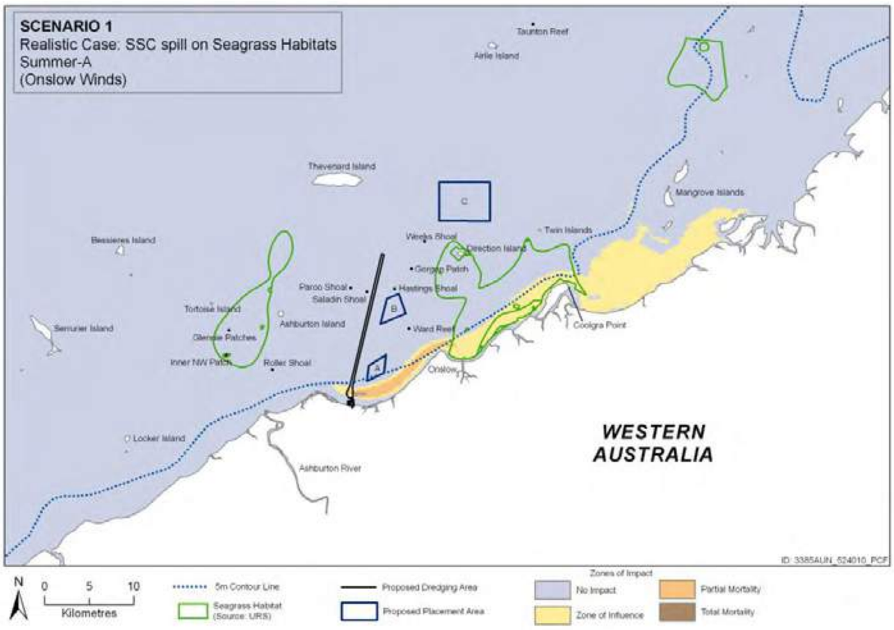


Figure B.3 *Scenario 1, Summer-A, Realistic: SSC Zones of Impact for Seagrass during Summer Conditions with Realistic Spill based on Onslow winds*

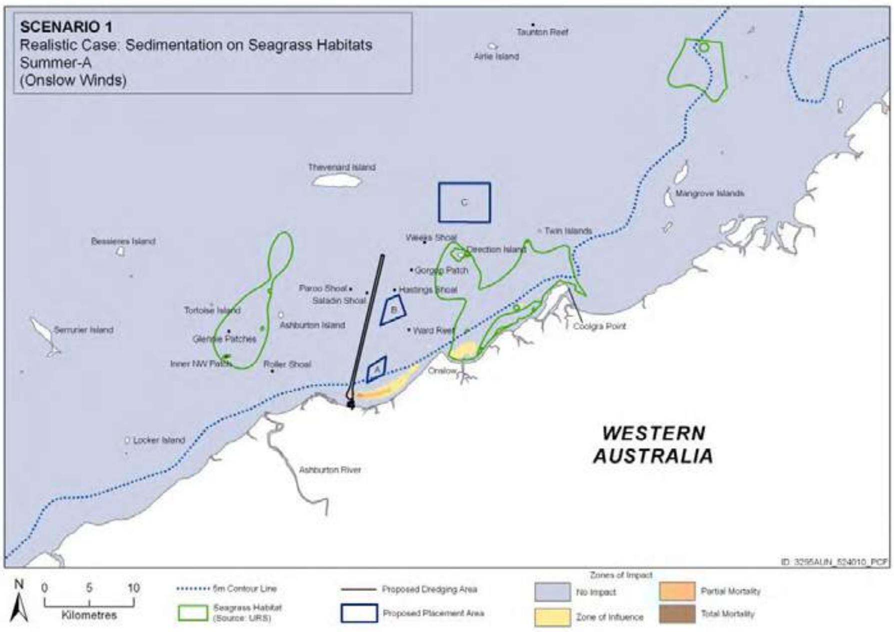


Figure B.4 *Scenario 1, Summer-A, Realistic: Sedimentation Zones of Impact for Seagrass during Summer Conditions with Realistic Spill based on Onslow winds*

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B.1.2 Summer-B, Realistic Spill Scenario

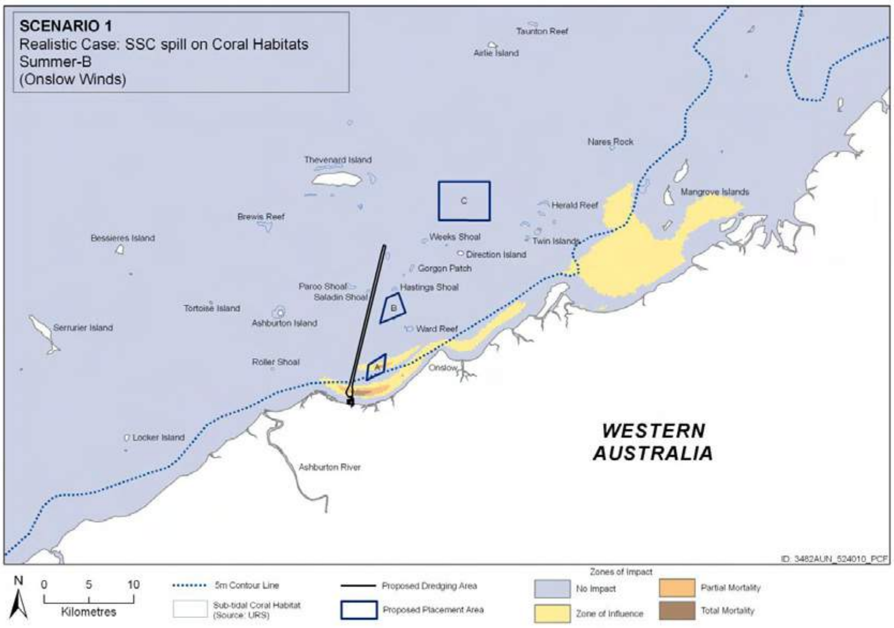

Figure B.5 Scenario 1, Summer-B, Realistic: SSC Zones of Impact for Corals during Summer Conditions with Realistic Spill based on Onslow winds

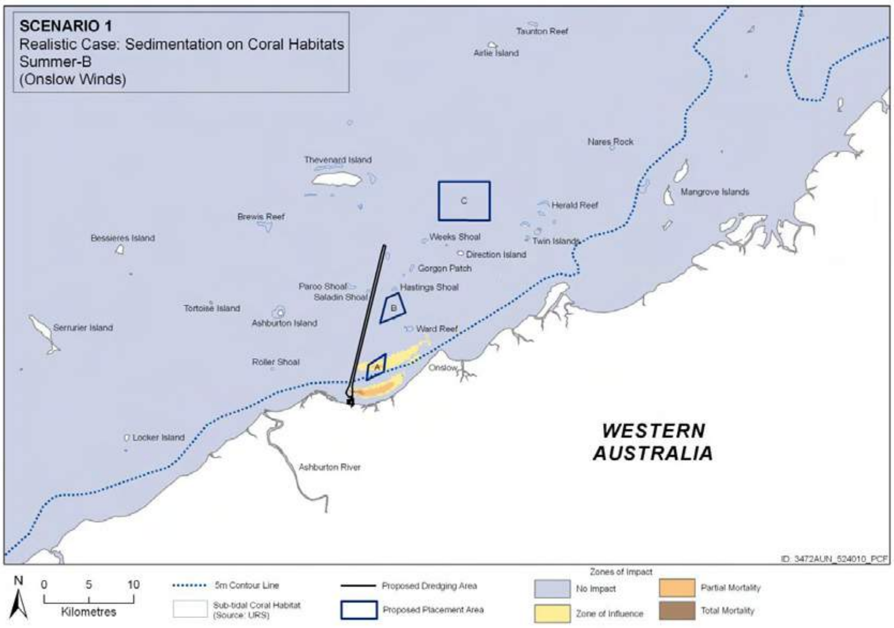

Figure B.6 Scenario 1, Summer-B, Realistic: Sedimentation Zones of Impact for Corals, during Summer Conditions with Realistic Spill based on Onslow winds

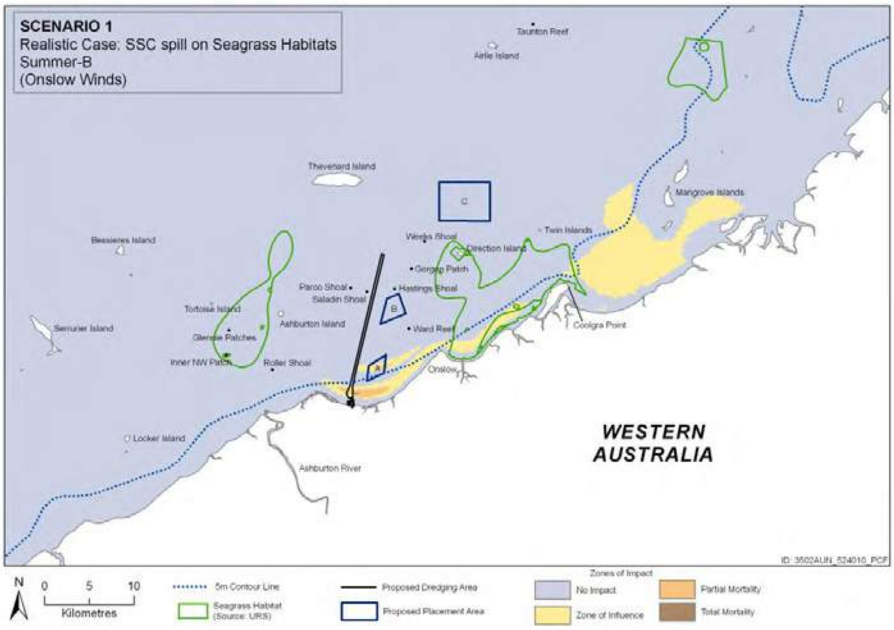

Figure B.7 *Scenario 1, Summer-B, Realistic: SSC Zones of Impact for Seagrass during Summer Conditions with Realistic Spill based on Onslow winds*

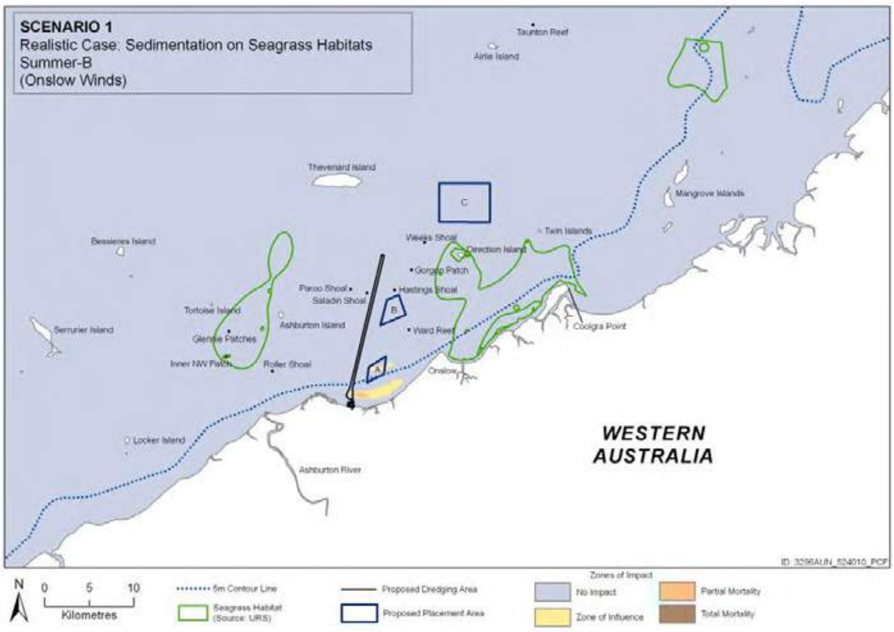

Figure B.8 *Scenario 1, Summer-B, Realistic: Sedimentation Zones of Impact for Seagrass during Summer Conditions with Realistic Spill based on Onslow winds*

A.1.3 Winter-A, Realistic Spill Scenario

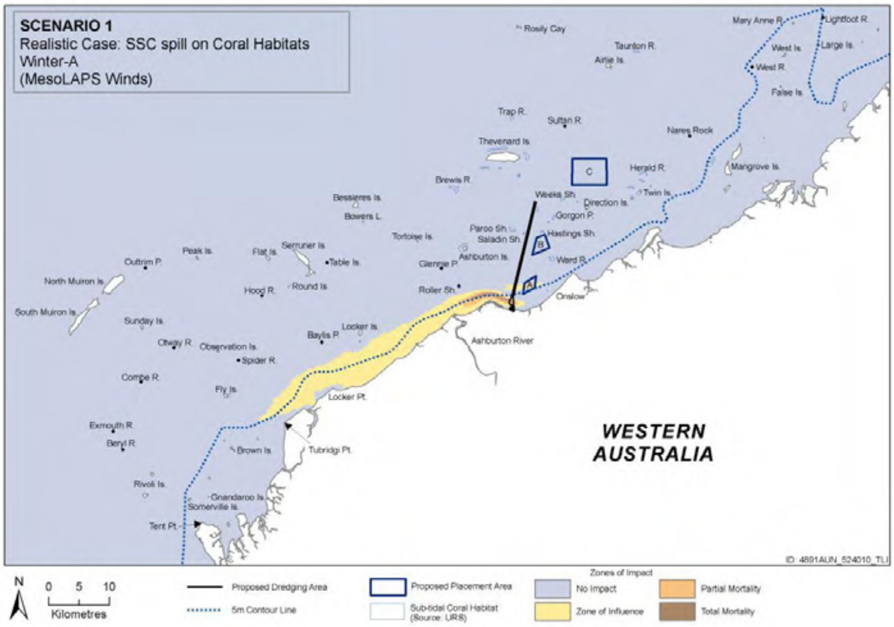

Figure A.9 Scenario 1, Winter-A, Realistic: SSC Zones of Impact for Corals during Winter Conditions with Realistic Spill based on MesoLAPS winds

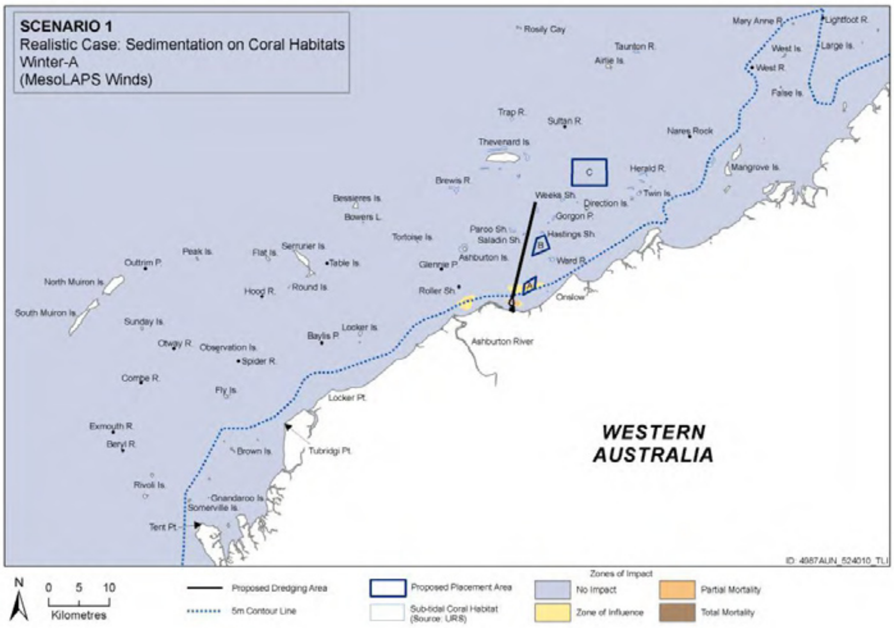

Figure A.10 Scenario 1, Winter-A, Realistic: Sedimentation Zones of Impact for Corals, during Winter Conditions with Realistic Spill based on MesoLAPS winds

SG5240-06/Chevron Wheatstone Dredge Plume Impact Assessment/Final/mjj/05-10

A-9

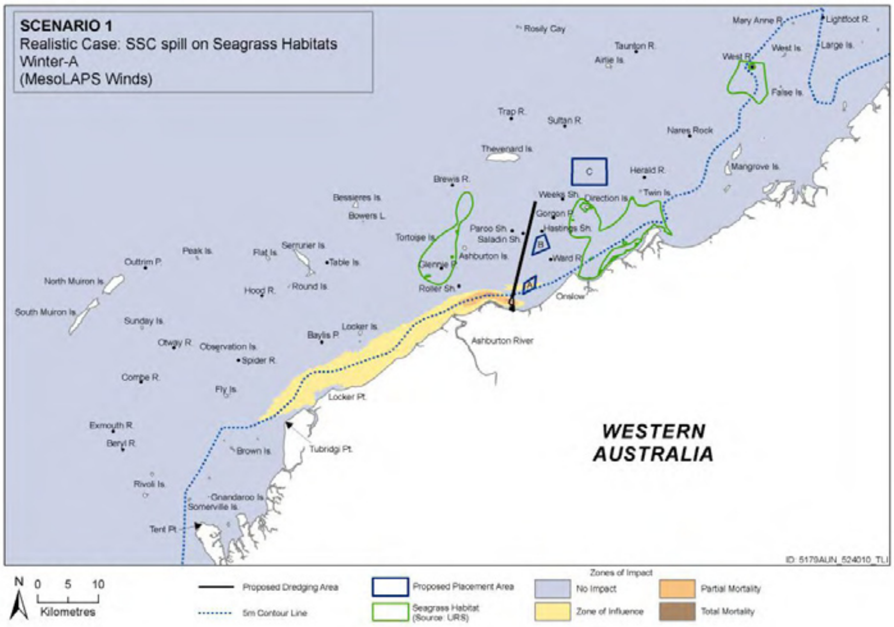

Figure A.11 Scenario 1, Winter-A, Realistic: SSC Zones of Impact for Seagrass during Winter Conditions with Realistic Spill based on MesoLAPS winds

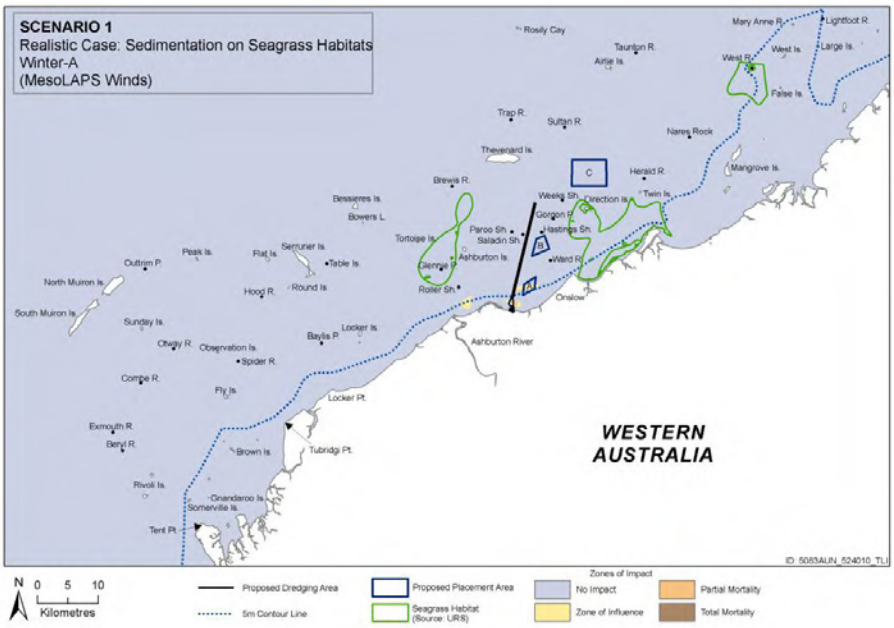

Figure A.12 Scenario 1, Winter-A, Realistic: Sedimentation Zones of Impact for Seagrass during Winter Conditions with Realistic Spill based on MesoLAPS winds

SG5240-06/Chevron Wheatstone Dredge Plume Impact Assessment/Final/mjj/05-10

A.1.4 Winter-B, Realistic Spill Scenario

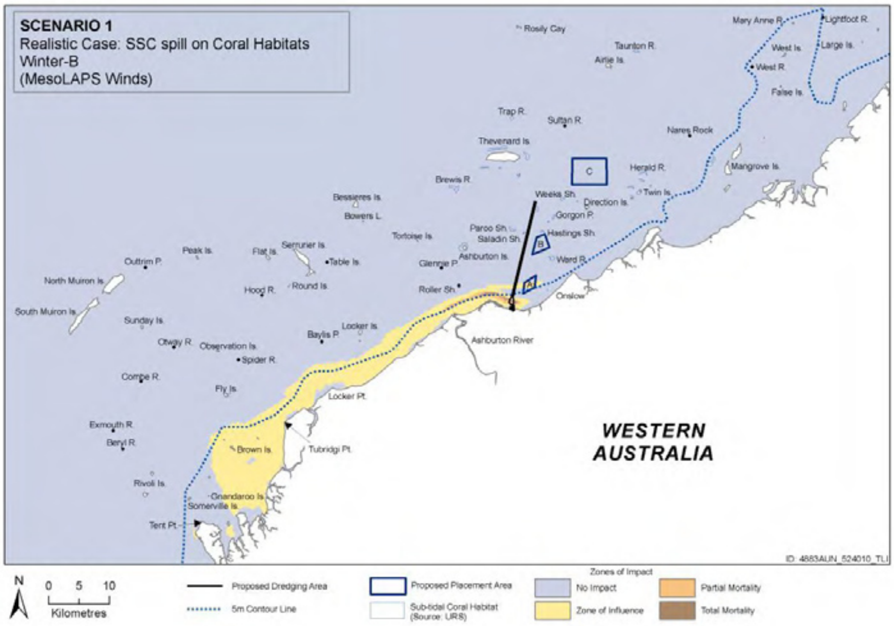

Figure A.13 Scenario 1, Winter-B, Realistic: SSC Zones of Impact for Corals during Winter Conditions with Realistic Spill based on MesoLAPS winds

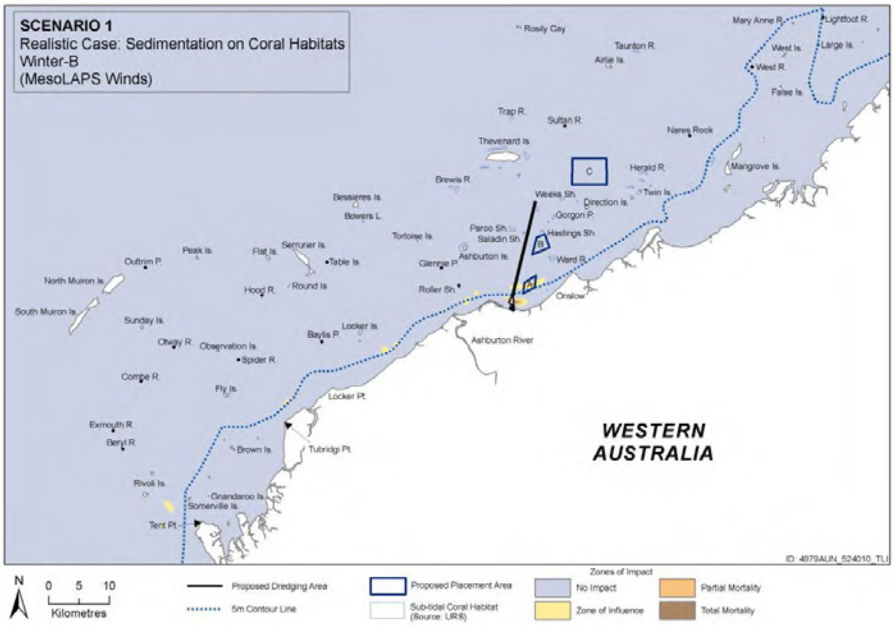

Figure A.14 Scenario 1, Winter-B, Realistic: Sedimentation Zones of Impact for Corals, during Winter Conditions with Realistic Spill based on MesoLAPS winds

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A-12

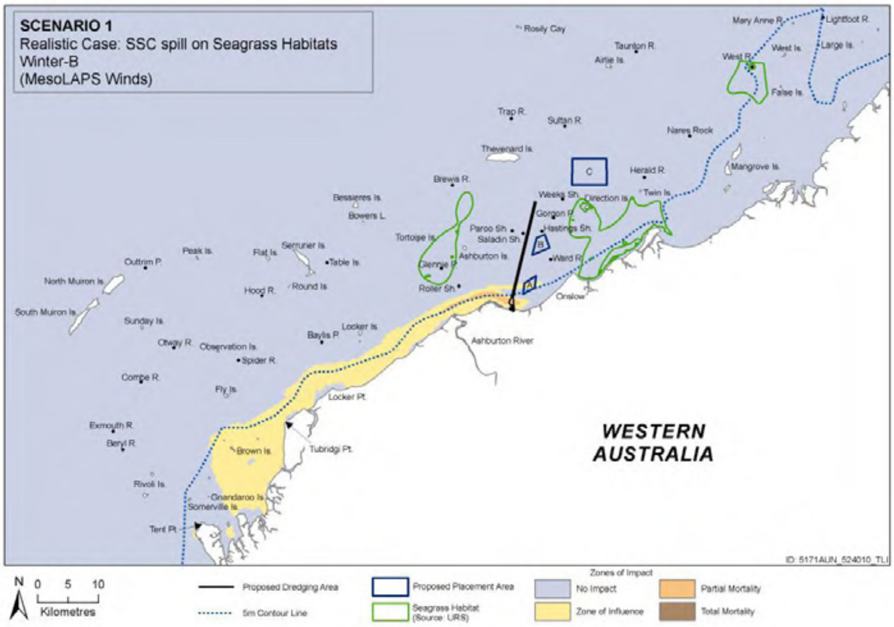

Figure A.15 *Scenario 1, Winter-B, Realistic: SSC Zones of Impact for Seagrass during Winter Conditions with Realistic Spill based on MesoLAPS winds*

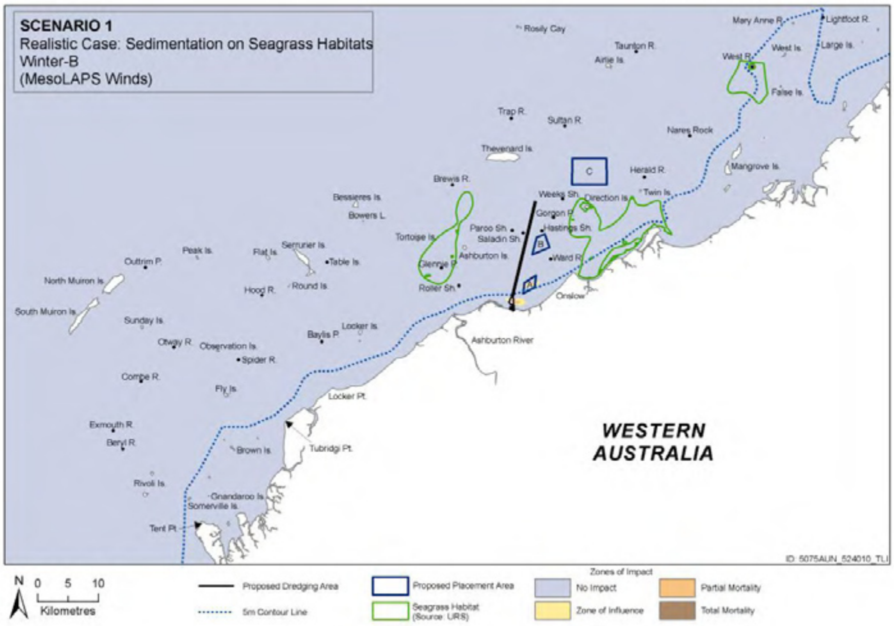

Figure A.16 *Scenario 1, Winter-B, Realistic: Sedimentation Zones of Impact for Seagrass during Winter Conditions with Realistic Spill based on MesoLAPS winds*

SG5240-06/Chevron Wheatstone Dredge Plume Impact Assessment/Final/mjj/05-10

A.1.5 Transitional-A, Realistic Spill Scenario

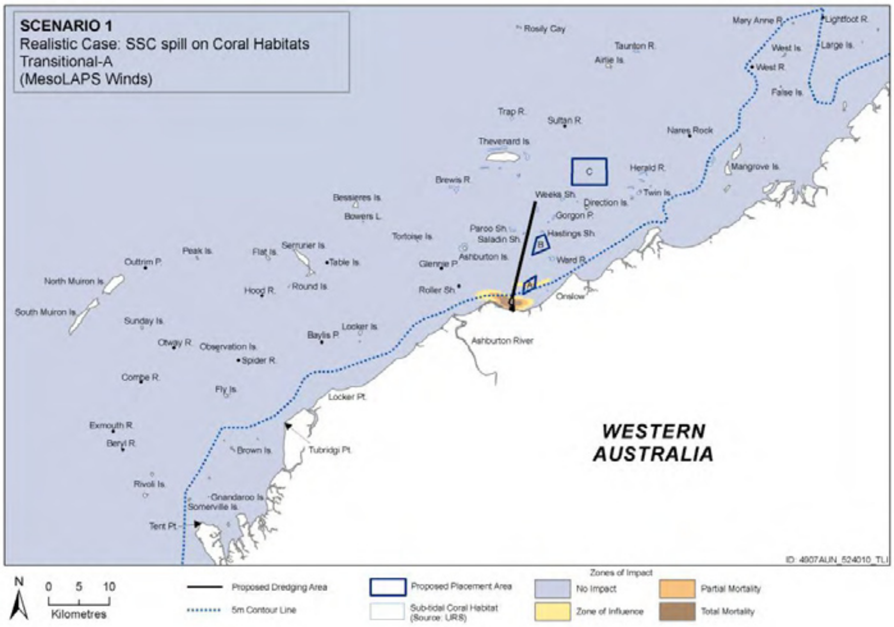

Figure A.17 Scenario 1, Transitional-A, Realistic: SSC Zones of Impact for Corals during Transitional Conditions with Realistic Spill based on MesoLAPS winds

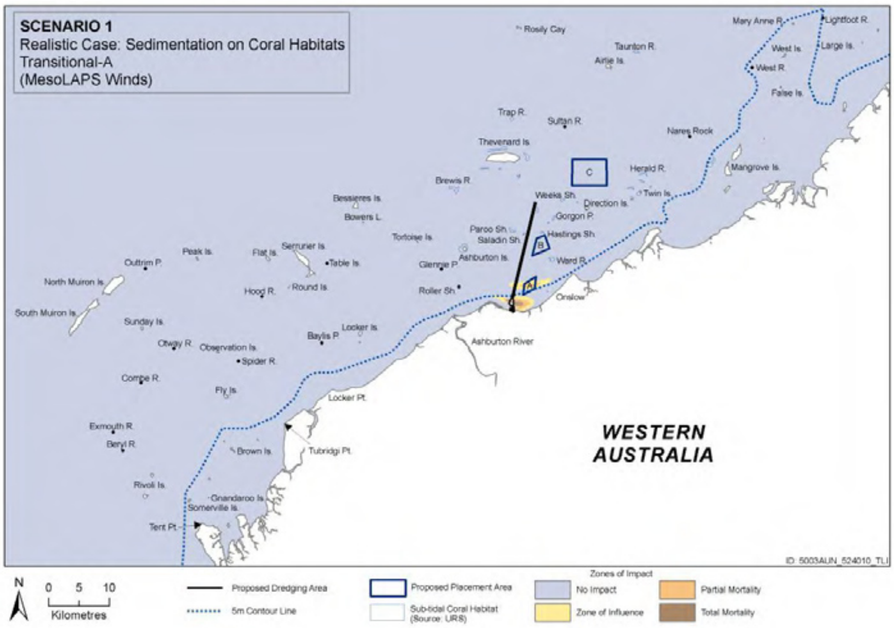

Figure A.18 Scenario 1, Transitional-A, Realistic: Sedimentation Zones of Impact for Corals, during Transitional Conditions with Realistic Spill based on MesoLAPS winds

A-15

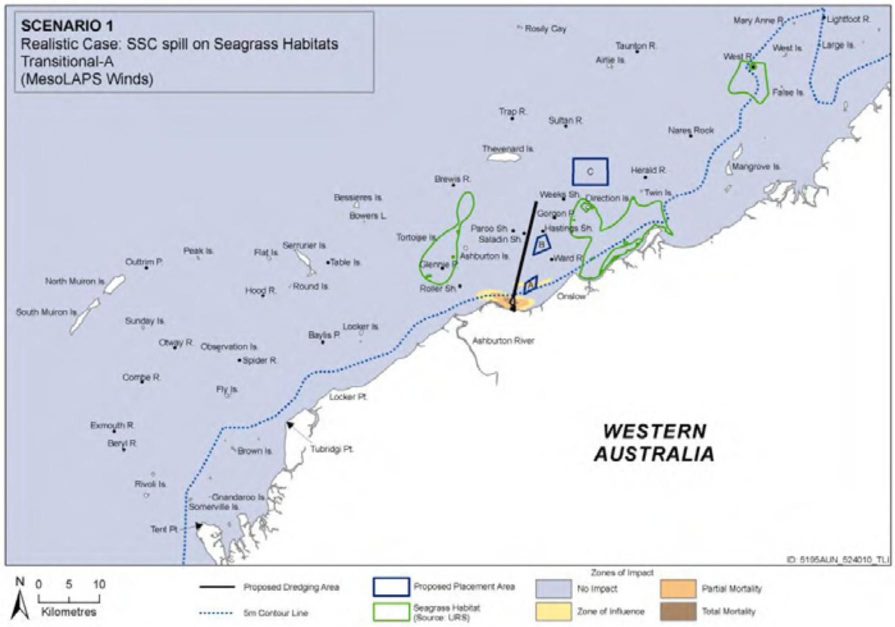

Figure A.19 Scenario 1, Transitional-A, Realistic: SSC Zones of Impact for Seagrass during Transitional Conditions with Realistic Spill based on MesoLAPS winds

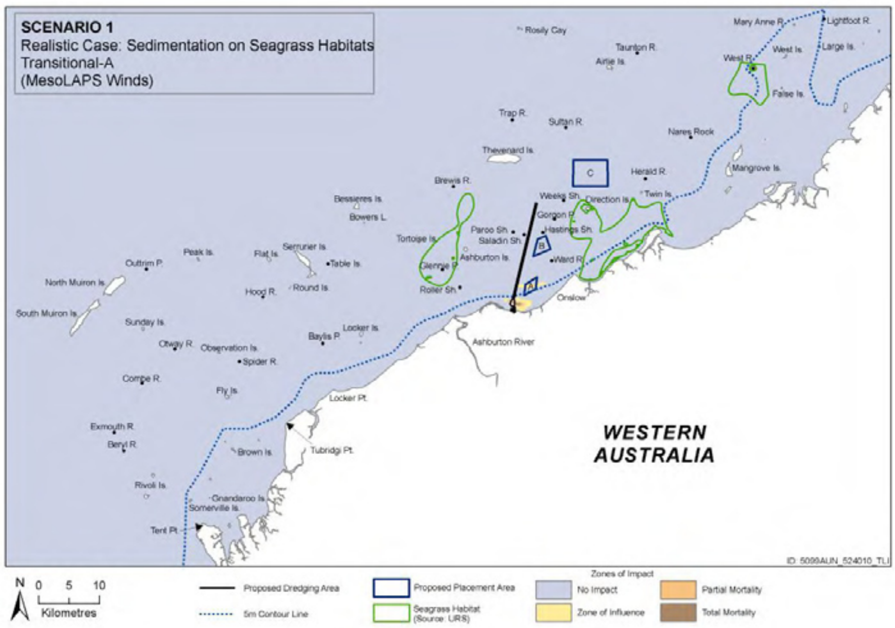

Figure A.20 Scenario 1, Transitional-A, Realistic: Sedimentation Zones of Impact for Seagrass during Transitional Conditions with Realistic Spill based on MesoLAPS winds

SG5240-06/Chevron Wheatstone Dredge Plume Impact Assessment/Final/mjj/05-10

A.1.6 Transitional-B, Realistic Spill Scenario

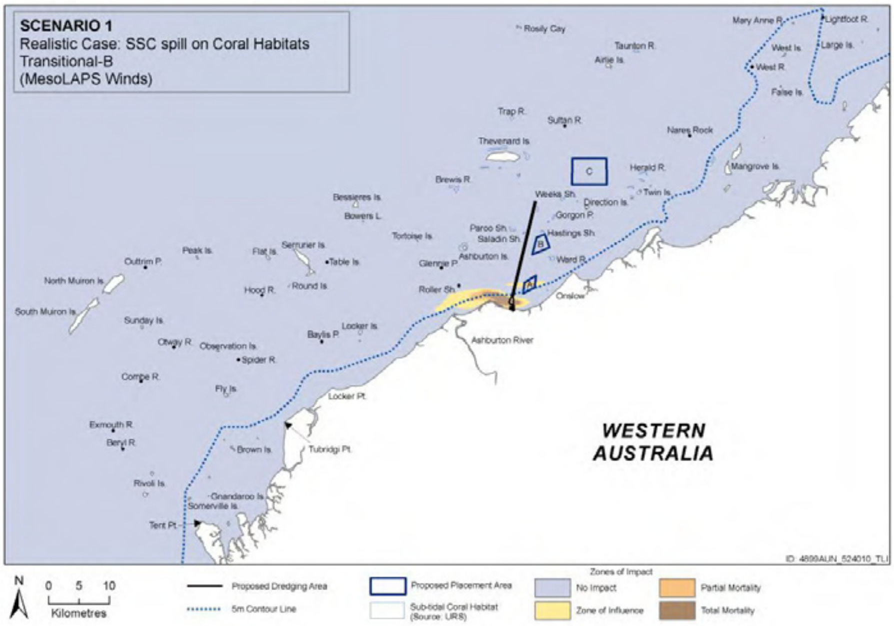

Figure A.21 Scenario 1, Transitional-B, Realistic: SSC Zones of Impact for Corals during Transitional Conditions with Realistic Spill based on MesoLAPS winds

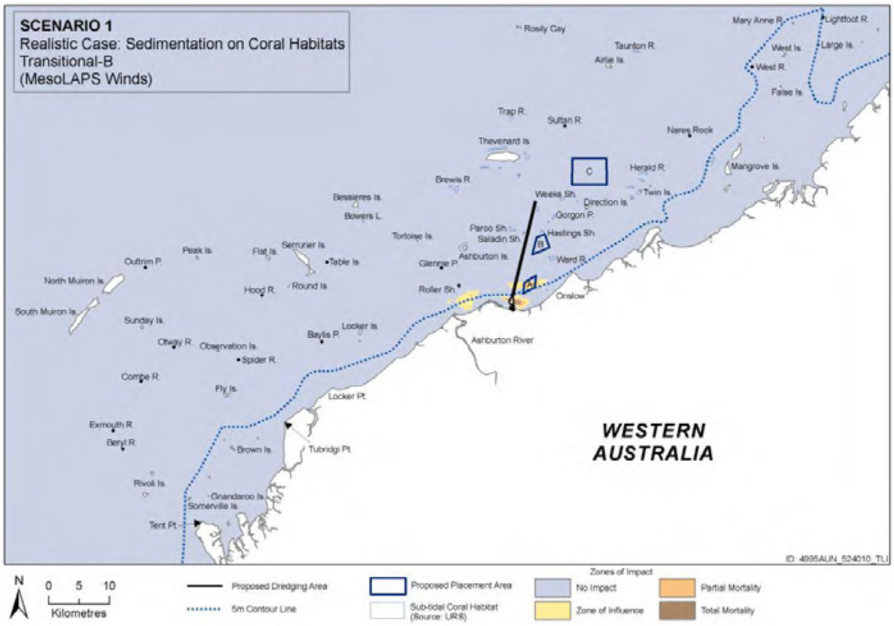

Figure A.22 Scenario 1, Transitional-B, Realistic: Sedimentation Zones of Impact for Corals, during Transitional Conditions with Realistic Spill based on MesoLAPS winds

SG5240-06/Chevron Wheatstone Dredge Plume Impact Assessment/Final/mjj/05-10

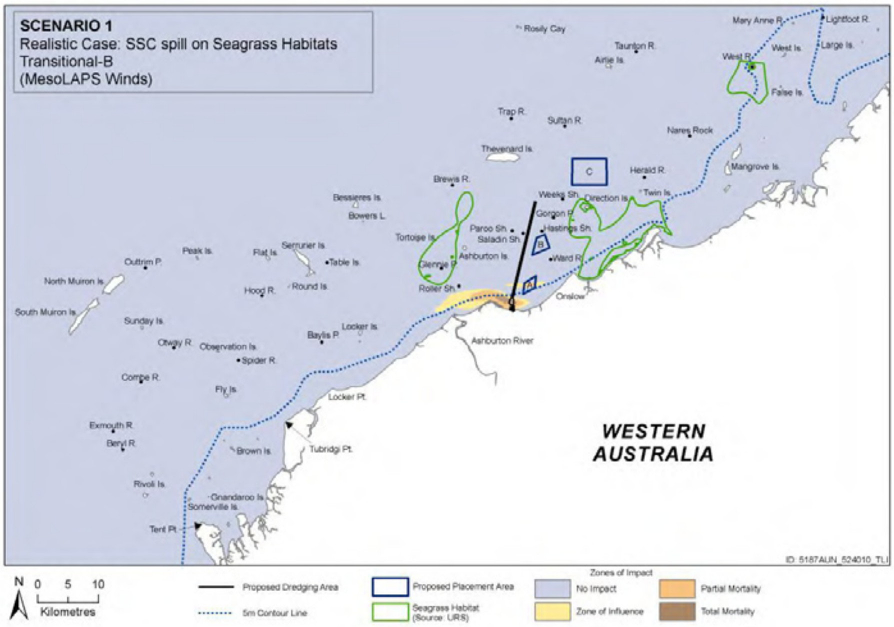

Figure A.23 Scenario 1, Transitional-B, Realistic: SSC Zones of Impact for Seagrass during Transitional Conditions with Realistic Spill based on MesoLAPS winds

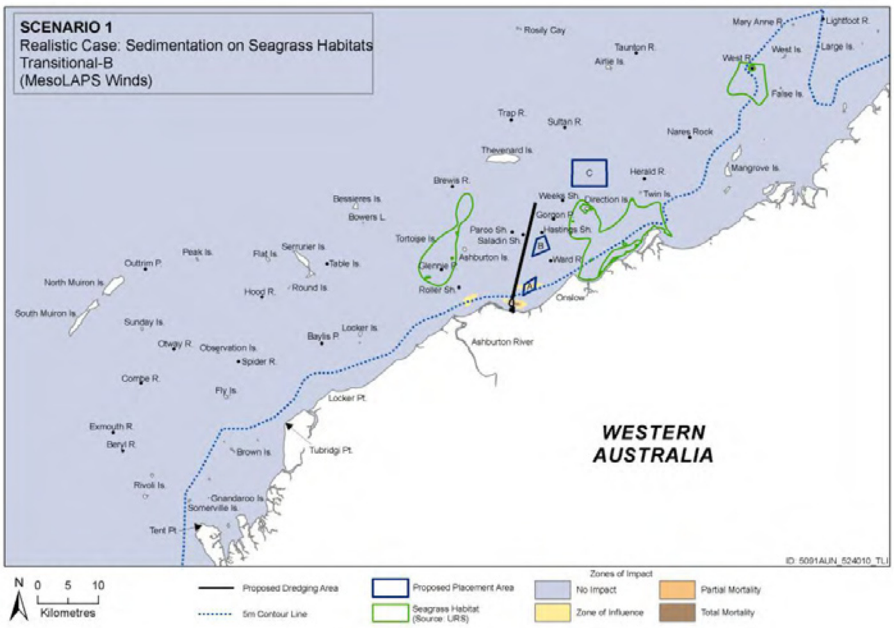

Figure A.24 Scenario 1, Transitional-B, Realistic: Sedimentation Zones of Impact for Seagrass during Transitional Conditions with Realistic Spill based on MesoLAPS winds