Volume 3

Technical Appendices FJ to FP and H1

Final Environmental Impact Statement/Response to Submissions on the Environmental Review and Management Programme for the Proposed Wheatstone Project

February 2011

Wheatstone Project

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Volume 3: Technical Appendices FJ to FP and H1

Appendix FJ

MOF Layout Change

This report has been provided as part of the supplementary information required to complete the Final Response to Submissions on the Draft EIS/ERMP. As part of the continued development of the Project design, an alternative Materials Offloading Facility layout has been proposed. This new layout differs to the layout presented and assessed in the Draft EIS/ERMP. Key differences between the Alternative layout and the Base Case layout, assessed in the Draft EIS/ERMP, are that:

- The Base Case layout has a main western and an eastern breakwater, while the Alternative layout has a single western breakwater
- The western breakwater for the Alternative layout has been extended seaward by approximately 250 m.

The layout change affects coastal impacts modelling completed to support the Draft EIS/ERMP for coastal processes; dredge plume modelling for the nearshore area; and hydrocarbon spill modelling for the Materials Offloading Facility. Key coastal processes impacts are similar for both layouts, with some change to sediment accumulation and slight alteration to the main zone of erosion to the east of the Materials Offloading Facility. However, the overall sediment budget for both layouts is similar. In terms of dredge plume modelling, while the change in Materials Offloading Facility layout does lead to a significant change in the impact predictions for Dredge Scenario 3, the contingency in the scenario modelling approach ensures that the overall prediction using the Base Case layout can be considered to also cover the Alternative layout of the Materials Offloading Facility. Further, for the hydrocarbon spill modelling, only the simulated spill within the Materials Offloading Facility changes significantly with the alternative Materials Offloading Facility layout. The design of the Base Case layout encloses the spill within the Materials Offloading Facility, while the Alternative layout often induces a stronger eddy circulation running through the Materials Offloading Facility basin, which may draw the spill out from the Materials Offloading Facility basin. This will likely result in a higher probability, but shorter time of exposure for the Alternative layout compared to the Base Case layout of the Materials Offloading Facility.

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MOF Layout Change

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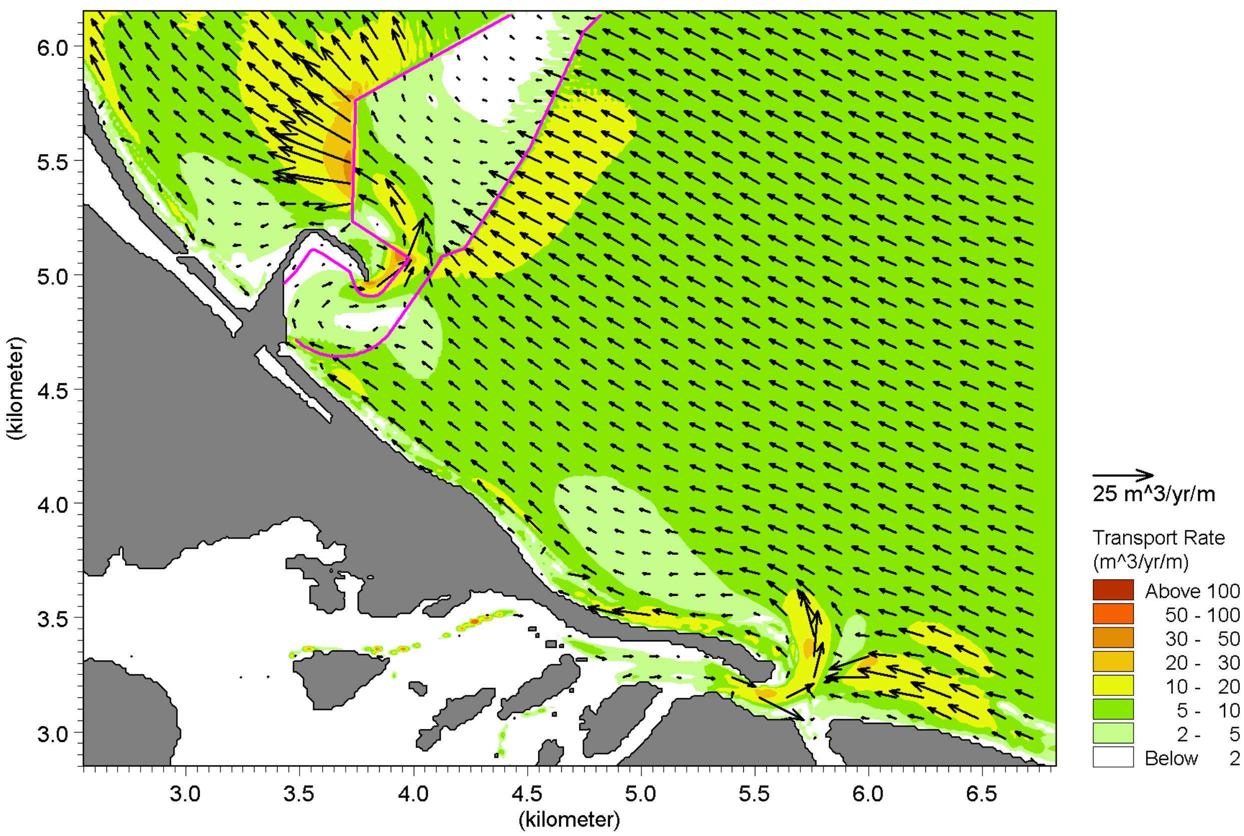

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Report

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MOF Layout Change

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FIGURES AND TABLES

1.0 INTRODUCTION

This document provides a Wheatstone Project update on an Alternative MOF layout that is currently being considered as a potential alternative design to that of the Base Case MOF Layout assessed in the Draft EIS/ERMP and in detail in EIS Appendix P2. The Base Case MOF Layout assessed in the Draft EIS/ERMP and the Alternative MOF Layout are illustrated in Figure 1.1. Key differences include:

- The Base Case MOF Layout, which formed the basis for the draft EIS/ERMP assessment, has a main western and an eastern breakwater.
- The Alternative MOF Layout has a single western breakwater.
- The western breakwater for Alternative MOF Layout is extended seaward by about 250m

The present document compares the key potential impacts from the Alternative MOF Layout with the Base Case MOF Layout assessed in detail in the Draft EIS/ERMP.

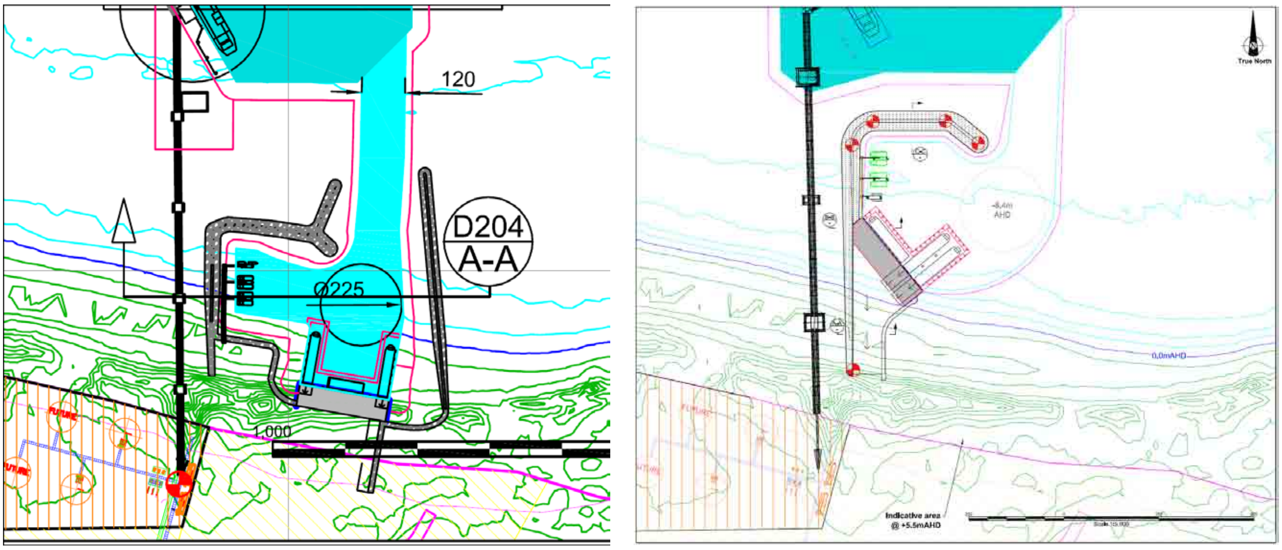


Figure 1.1 MOF Layouts: Left: Base Case MOF Layout addressed in the Draft EIS; Right: Alternative MOF Layout layout.

2.0 SUMMARY

A MOF layout change affects the modelling carried out to support the EIS in three key component areas:

- Coastal processes and impacts
- Dredge plume modelling for the nearshore area
- Hydrocarbon spill modelling for the MOF

Remodelling with the MOF Alternative MOF Layout has been carried out and compared to the findings for the Base Case MOF Layout presented in the Draft EIS/ERMP for all three components. A brief summary of the findings is provided below, with selected documentation from the modelling provided in Sections 3.0, 4.0 and 5.0.

2.1 Coastal Impacts

The key impacts, which are related to a complete blockage of the littoral sediment transport by the MOF and associated dredged access channel, are similar for the two MOF layout options. Unmitigated, this will on average lead to a build-up of sand to the west of the MOF, a smaller accumulation of sand immediately east of the MOF and erosion further to the east of the MOF, although there may be years with a reversal of this pattern, in particular under influence of cyclones.

Sediment accumulated on the eastern side of the eastern breakwater in the Base Case MOF Layout will tend to be transported into the MOF basin for the Alternative MOF Layout. Whereas the sediment accumulation in the downdrift sheltered zone for the Base Case MOF Layout will initially cause an additional lack of sediment further to the east in the overall sediment budget, this will stabilise within a few years as a new quasi-equilibrium state of the coastline is reached. For the Alternative MOF Layout, regular maintenance of the MOF basin will be required to maintain it fully operational, and this will prevent a new quasi-equilibrium coastline to establish on the downdrift side of the MOF. A continued “sediment sink” is therefore expected for the Alternative MOF Layout.

The differences in sheltering zones by the two layouts considered leads to some differences in the main zones of erosion to the east of the MOF. The sheltering by the eastern breakwater in Base Case MOF Layout tends to stretch further eastward than the sheltering induced by the Alternative MOF Layout during summer conditions. This would likely lead to a shift westward of the main erosion zone for Alternative MOF Layout compared to Base Case MOF Layout. This may, however, be limited by a rock platform in this area, which is presently partly exposed. The erosion will gradually migrate further eastward if left unmitigated.

The overall impacts on the coastal morphology will depend on the coastal management strategy implemented. If the beach sediments settling out adjacent to the MOF area are returned to the downdrift beach as part of a management scheme, then the difference in coastal impacts between the two layouts will be restricted to a difference in the coastal configuration in the vicinity of the MOF. The overall sediment budget will be similar.

2.2 Dredge Plume Impacts

The changes in current patterns due to the Alternative MOF Layout are localised and will not impact the farfield plume dispersion, but will impact the initial dispersion from the source(s) when dredgers are working within or in the vicinity of the MOF.

The largest differences in plume dispersion for the Alternative MOF Layout are realised for Dredge Scenario 3 with CSD dredging inside the MOF during winter. Whereas the plume from the cutter head to a large extent remains within the Base Case MOF Layout, it is pushed seaward during winter and mixes with the plume from the overflow and the simultaneous TSHD dredging for the Alternative MOF Layout, leading to higher combined concentrations and larger predicted impact zones.

Dredge Scenario 2 also has CSD dredging in the nearshore area, but outside the MOF, such that the difference between the two MOF layouts for this dredge scenario is insignificant. Although Dredge Scenario 2 does not include simultaneous TSHD dredging, the nearshore impact zones derived from this dredge scenario are larger than the impact zones for Dredge Scenario 3 for the Base Case MOF Layout, and fairly similar to the impact zones derived for Dredge Scenario 3 for the Alternative MOF Layout.

Whereas the Alternative MOF Layout does lead to a significant change in the impact predictions for Dredge Scenario 3, the contingency in the scenario modelling approach of having other dredge scenarios with similar spills outside of the MOF ensures that the overall impact prediction can be considered to also cover the Alternative MOF Layout.

Overall it is concluded that the dredge plume modelling carried out in support of the impact assessment based on the Base Case MOF Layout can also be deemed to cover the Alternative MOF Layout.

2.3 Hydrocarbon Spill Modelling

Only the simulated hydrocarbon (diesel) spill within the MOF changes significantly with the Alternative MOF Layout.

The Base Case MOF Layout encloses the spill within the MOF. Depending on wind and tide, the spill may remain within the MOF for an extended period of time before gradually “escaping” the MOF. The Alternative MOF Layout in contrast often induces a stronger eddy circulation running through the MOF basin, and this may draw the spill out from the MOF basin.

Whereas the patterns vary with current and wind conditions, it generally leads to a higher probability of exposure and a shorter time to exposure for the Alternative MOF Layout compared to the Base Case MOF Layout.

3.0 IMPACTS ON COASTAL MORPHOLOGY

Modelling of the impacts of the MOF on the coastal sediment transport patterns and expected morphological impacts was reported in EIS Appendix P2. A brief summary of key changes to the existing coastal sediment transport patterns and associated potential morphological impacts is included below, followed by a comparative assessment of the Alternative MOF Layout.

3.1 Key Potential Morphological Impact of Base Case MOF Layout

The following key changes to the existing littoral transport and coastal processes identified for the Base Case MOF Layout were reported in EIS Appendix P2:

- Blockage of a net easterly littoral sediment transport in the order of 50,000 m^3/year on average, which may vary significantly from year to year.
- The pattern of sediment transport experiences a seasonal reversal during winter months.
- Tropical cyclones may induce transport in either direction, and under extreme conditions, may transport a volume of sediment over several days; this is a similar order of magnitude to annual net transport.
- Coarser sediments bypassing the MOF breakwaters will get trapped in the dredged navigation channel, in effect leading to no bypass of the MOF of beach sediments.
- Establishment of a sheltered area to the east of the eastern breakwater, which will generate a current eddy and the potential to accumulate sediments up against the eastern breakwater.
- Disruption of the littoral transport patterns to the east of the MOF where the littoral transport will gradually re-establish from the MOF and eastward.

Key morphological impacts without any mitigation include:

- Large accumulation of sediments on the western side of the MOF. Due to the high variability in littoral transport rates (primarily driven by the wave climate), years with erosion to the west of the western breakwater can occur, in particular under the influence of cyclones which in single events can create severe morphological impacts on either side of the breakwater.
- A small accumulation of sediments immediately adjacent to the eastern side of the MOF, within the area sheltered from summer northeast waves.
- Downdrift erosion on the eastern side of the MOF, outside the area sheltered from summer northeast waves. This is predicted to be concentrated in an area a short distance to the east of the eastern breakwater and stretch eastward to the entrance of Hooley Creek.
- Destabilisation of the Hooley Creek entrance spit.
- Some sedimentation in the dredged channel and basins which is likely to require maintenance dredging at regular intervals.

3.2 Comparison of Alternative MOF Layout to Base Case MOF Layout

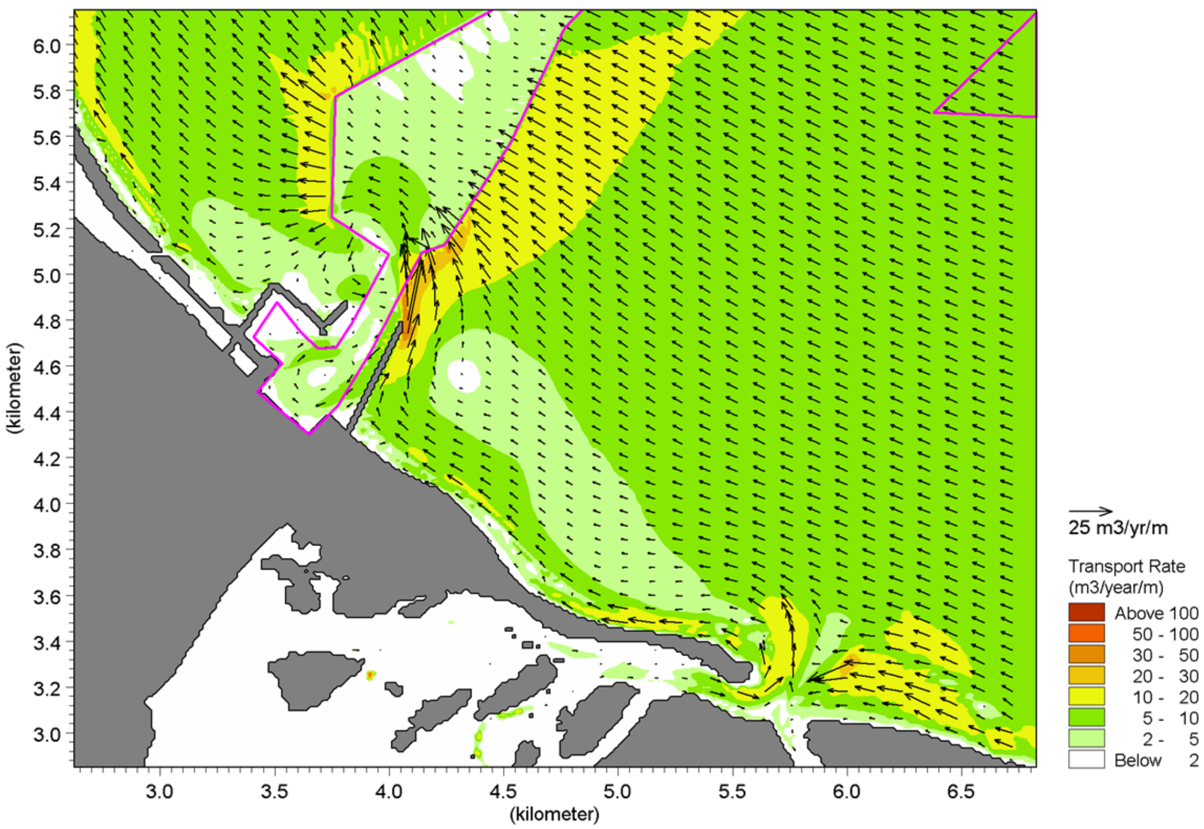
The overall changes to the sediment transport patterns and coastal processes caused by Alternative MOF Layout are similar to those outlined for the Base Case MOF Layout reported in the previous subsection.

- The seaward extension of the western breakwater further "enhances" blockage of the littoral transport. This will lead to a similar net accumulation of sediment on the western side of the western breakwater, which on average is expected to be in the order of 50,000 m^3/year, but which can show a larger variation due to year-to-year variability, in particular under the influence of cyclones.
- Any coarser sediment bypassing the western MOF breakwater towards the east will be trapped in the dredged channel.
- The proposed dredged basin cuts into the existing seabed, with its shoreward extent at approximately –2.0m AHD, which is within the zone of high littoral transport. Without any intervening structures, the seabed and beach may respond locally by slumping into the dredged basin, which is facilitated through waves and tidal currents.
- During winter months, westward sediment transport will be directly transported into the MOF dredged basin. This is expected to be at least 20,000 m^3/year, and is in addition to sedimentation due to local beach slumping.
- During summer months, the breakwater provides a sheltered area immediately to the east of the MOF. Without an eastern breakwater, the eddy current generated in the sheltered area will extend into the MOF area, and the sediments expected to accumulate up against the eastern breakwater for the Alternative MOF Layout will tend to deposit within the MOF area.
- Similar to the Base Case MOF Layout , the blockage of the littoral sediment transport and the accumulation of sediment immediately to east (and within) the MOF basin for the Alternative MOF Layout will lead to downdrift erosion and destabilisation of the Hooley Creek entrance spit if not mitigated.
- Sedimentation in the main approach channel and in the PLF berthing and turning basin will be of similar magnitude for Alternative MOF Layout. However, sedimentation within the MOF will likely be severe for Alternative MOF Layout due to the absence of the eastern breakwater.

The main difference between the Base Case MOF Layout and Alternative MOF Layout in terms of changes to the sediment transport patterns and morphological impacts is related to the transport patterns immediately to east of the MOF and the likely sedimentation in the MOF. These differences are illustrated in Figure 3.1 and Figure 3.2 which compare simulated time averaged transport patterns for fine sand for the two layouts for typical winter and summer conditions. During westerly directed transport (primarily over winter or during about 60% of cyclones), the eastern breakwater tends to block the littoral transport for Base Case MOF Layout, although it is noted that the formation of rip currents close to the MOF draws sediment seaward, which will tend to settle out in the dredged channel at the MOF entrance. The absence of an eastern breakwater in Alternative MOF Layout allows the westerly directed transport to penetrate into the MOF and deposit sediments in the sheltered MOF area.

Due to the large angle of the incoming waves relative to the coastline normal, there is a relatively large sheltered zone to the east of the MOF during summer conditions, which results in the formation of a large-scale eddy structure. The eddy is driven by a combination of tidal currents and differences in wave generated setup. For Base Case MOF Layout, the western limit of the eddy is controlled by the eastern breakwater, and the eddy stretches in the order of 500m east of the eastern breakwater. In the case of Alternative MOF Layout, the eddy penetrates into the MOF area, and this will carry sediments into the MOF area and lead to sedimentation here.

The sediment trapped in the sheltered area to the east of the eastern breakwater for Base Case MOF Layout, and within the MOF for Alternative MOF Layout, acts as an additional sediment sink for the area further to the east outside the accumulation zone. For Base Case MOF Layout, a semi-equilibrium plan form of the coastline is expected to establish within the sheltered area, and the sediment sink primarily impact the morphology further to the east while a new dynamic equilibrium profile establishes. For the Alternative MOF Layout, required maintenance dredging to maintain the MOF operational will likely prevent a new semi equilibrium plan form to establish. Unless the sediment removed from the MOF during maintenance is placed back in the littoral system to the east of the MOF, an additional sediment sink will continue to exist.



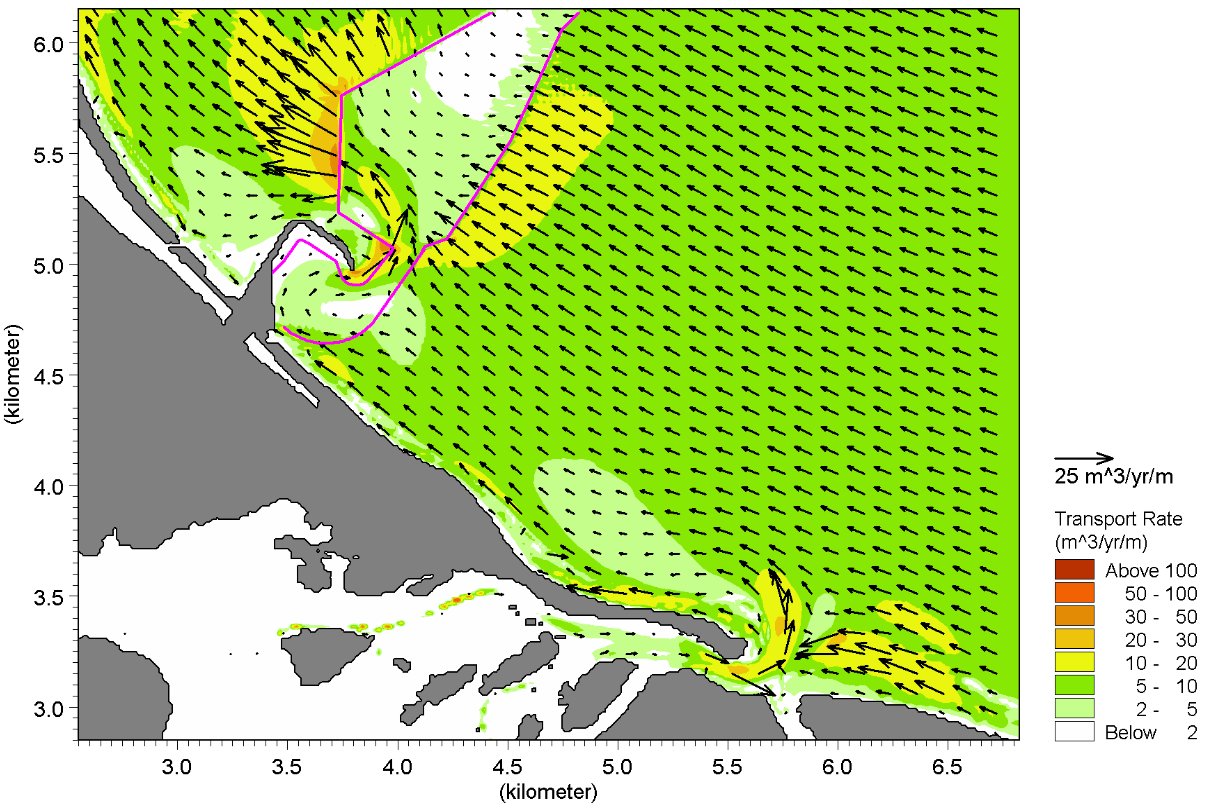
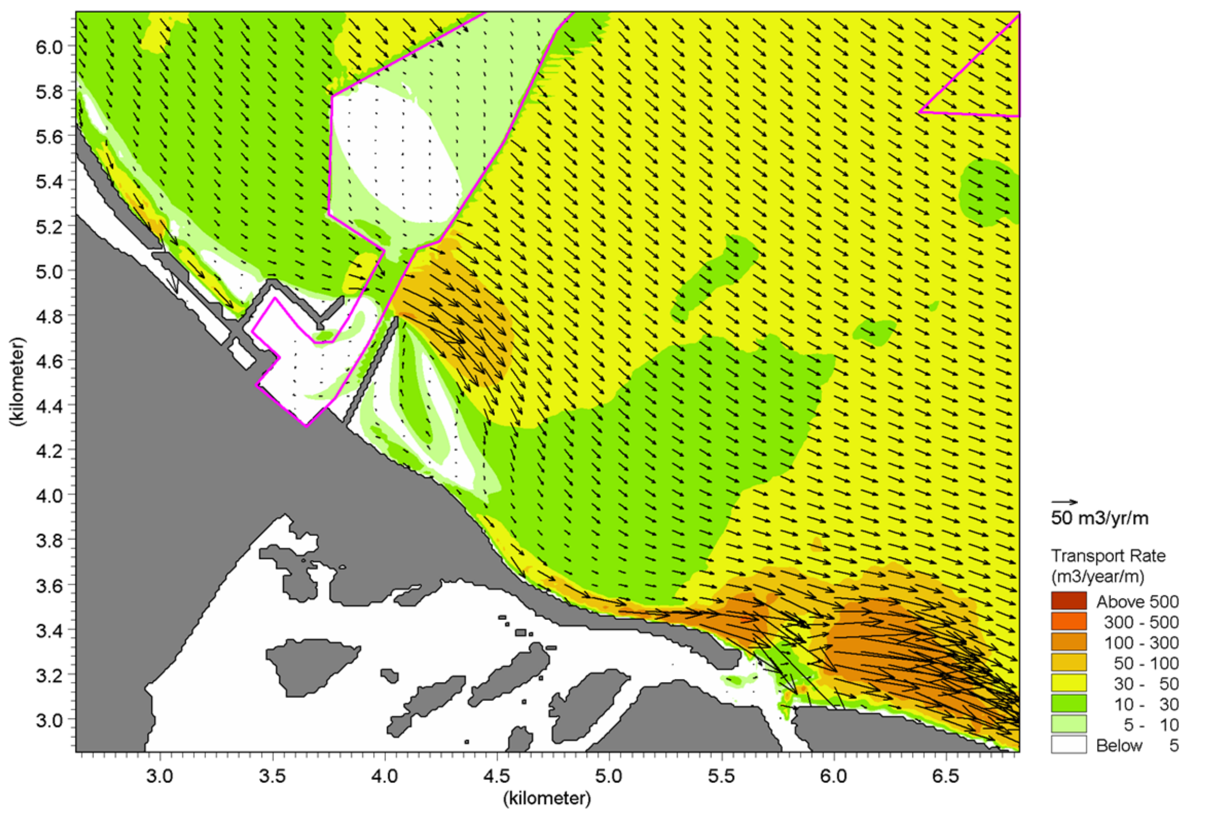


Figure 3.1 Average transport patterns for representative winter conditions for fine sand. Top: Base Case MOF Layout; Bottom: Alternative MOF Layout.



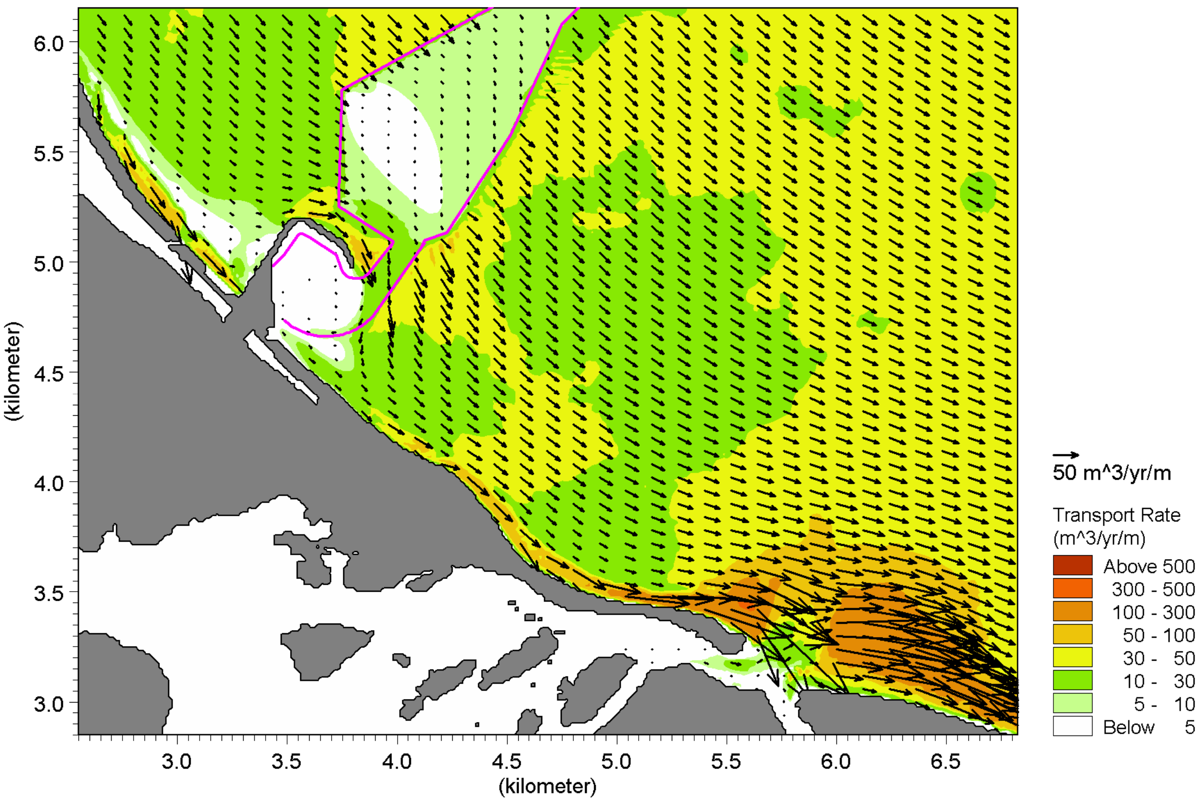


Figure 3.2 Average transport patterns for representative summer conditions for fine sand. Top: Base Case MOF Layout; Bottom: Alternative MOF Layout.

4.0 DREDGE PLUME ASSESSMENT

Changes in current patterns due to the different MOF layout are restricted to the nearshore and nearfield area. These changes will not impact the farfield plume dispersion, but can potentially impact the initial dispersion from the source(s) when working in the vicinity of the MOF.

The dredge scenarios defined for the dredge plume modelling included 3 nearshore dredge scenarios with a Cutter Suction Dredger working in the nearshore area. Dredge Scenario 3 has a CSD working in the MOF basin after the construction of the MOF with pumping to barges in the PLF area. In parallel, there is a TSHD dredger working the inner part of the PLF approach channel. With this dredge configuration, the plume derived from the CSD dredging (at the cutterhead) tends to remain within the MOF for the Base Case MOF Layout, while the plume during winter conditions gets pushed seaward past the outer breakwater and thereby mixes with the plume from the barge overflow for the Alternative MOF Layout of the MOF. This is illustrated in Figure 4.1, which shows instantaneous plumes derived during strong winter conditions. The combined plumes from the barge overflow and cutter-head release leads to higher concentration plumes for the Alternative MOF Layout. This leads to larger impact zones for this particular dredge scenario, see comparison of impact zones derived from SSC impact on corals for Winter-A conditions for Base Case MOF Layout and Alternative MOF Layout in Figure 4.2.

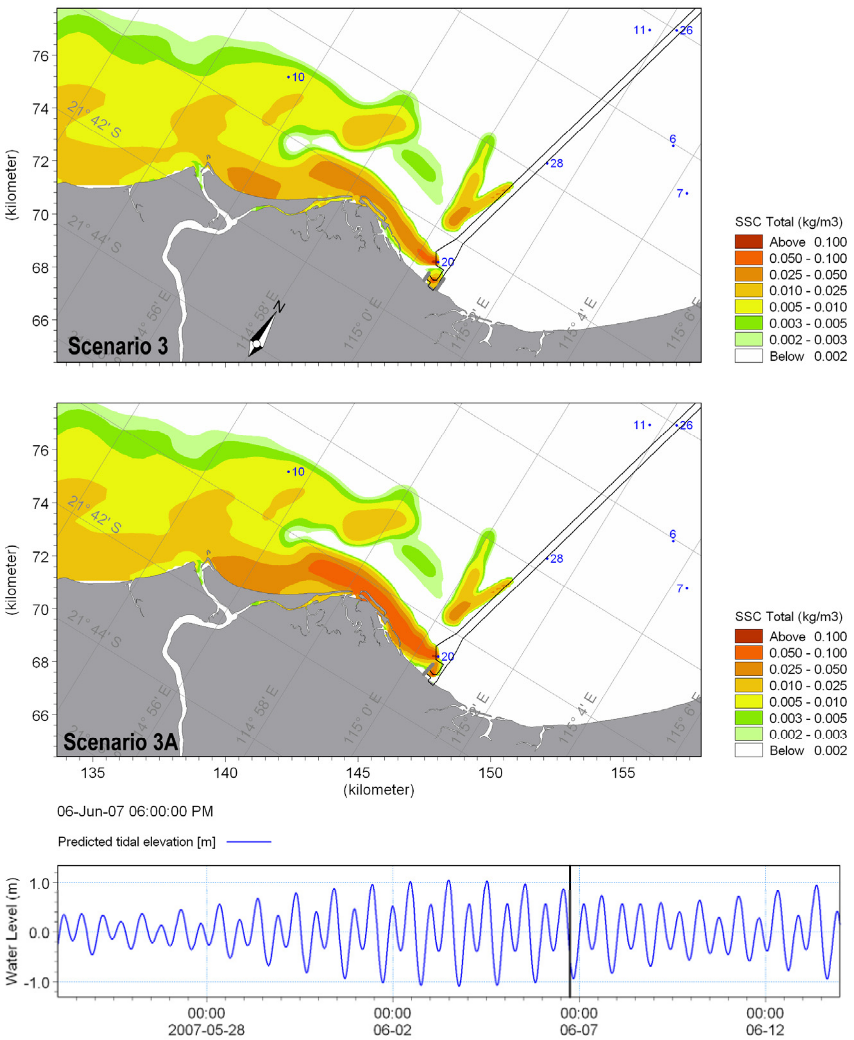
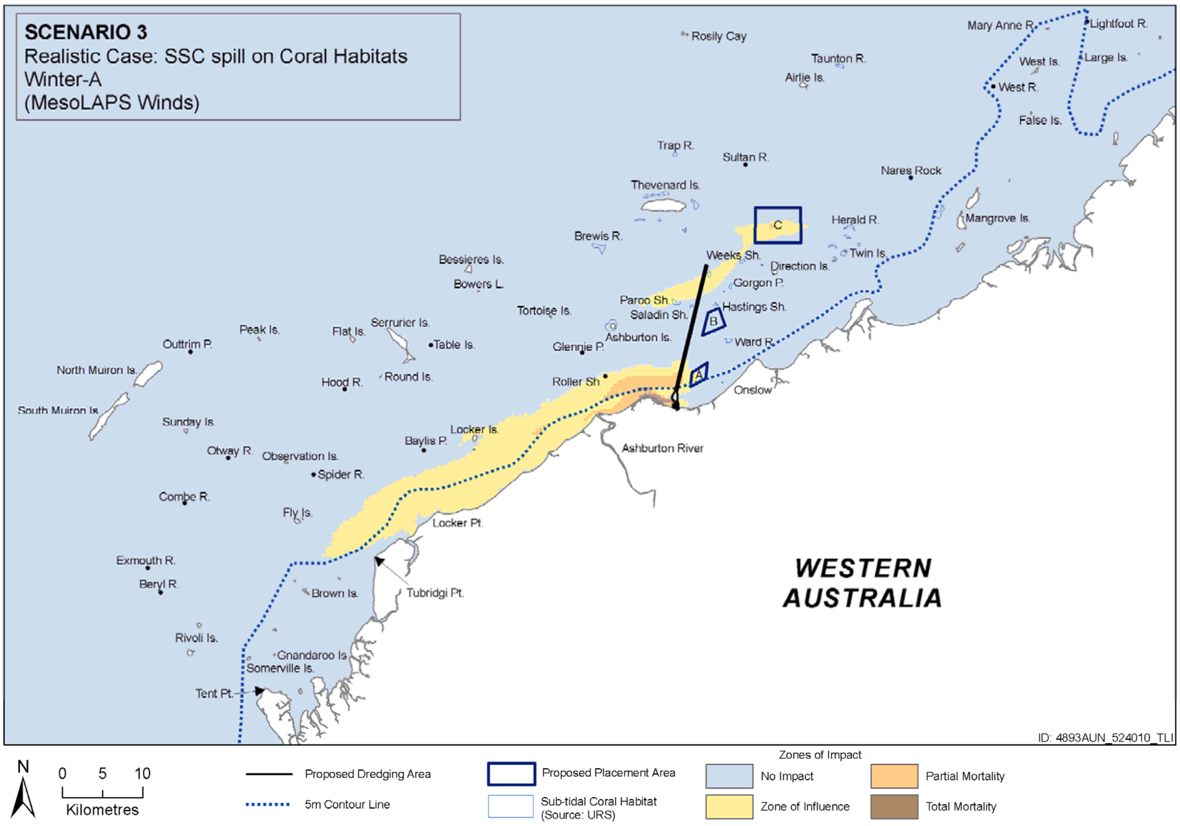


Figure 4.1 Comparison of instantaneous plots of dredge plumes from Dredge Scenario 3 for the Base Case MOF Layout (top) and Alternative MOF Layout (bottom.



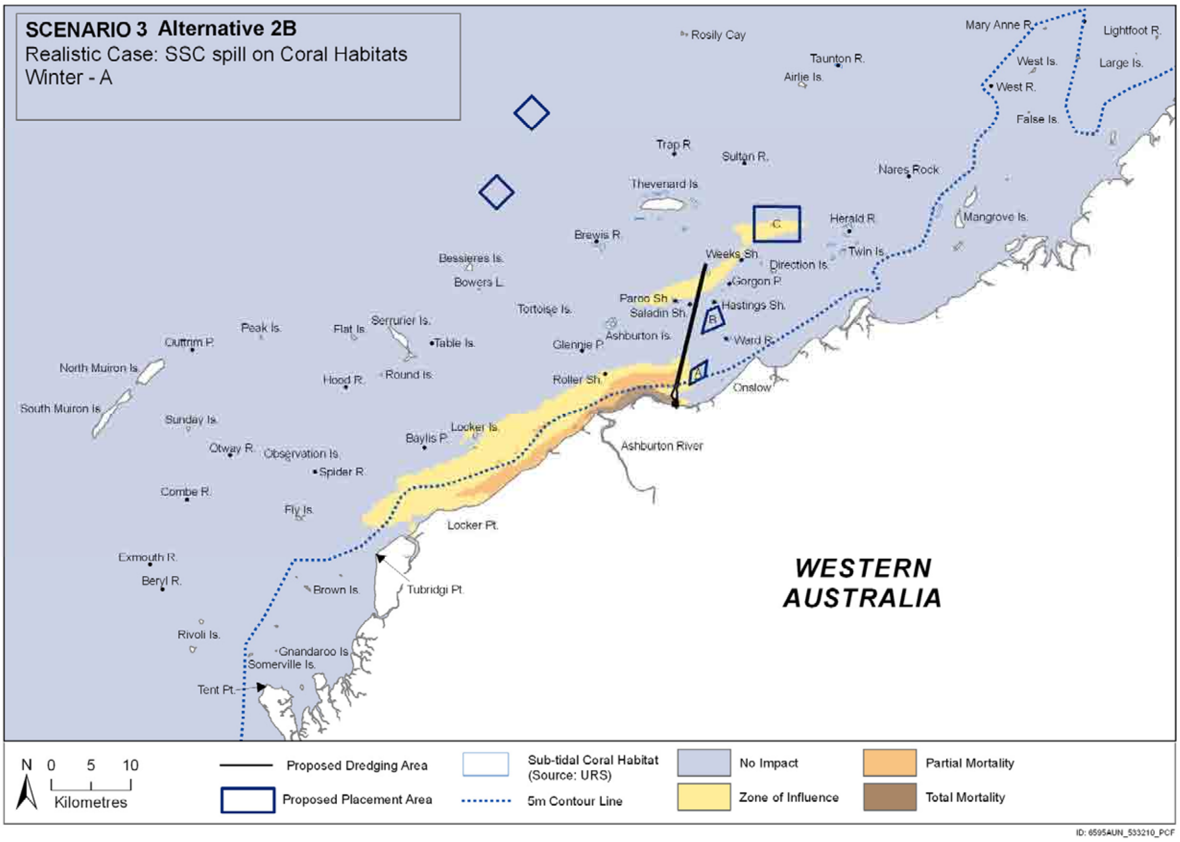


Figure 4.2 Comparison of impact zones for SSC impacts on corals for winter conditions for Dredge Scenario 3 with dredging inside the MOF for Base Case MOF Layout (top) and Alternative MOF Layout (bottom).

In terms of the overall impact assessment, Dredge Scenario 2 also has CSD dredging in the nearshore area, but outside the MOF, such that the difference between the two MOF layouts for this dredge scenario is insignificant. Although Dredge Scenario 2 does not include simultaneous TSHD dredging, the nearshore impact zones derived from this dredge scenario are larger than the impact zones for Dredge Scenario 3 for the Base Case MOF Layout, and fairly similar to the impact zones derived for Dredge Scenario 3 for the Alternative 2 layout, see zones for Winter-A conditions for SSC impacts on coral habitats derived from Dredge Scenario 2 in Figure 4.3.

Whereas the Alternative MOF layout does lead to a significant change in the impact predictions for Dredge Scenario 3, the contingency in the scenario modelling approach of having other dredge scenarios with similar releases outside of the MOF ensures that the overall impact prediction can be considered to also cover the Alternative MOF layout.

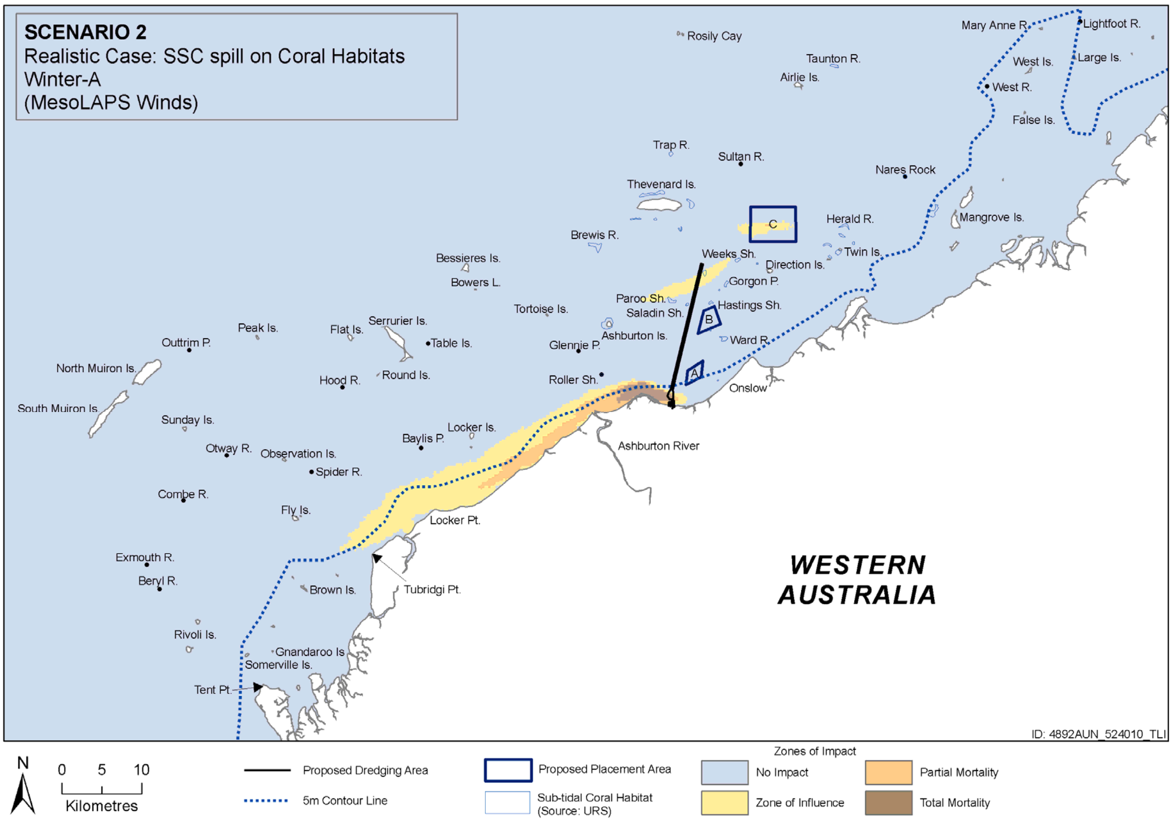
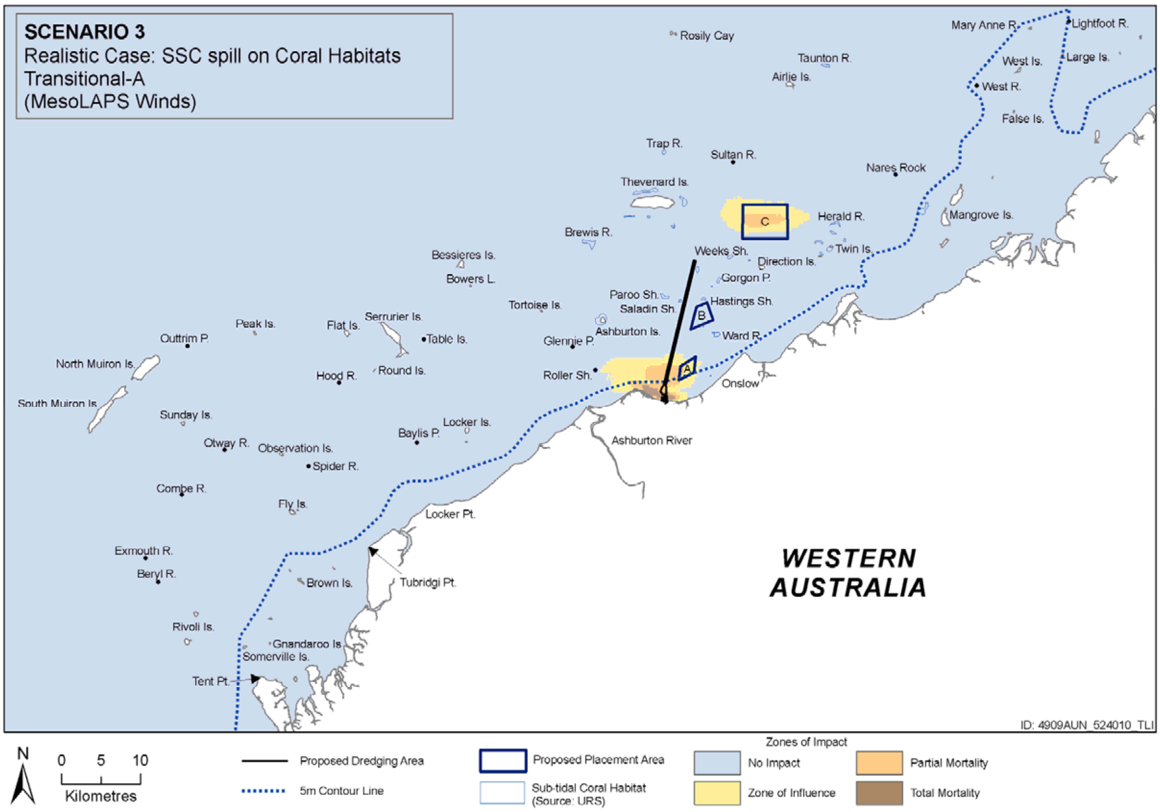


Figure 4.3 Impact zones for SSC impacts on corals for winter conditions for Dredge Scenario 2 with dredging outside of MOF for Base Case MOF Layout.

For transitional and summer conditions, the plume from the CSD cutter head is not pushed as far seaward by the MOF breakwater in Alternative MOF Layout as for winter conditions, and therefore doesn't mix as much with the plume generated by the overflow. The impact zones derived for transitional and summer conditions are much more similar for Alternative MOF Layout compared to Base Case MOF Layout than for winter conditions, see Figure 4.4 and Figure 4.5, and the total impacts are well covered by the combination of impacts from all dredge scenarios, see Figure 4.6. The overall picture and conclusion is similar for impacts on seagrasses and impacts through sedimentation as well as simulations based on Onslow winds. The larges differences are found for the winter conditions for the strong MesoLAPS winds for SSC impacts on coral habitats. Overall it is concluded that the dredge plume modelling carried out in support of the impact assessment based on the Base Case MOF Layout can also be deemed to cover the Alternative MOF Layout.



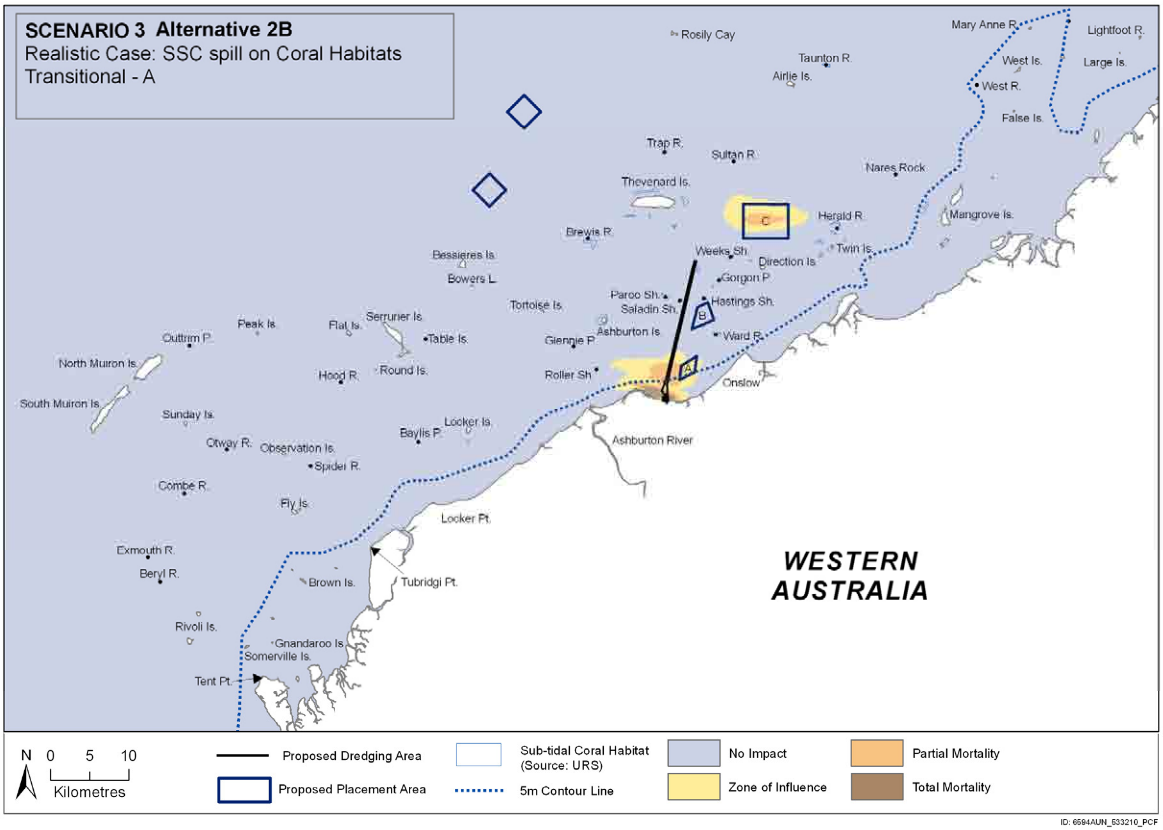
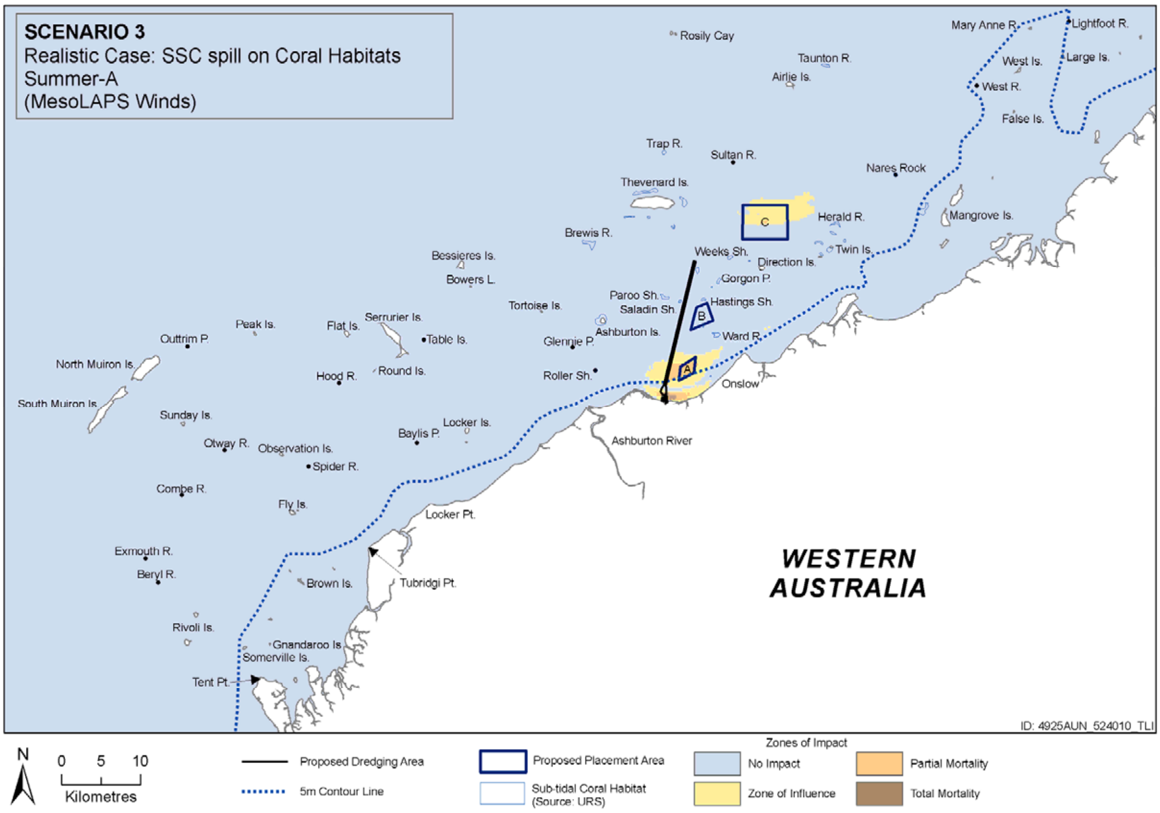


Figure 4.4 Comparison of impact zones for SSC impacts on corals for transitional conditions for Dredge Scenario 3 with dredging inside the MOF for Base Case MOF Layout (top) and Alternative MOF Layout (bottom).



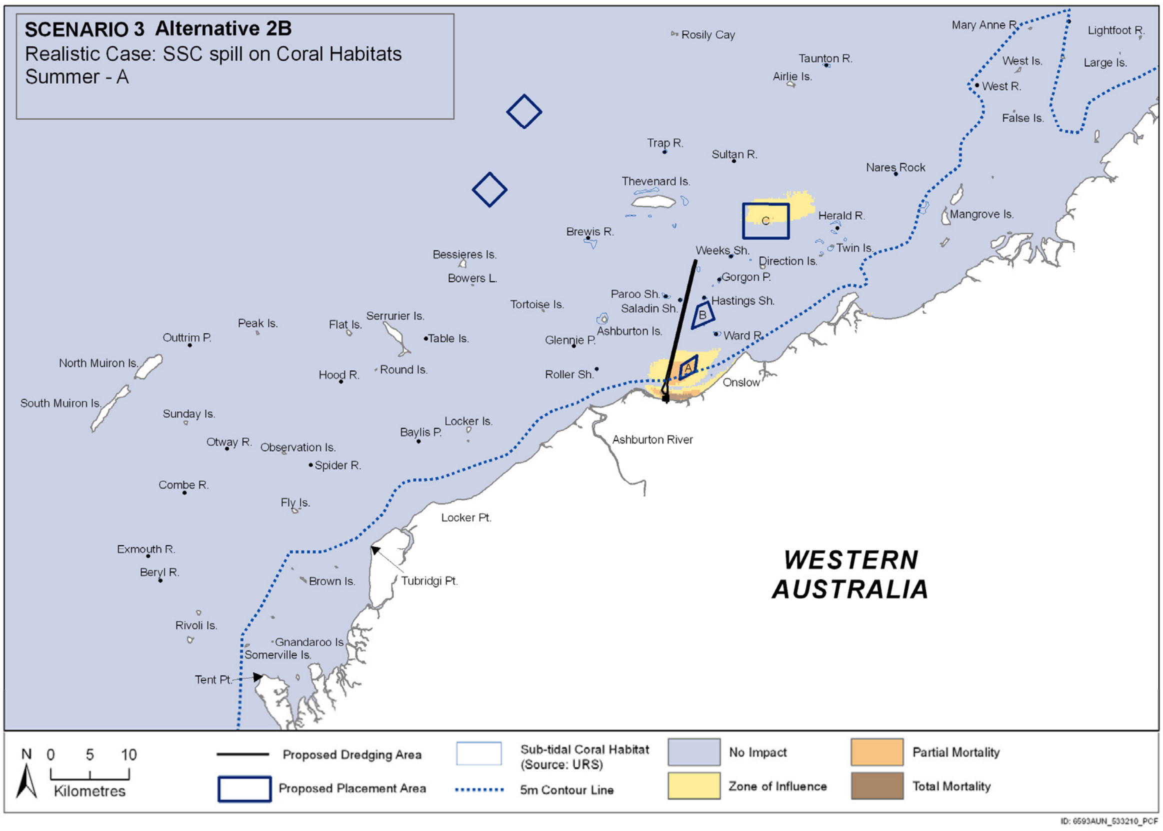


Figure 4.5 Comparison of impact zones for SSC impacts on corals for summer conditions for Dredge Scenario 3 with dredging inside the MOF for Base Case MOF Layout (top) and Alternative MOF Layout (bottom).

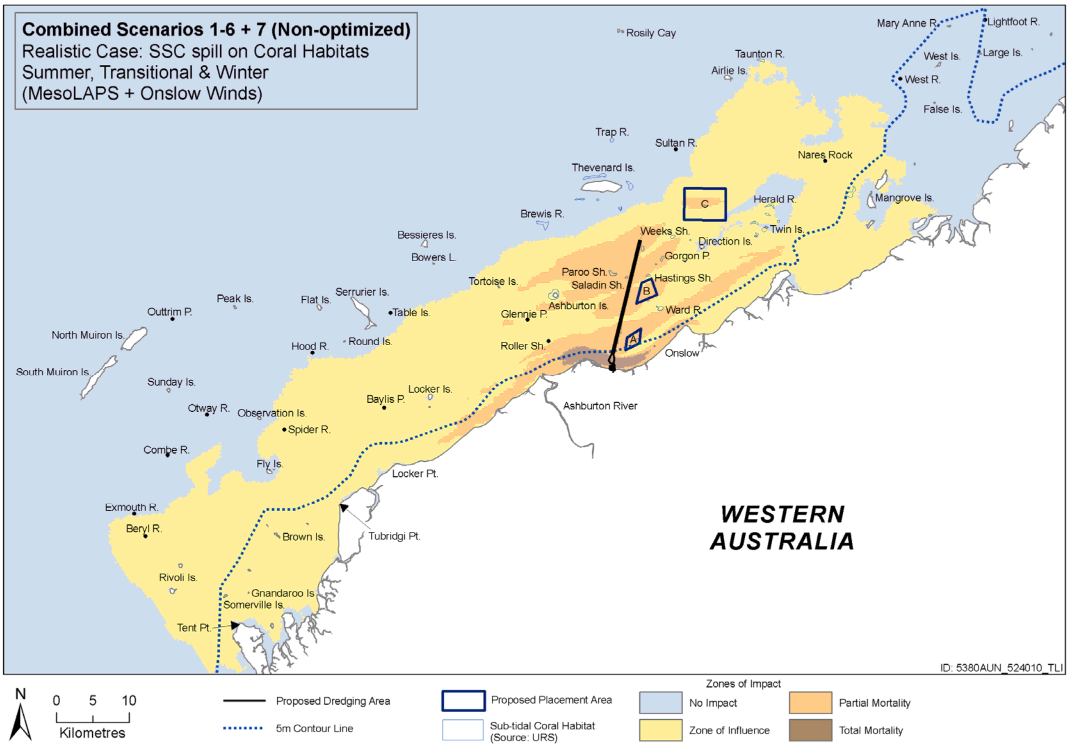


Figure 4.6 Impact zones derived from combined scenarios for SSC release on coral habitats.

5.0 HYDROCARBON SPILL MODELLING

Please refer to EIS Appendix Q2 for details of the hydrocarbon spill modelling carried out for the EIS.

Only the simulated spill within the MOF changes significantly with the Alternative MOF Layout. The spill at the PLF changes to a lesser degree due to the effects on the current fields at the PLF by the seaward extension of the western MOF breakwater. Both scenarios reported in EIS Appendix Q2 have been re-run in full with the Alternative MOF Layout. The main findings are briefly outlined below.

The Base Case MOF Layout encloses the spill within the MOF. Depending on wind and tide, the spill may remain within the MOF for an extended period of time before gradually “escaping” the MOF. The Alternative MOF Layout in contrast often induces a stronger eddy circulation running through the MOF basin, and this may draw the spill out from the MOF basin. This is illustrated in Figure 5.1 to Figure 5.3 which compares instantaneous distributions of the spills for the two layouts 0.5, 1.5, 3 and 6 hours after the spill occurred for scenarios during summer, transitional and winter conditions, respectively. For the summer scenario, the spill is still in the MOF entrance area after 6 hours for the Base Case MOF Layout, whereas it has moved more than a kilometre to the east under the prevailing current and wind conditions for the Alternative MOF Layout. A similar pattern of higher and faster dispersion for the Alternative MOF Layout it found for the transitional scenario. For the shown winter scenario, the plume is exiting the MOF basin after 6 hours for the Base Case MOF Layout, whereas it is caught in the eddy within the MOF for the Alternative MOF Layout.

Whereas the patterns vary with current and wind conditions, it generally leads to a higher probability of exposure and a shorter time to exposure for the Alternative MOF Layout compared to the Base Case MOF Layout. . This is illustrated in Figure 5.4 and Figure 5.5 for summer conditions. It is noted that the shown times of exposure in Figure 5.5 are the “minimum” time derived from a large number of simulations. Some spills escape from the MOF relatively quickly, also for Base Case MOF Layout, and the difference in minimum time of exposure is therefore limited.

MOF - Summer

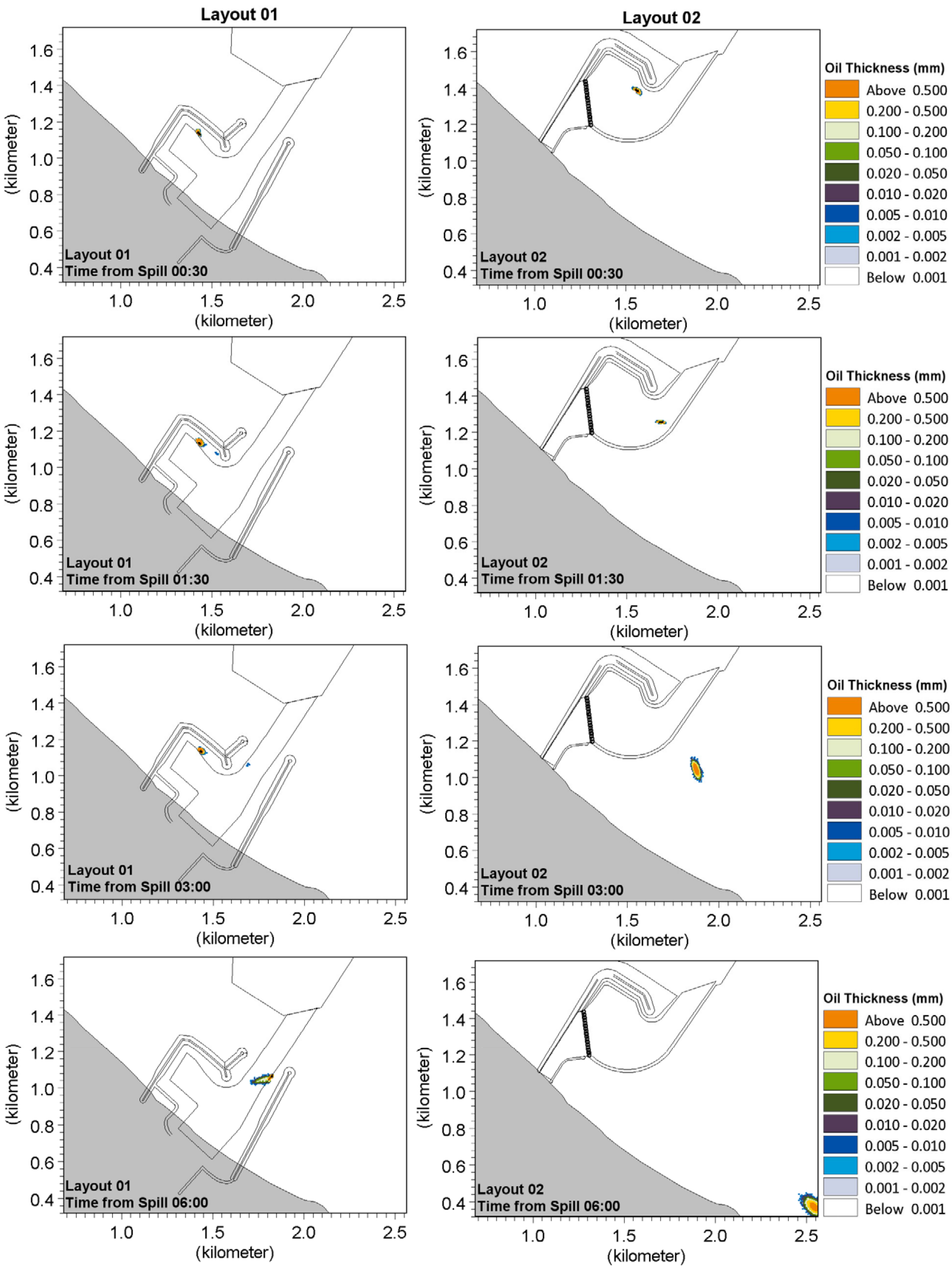


Figure 5.1 Sample comparison of instantaneous plumes in the Base Case MOF Layout (Layout 01 on the left) and Alternative MOF Layout (Layout 02 on the right) for summer climatic conditions.

MOF - Transitional

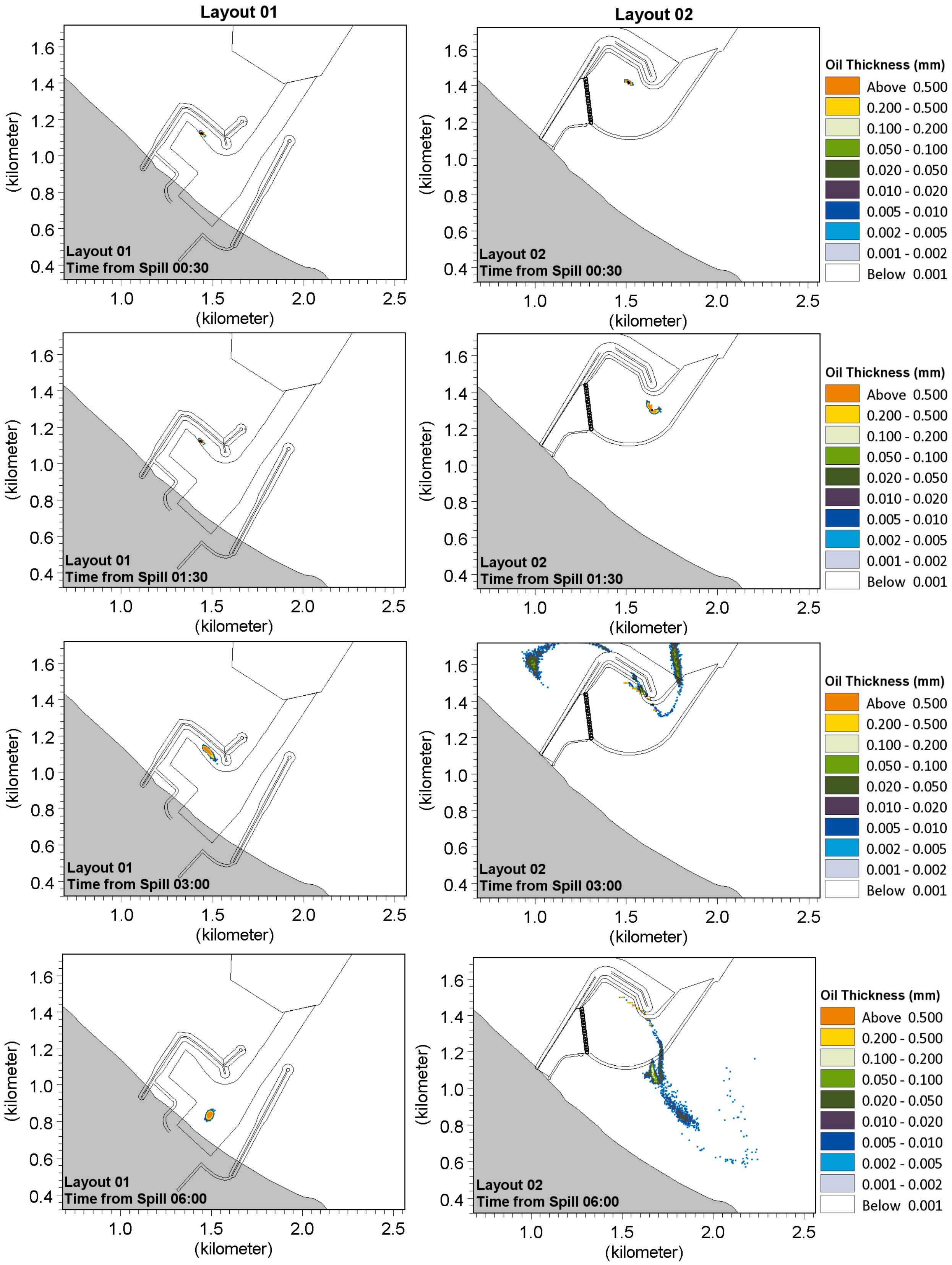


Figure 5.2 Sample comparison of instantaneous plumes in the Base Case MOF Layout (Layout 01 on the left) and the Alternative MOF Layout (Layout 02 on the right) for transitional climatic conditions.

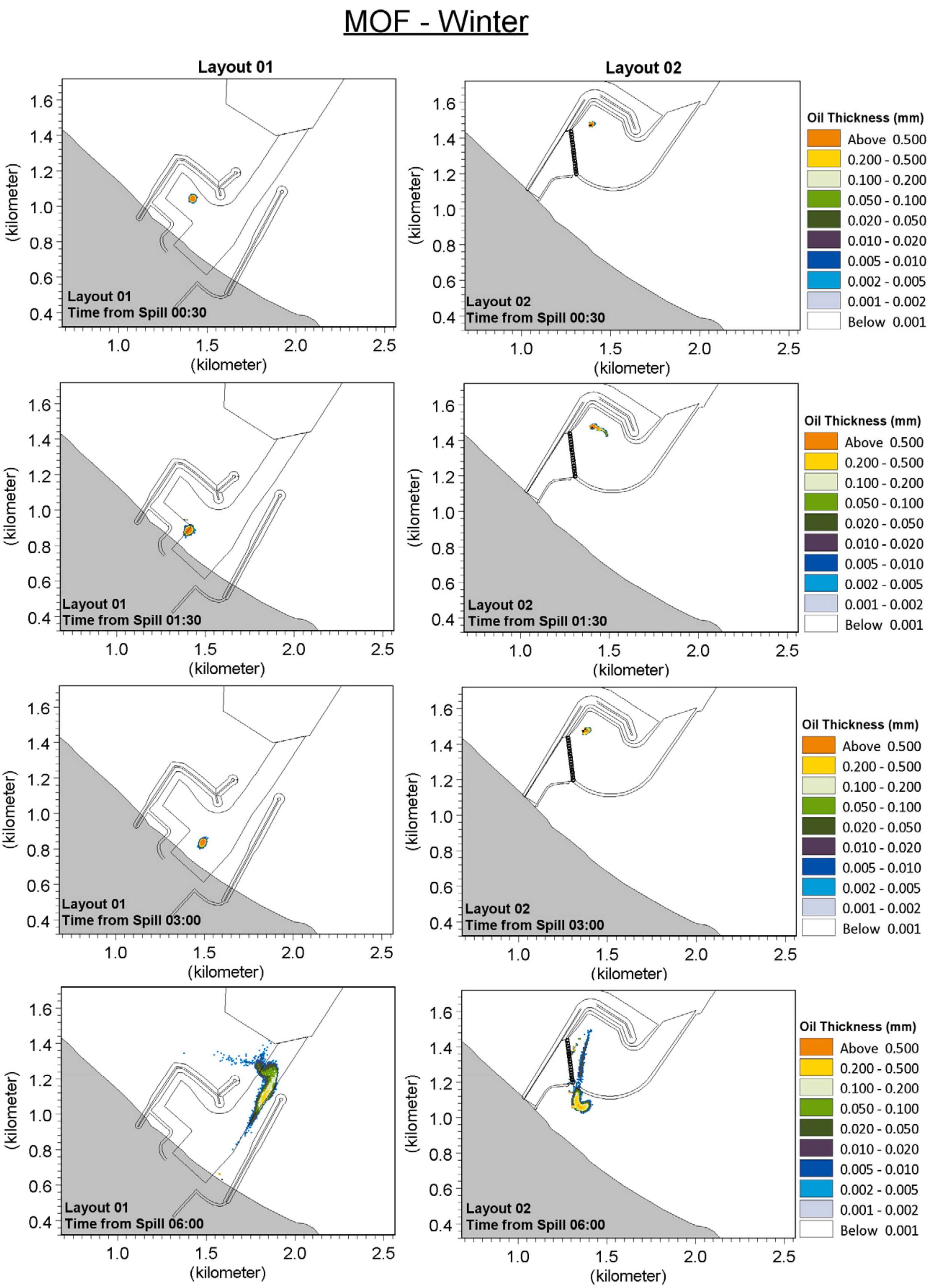


Figure 5.3 Sample comparison of instantaneous plumes in the Base Case MOF Layout (Layout 01 on the left) and the Alternative MOF Layout (Layout 02 on the right) for winter climatic conditions.

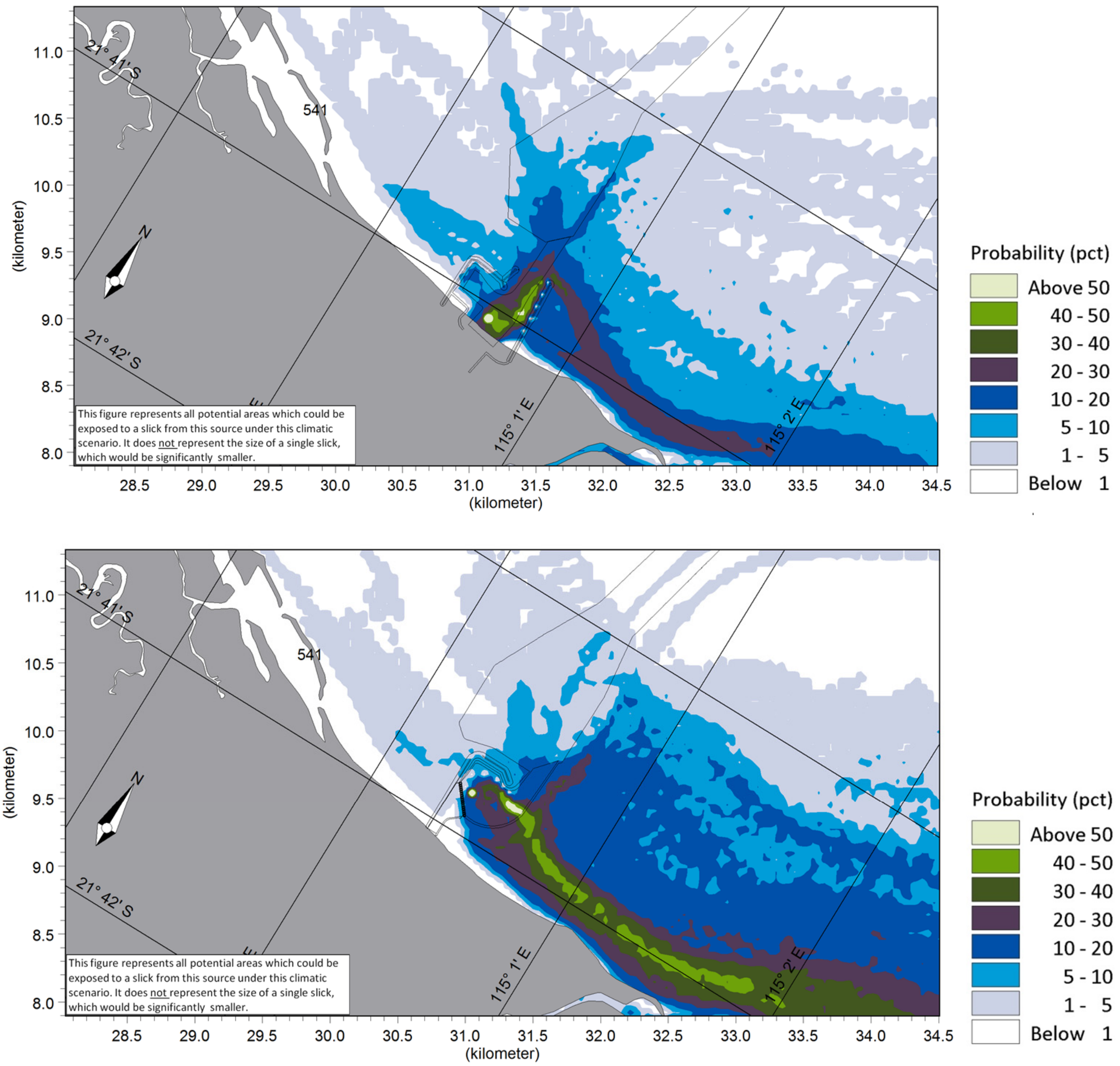
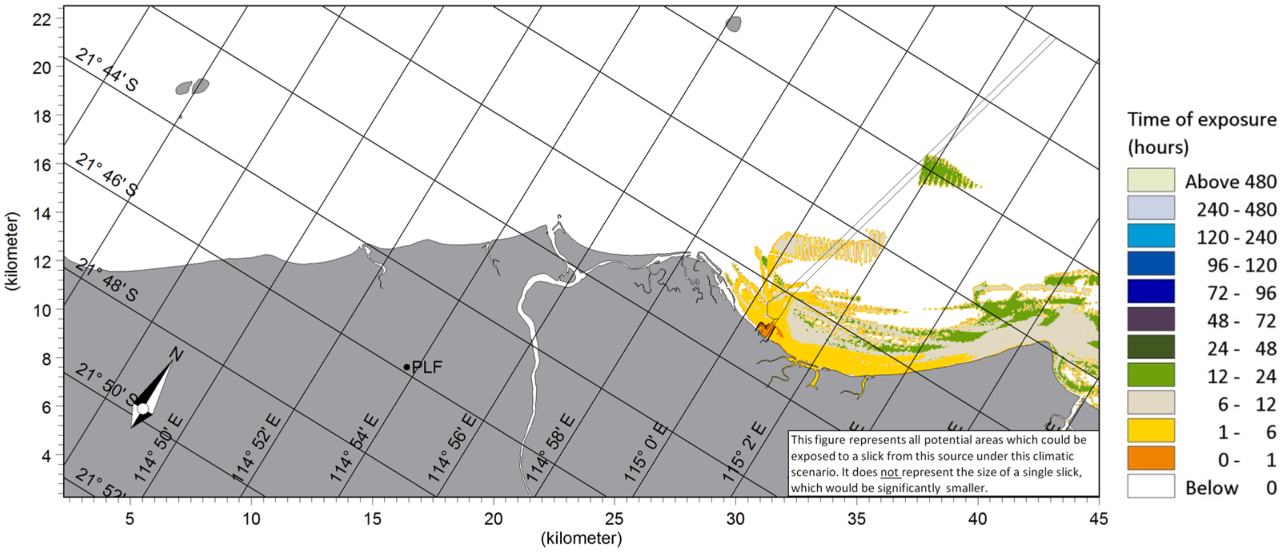


Figure 5.4 Comparison of simulated probability of exposure in vicinity of MOF for Base Case MOF Layout (top) and Alternative MOF Layout (bottom). Diesel spill in MOF basin during summer conditions.



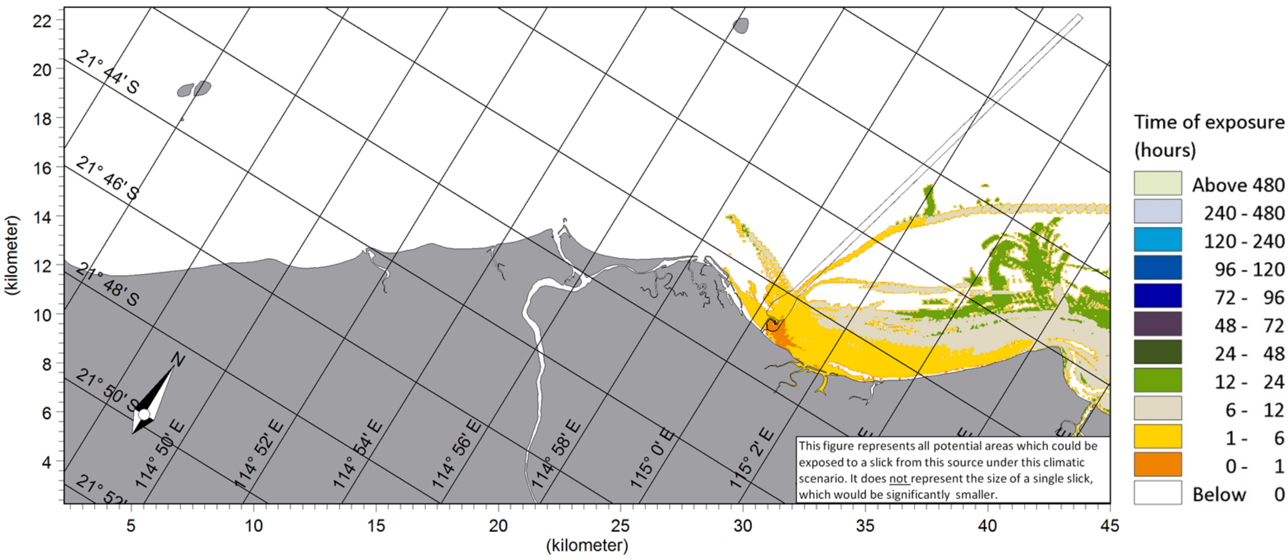


Figure 5.5 Comparison of simulated first time of exposure for Base Case MOF Layout (top) and Alternative MOF Layout (bottom). Diesel spill in MOF basin during summer conditions.

Appendix FK

EPA Requirement Notice 2010 Written Report

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APPENDICES

1.0 INTRODUCTION

Chevron Australia Pty Ltd (Chevron Australia) is the proponent of the Wheatstone Project (Project), a proposed Liquefied Natural Gas (LNG) and domestic gas (Domgas) plant at the Ashburton North site in the Shire of Ashburton, situated approximately 12 km south-west of Onslow. The site has operated as a pastoral station for over 100 years.

The Project was referred to the Environmental Protection Authority (EPA) in October 2008 under section 38 of the Act and an ERMP level of assessment was set.

For the purposes of the Environmental Protection Authority's assessment of the Wheatstone project, pursuant to section 40(2) of the Environmental Protection Act 1986 (the Act), the EPA required that Chevron Australia undertake an environmental review and report thereon.

In June 2010, to further inform the environmental review, Chevron Australia was directed by the EPA under Section 40(2)(b) of the Act to undertake additional site investigations, and thereby authorised (subject to compliance with certain conditions) to clear native vegetation for the purpose of conducting those site investigations.

The directions were communicated to Chevron Australia in letters received from the EPA on the 4th and 18th of June 2010. Four separate but similarly worded *Requirement Notices* (RN 2908/4, RN 3052/2, RN 3165/2 and RN 2915/3) were issued with these letters. An additional Requirement Notice (3846/1) and an updated Requirement Notice (3165/3) was issued to Chevron Australia under cover of EPA correspondence dated the 17th September 2010. Each Requirement Notice applied to a different spatial area.

This document typically refers to the Requirement Notices solely by their primary number (e.g. 3165) and no distinction is made between the revisions (e.g. 3052/1 vs. 3052/2) except where it is essential for compliance reporting.

Part II, sections 10 and 11 of RN 2908, RN 3052, RN 3165 and RN 3846; and sections 2 and 3 of RN 2915; require Chevron Australia report the outcomes of the investigations, to keep certain records relating to the cleared vegetation and to report on those records. This document has been prepared to fulfil those reporting requirements.

2.0 BACKGROUND

2.1 Investigation Area

The Ashburton North site extends over several pastoral stations, non-operational parts of the Onslow Salt mining lease and the waters of the Onslow Port Area. Geotechnical and archaeological investigations were categorised by Chevron as Onshore or Nearshore.

- Onshore investigations were implemented on land (including the inter-tidal mudflats) described in RN 2908, RN 3052, RN 3165 and RN 3846; and
- Nearshore investigations were implemented on the beach, seabed and sub-tidal coastal shoreline described in RN 2915.

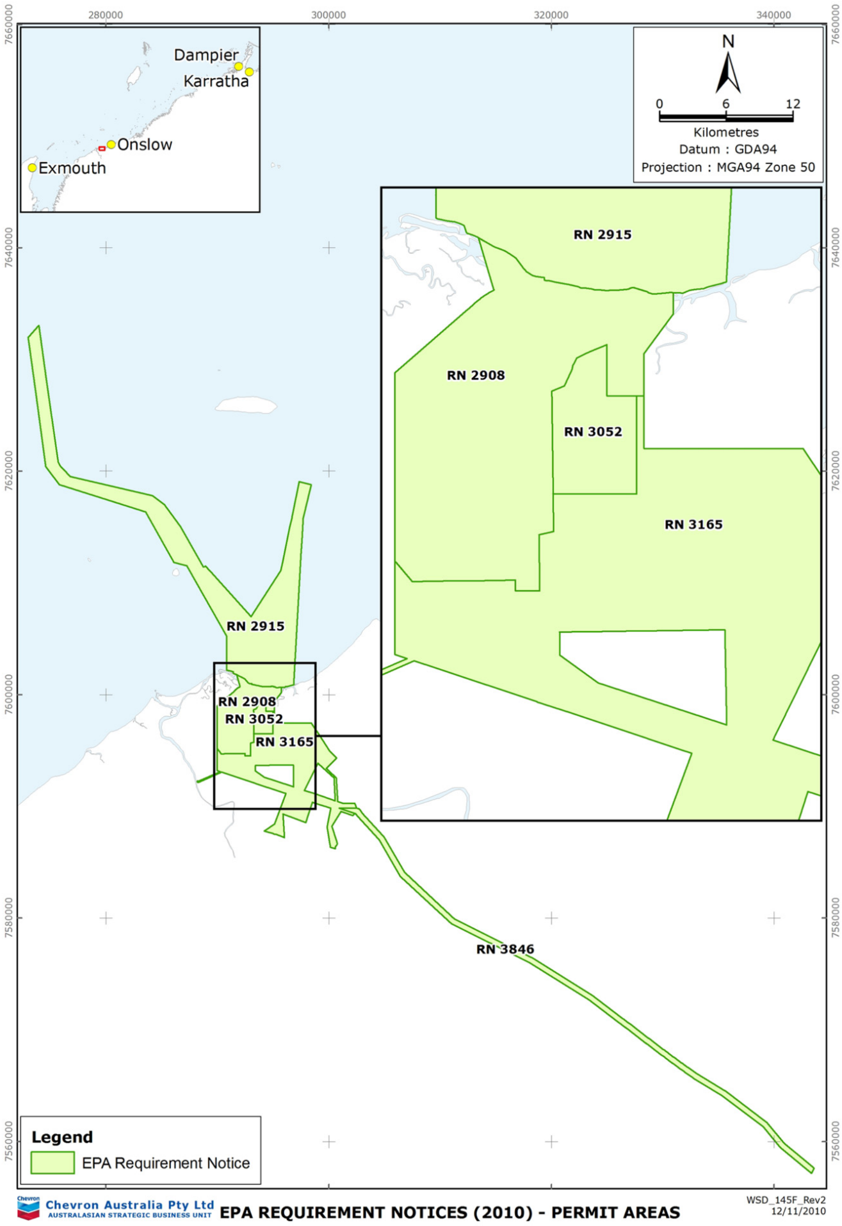

Figure 1 – EPA Requirement Notice Locations and Boundaries

3.0 SITE INVESTIGATIONS

3.1 Onshore

The onshore investigations undertaken by Chevron Australia under the direction of the requirement notices are outlined below:

Geotechnical

Onshore geotechnical investigation activities comprised the construction of cored boreholes, static cone penetrometer testing, test pit excavations, potential acid sulphate soil sampling and the installation of groundwater monitoring wells.

This work was undertaken to improve confidence in the subsurface characteristics of the project area, to enable the identification of any necessary adjustments in the location, alignment or design of the infrastructure that is proposed to be constructed and operated.

Investigations were also conducted within proposed borrow pit locations, allowing for the geotechnical characteristics and available volume of fill material resource to be better understood. The installed groundwater wells continue to be monitored as part of the ongoing hydrological monitoring program.

Archaeological

Onshore archaeological investigations comprised the implementation of excavations and surveys of the Old Onslow jetty port area and tram causeway, in accordance with a plan approved by the Heritage Council of Western Australia (HCWA) after consultation with the WA Maritime Museum and Shire of Ashburton.

These investigations were required to assist in identifying and assessing any potential impact of the Wheatstone Project on heritage values associated with the original Onslow settlement, which was established in 1883 and abandoned in 1927.

3.2 Nearshore

The nearshore investigations undertaken by Chevron Australia under the direction of the requirement notices are outlined below:

Geotechnical

Nearshore geotechnical investigation activities comprised the construction of cored boreholes and static cone penetrometer testing conducted from small nearshore jack-up platforms.

These investigations were undertaken to improve confidence in the definition of subsurface characteristics within the project area, thereby enabling the identification of any adjustments in the location, alignment, design and construction methods for the infrastructure that is proposed to be constructed in the nearshore area.

4.0 INVESTIGATION OUTCOMES

Chevron has conducted the investigations required by the EPA Requirement Notices issued under section 40(2)(b) of the Act. Those investigations have provided additional information to assist the assessment of the following components of the Wheatstone Project proposal:

- Pipeline Shore Crossing
- Onshore Infrastructure and Facilities
- Fill Sources (Quarries / Borrow Pits)
- Domestic Gas Pipeline
- Seabed Dredging and Trenching

The conditions of the requirement notices require that Chevron provide a written report to the EPA of the activities it has undertaken under the direction of the requirement notice; on or before the time when Chevron Australia lodges its response to the public submissions made in respect of the environmental review.

The outcomes of the investigation activities have contributed to an improved understanding of the project area, and improved confidence in the technical feasibility of the proposed project location, design and construction methods. In addition, pre-clearing flora inspections have improved our knowledge of the vegetation and flora of the site.

The outcomes have assisted in the preparation of responses to submissions received during the EIS/ERMP public review period and in responding to information requests from the EPA. Further details on the outcomes of the investigations are provided below.

4.1 Onshore Geotechnical

Pipeline Shore Crossing

The preferred option for the pipeline shore crossing is to use the micro-tunnelling technique. This would reduce the impact on the environment considerably, but requires a detailed investigation to assess the suitability of the subsurface.

The geotechnical investigations within RN 2908 and RN 2915 collected information to assess whether the micro-tunnelling technique is technically feasible. Preliminary findings suggest it to be so; however a final determination is subject to final materials analysis reports. The investigations have also improved our understanding of acid sulphate soil risk and erosion risk posed by the coastal and nearshore sediments.

Onshore Infrastructure and Facilities

Geotechnical core drilling and probe testing was undertaken within RN 2908, RN 3052 and RN 3165 with the drilling of several groundwater monitoring wells and geophysics surveys also occurring within RN 3165. The collation of this data has improved knowledge of the soils, geology and hydrogeology. The site investigations confirmed the geotechnical suitability of the proposed locations and alignments of onshore infrastructure and facilities within the LNG Plant area, shared infrastructure corridor and construction camp area. The investigations found no major geological constraints to the construction and operation of the onshore infrastructure for the Wheatstone Project.

Fill Sources (Quarries / Borrow Pits)

As the majority of the site is very low (<10 mAHD) and susceptible to inundation from flooding and storm surge events, the EIS/ERMP identified the need for a substantial volume of fill materials with the geotechnical characteristics to provide a safe structural base and armour protection for the LNG plant infrastructure and facilities. At the same time, the fill material needed to be close enough to the project site to reduce transport emissions during construction.

Geotechnical investigations within RN 3052 and RN 3165 confirmed that the four nearby potential fill sources that were proposed as borrow pit locations in the EIS/ERMP contain fill materials with characteristics considered suitable for the project requirements.

Domestic Gas Pipeline

Geotechnical test pits were excavated at selected points along the alignment of the domestic gas pipeline that was proposed in the EIS/ERMP. The results from these test pit excavations (within RN 3846) suggest that trenching may require heavier than normal excavation equipment and possibly the use of special rock breaking methods in certain locations.

The test pit reports also provided preliminary information on excavation stability, trafficability and soil and groundwater conditions; however this information cannot be confirmed until the completion of laboratory analysis. The finalised data will aid in assessing the technical feasibility of proposed construction methods.

A detailed topographical survey of the proposed domestic gas pipeline alignment was conducted in October 2010. It identified an opportunity to optimise the alignment by relocating the 12 kilometre section south of Twitchen Road to the flat/level ground on the eastern side of Onslow Road. This optimisation would make construction easier, whilst also avoiding impacts on a dune landform that has greater vegetation and visual landscape values. It should be noted that for the relocation of the Wheatstone domestic gas pipeline alignment to have full value, any pipeline alignments proposed by third parties would also need to be located on the eastern side of Onslow Road.

4.2 Onshore Archaeological

Archaeological investigations were undertaken at the Old Onslow Townsite port and jetty areas and along the Old Onslow tramway/causeway. Activities comprised DGPS surveys and 3D digital feature mapping, trench and test square excavations, and the methodical recording of all discovered artefacts. The key outcomes from the onshore archaeological investigations are listed below:

Terrestrial Archaeology

Six archaeological trenches and a total of 23 test squares were excavated within the old port and tramway/causeway area. A broad surface level artefact search was also conducted, as well as an excavation of a trench across the tramway/causeway formation.

Within the old tramway-causeway area, remnant sections of tramway and visible artefacts were surveyed, including timbers from a 20th century jetty; and a single archaeological trench was excavated across the tramway-causeway formation.

A total of 9170 artefacts and fragments of cultural material were collected for further laboratory analysis; however the significance of these findings is yet to be determined by the Heritage Council of Western Australia.

Marine Archaeology

Six sites were examined adjacent to the lagoon shoreline. The discovery of the construction drawings for the second Onslow jetty (1899) revealed the location of the first Onslow jetty (1896) and the subsequent discovery of artefacts from both jetty structures.

The subsequent overlaying of recent magnetic resonance imaging data over the construction drawings showed numerous magnetic anomalies along the alignment of the first Onslow jetty (1896). The nearest anomalies are approximately 20 metres from the nearest pylons of the LNG loading jetty as proposed in the EIS/ERMP.

The heritage significance of the 1896 and 1899 jetties and associated artefacts will be determined by the Heritage Council of Western Australia and the WA Maritime Museum.

4.3 Nearshore Geotechnical

The near shore investigative works program was aimed at defining the subsurface and seabed conditions at the locations of the LNG jetty, Material Offloading Facility (MOF), and gas feed pipelines. The key outcomes from the nearshore geotechnical investigations are listed below:

Nearshore Infrastructure

Nearshore investigative works included cored boreholes and static cone penetrometer tests (CPTs) conducted from small nearshore Jack-Up platforms within RN 2195.

These site investigations have improved Chevron's confidence in the geotechnical suitability of the proposed locations and alignments of nearshore infrastructure. It also provided information to assist with the calibration and validation of dredge and trench plume modelling.

The information has assisted with the finalisation of the project design and construction methods; the preparation of responses to EIS/ERMP submissions and the selection of environmental management measures for the proposed dredging and trenching works.

5.0 VEGETATION MANAGEMENT

5.1 Authorised Clearing

The requirement notices authorise the clearing of vegetation where necessary to undertake the required investigations, subject to compliance with certain conditions. The conditions define the authorised area of clearing and the spatial boundaries within which the investigations and ancillary vegetation clearing are authorised.

'Clearing' is defined in the *Environmental Protection Act* (1986) as:

(a) the killing or destruction of;
(b) the removal of;
(c) the severing or ringbarking of trunks or stems of; or
(d) the doing of any other substantial damage to, some or all of the native vegetation in an area, and includes the draining or flooding of land, the burning of vegetation, the grazing of stock, or any other act or activity, that causes:
(e) the killing or destruction of;
(f) the severing of trunks or stems of; or
(g) any other substantial damage to, some or all of the native vegetation in an area;

The EPA requirement notices had regard for clearing areas and boundaries authorised by Vegetation Clearing Permits previously issued within the Ashburton North project area by the Department of Environment and Conservation (DEC).

The EPA requirement notices authorised the clearing of vegetation as follows:

- Additional clearing of up to 5.0ha of native vegetation for the purposes of geotechnical investigations and archaeological excavation in the expanded spatial boundaries depicted in Plan 2908/4;

- Additional clearing of up to 1.5ha of native vegetation for the purposes of geotechnical investigations within the original area depicted in Plan 3052/2.

- Additional clearing of up to 10ha of native vegetation for the purposes of geotechnical investigations; within an expanded area depicted in Plan 3165/3.

- Clearing up to 8 hectares of native vegetation for the purposes of geotechnical investigations; within the area depicted in Plan 3846/1.

- Clearing of up to 1.0 ha of native vegetation for the purpose of geotechnical investigations; within the original area depicted in Plan 2195/3.

The history of the DEC Vegetation Clearing Permits and EPA Requirement Notices are summarised below in Table 5.1 and Table 5.2.

Table 5.1 – Onshore Permit and Requirement Notice History

Permit/ Notice No.	Amendment Purpose	Change to Conditions	Approval Date
CPS 2908/1	Original Permit (5 ha)	NA	5 March 2009
CPS 2908/2	Increase clearing area from 5 ha to 15 ha	Condition 3 changed to specify 15 ha.	27 April 2009
CPS 2908/3	Increase clearing area from 15 ha to 25 ha	Condition 3 changed to specify 25 ha.	8 October 2009
RN 2908/3	Initial Requirement Notice		4 June 2010
RN 2908/4	Initial Requirement Notice. Increased clearing area from 25 ha to 30 ha	Condition 3 changed to specify 30 ha and phrasing and definitions were modified to improve consistency between RNs.	18 June 2010
CPS 3052/1	Original Permit (3.5 ha)	NA	30 April 2009
RN 3052/1	Initial Requirement Notice		4 June 2010
RN 3052/2	Increase clearing area from 3.5 ha to 5 ha	Condition 3 changed to specify 5 ha and phrasing and definitions were modified to improve consistency between RNs.	18 June 2010
CPS 3165/1	Original Permit (15 ha)	NA	10 July 2009
RN 3165/1	Initial Requirement Notice		4 June 2010
RN 3165/2	Increase clearing area from 15 ha to 25 ha	Condition 3 changed to specify 25 ha and phrasing and definitions were modified to improve consistency between RNs.	18 June 2010
RN 3165/3	Increased boundaries within which clearing can occur.	No change to conditions by Plan 3195 modified.	17September 2010
RN 3846/1	Initial Requirement Notice (8 ha)	NA	17 September 2010

Table 5.2 – Nearshore Permit and Requirement Notice History

Permit/ Notice No.	Amendment Purpose	Change to Condition	Approval Date
CPS 2915/1	Original Permit (0.5 ha)	NA	9 May 2009
CPS 2915/2	Increased boundaries within which clearing can occur.	No change to conditions but Plan 2915 modified.	11 June 2009
CPS 2915/3	Increase clearing area from 0.5 ha to 1 ha to facilitate a trenching trial.	Condition 3 changed to specify 1.0 ha.	17 December 2009
RN 2915/3	Initial Requirement Notice		4 June 2010

This document typically refers to the Requirement Notices solely by their primary number (e.g. 3165) and no distinction is made between the revisions (e.g. 3052/1 vs. 3052/2) except where it is essential for compliance reporting.

5.2 Records and Reporting

The conditions also require the implementation of management procedures and the keeping and reporting of records to demonstrate compliance with the conditions. Not all of the notices share exactly the same conditions. The applicability of the various conditions is summarised below in Table 5.3.

Table 5.3 – Summary of Reporting Requirements for Requirement Notices

Requirement	2908	3052	3165	3846	2915
Perform pre-clearing conservation significant taxa inspections.	Y	Y			
Perform pre-clearing priority flora taxa inspections.			Y		
Perform pre-clearing priority or undescribed flora or Eleocharis papillose inspections.				Y	
Within 18 months of laying vegetative material and topsoil on the cleared area, record and report the species composition, structure and density of the area revegetated and rehabilitated.	Y	Y	Y	Y	
Record and report the species composition, structure and density of cleared area.	Y	Y	Y	Y	Y
Record and report location of vegetation clearing using GDA94 expressed in eastings and northings.	Y	Y	Y	Y	Y
Record and report the date the vegetation clearing took place.	Y	Y	Y	Y	Y
Record and report the size of the cleared area (in hectares).	Y	Y	Y	Y	Y
Record and report Conservation Significant taxa locations using GDA94 as eastings and northings.	Y	Y			
Record and report the species of Conservation Significant taxa identified.	Y	Y			
Record and report the priority flora location using GDA94 expressed in eastings and northings.			Y		
Record and report the species of priority flora identified.			Y		
Record and report the priority or undescribed flora or Eleocharis papillose location using GDA94 expressed in eastings and northings.				Y	
Record and report the species of priority or undescribed flora identified.				Y	
Translocate mangrove specimens that would otherwise being cleared, then monitor the survival success and report this to the EPA.	Y				
Record and report the respread of vegetative materials location using GDA94 expressed in eastings and northings.	Y	Y	Y	Y	
Record and report the size of the areas where vegetative material was respread (in hectares).	Y	Y	Y	Y	

5.3 Activity Descriptions

Descriptions of the above-mentioned site activities are presented below with details on how their vegetation clearing impact was calculated. Photographs indicating the vegetation clearing impacts resulting from those activities are presented in Appendix 2.

5.3.1 Pad Clearing

Onshore Drill Pads

Geotechnical drill pads and groundwater monitoring well drill pads were created to provide a stable and safe working area for the drill-rig and personnel. Each pad varies in area (but is typically 0.03 ha) and was cleared using a backhoe to strip and temporarily stockpile the vegetation and topsoil, which was reinstated at a later time. The recorded pad clearing area also includes any peripheral clearing resulting from the rolled wheeltracks of vehicles that support and surround the drill rig.

Onshore Geotechnical CPT Pads

The cone penetrometer test (CPT) is performed from a heavy vehicle (CPT rig) that is driven over vegetation without requiring the stripping of vegetation or topsoil. Clearing for CPT pad access is included within the access track calculations as the actual CPT caused less than 0.5 m^2 of vegetation clearing, which results from the four outboard stabiliser legs used to brace the CPT rig. The CPT probe is under 5 cm in diameter and is penetrated without clearing vegetation.

Onshore Geotechnical Test Pits

Geotechnical test pits are conducted using a backhoe to excavate the ground to a specified depth or refusal. Each excavation has a clearing footprint less than 5 m^2 which includes the pit excavation, impact of the backhoe stabiliser legs and area where the vegetation, topsoil and pit material is stockpiled pending backfilling and reinstatement.

Onshore Geotechnical Geophysics Survey Grids

Gridlines were cleared within RN 3165 using a backhoe to strip vegetation and topsoil, upon which refractive geophysics surveys were undertaken. The average width of a stripped geophysics gridline was 1.8 metres.

Onshore Archaeological Activities

Archaeological investigations resulted in a variety of different sized clearing footprints. The various excavation locations were connected by defined access walkways and supported by archaeological work tent locations.

Nearshore Geotechnical Drilling and CPT Probes

The nearshore geotechnical activities were conducted from drilling and/or CPT rigs mounted on a four-leg jack-up barge. The estimated impact footprint of drilling was 5 m^2, whereas a combination of drilling and CPT testing resulted in an impact footprint of 8 m^2. These footprints are conservative but reflect the footprint of each jack-up leg, the drill/probe impact and the movement of the legs when performing both drilling and a CPT probe at the same location. It should also be noted that these investigations occurred where the seabed had either 5% cover of seagrass or 15% cover of macroalgae (URS, 2010), so it is considered likely that these Nearshore activities resulted in negligible clearing of marine vegetation.

5.3.2 Track Clearing

General Access Track

Access track was created over non-tidal areas by rolling vehicles and tracked machinery over the low grassland, low dune scrubland and/or samphire mudflat that dominates the site. The nominal wheeltrack width for general access tracks is 1.0 m (2 x 0.5 m) and reflects the varied tyre widths of the different site vehicles and the ongoing use of the tracks for several days or in some cases, months.

General Access Track calculations account for all clearing resulting from rolled tracks created by onshore investigation activities, other than the clearing resulting from the flattening of woody samphire vegetation by the Dura-Base mats and Marsh Buggy described separately below.

Dura-Base Track

Interconnecting Dura-Base plastic matting was laid over samphire (*Tecticornia* spp.) mudflat to provide a trafficable surface for heavy drill rigs to travel over damp ground without bogging. The Dura-Base mat is a 4.5 m wide interlocking plastic mat that spreads the wheel-bearing weight of vehicles across a wider ground surface to prevent them from bogging. This helped to avoid the visual scars and the duplication of tracks that result from bogged vehicles and the subsequent recovery efforts.

Marsh Buggy Track

Marsh buggy track was created by a tracked platform designed to traverse waterlogged and marshy damp ground without bogging. The low ground pressure of its broad tracks allowed heavy vehicles and machinery to be transported to locations where the use of Dura-Base Mat was not feasible. The use of the marsh buggy helped to avoid the visual scars and the duplication of tracks that result from bogged vehicles and recovery efforts.

Multiple Use Tracks

It should be noted that tracks were often used by different types of vehicles. A track that was pre-inspected and subsequently traversed by the Argo ATV might later be used by the Marsh Buggy.

Chevron has considered the wheeltracks of vehicles and machinery when calculating the clearing footprint of access tracks. This is reflected in the “Track Type” and “Width” columns in the tables presented in Appendices 4-9.

Vegetation clearing from tracks created before the 4th June 2010 (under the authority of DEC vegetation clearing permits) is not reported in this document. Those tracks will be reported in the separate annual reports that Chevron will prepare in early 2011 for its DEC vegetation clearing permits.

6.0 COMPLIANCE REPORTING

6.1 Requirement Notice 2908

Requirement Notice (RN) 2908 authorised the clearing of native vegetation for the purpose of geotechnical investigations and archaeological excavation. Figure 1 depicts the location and spatial boundaries of the permit area.

Data Recording and Reporting

Part II of RN 2908 requires that certain records be kept (Condition 10) and that those records be reported to the EPA at or before the response to public submissions stage of the assessment (Condition 11). Figures depicting the extent of clearing and tables containing the recorded data required to be reported are presented in Appendix 4 of this report, which is being submitted to the EPA in November 2010.

Condition 7 of this requirement notice requires a pre-clearing inspection for conservation significant taxa to be completed by a flora specialist and that records and protective measures be taken in the event of any taxa being identified.

Chevron utilised a Permit to Work system to ensure these inspections were completed. Records of all conservation significant taxa were submitted to the Department of Environment and Conservation in November 2010.

A summary of the required reporting data is provided in Table 6.1 and Table 6.2 below.

Table 6.1: RN 2908 Clearing Control

RN	Authorised Clearing Area (ha)	Work Pad Clearing (ha)	Track Clearing (ha)	Total Clearing (ha)	Cumulative Total Clearing Area (ha)
2908	30	0.17 #	0.86 #	1.03 #	17.62 *

Work completed during the requirement notice reporting period from the 4th of June 2010 to on or before the response to the public submissions is provided.
* Cumulative totals account for additional clearing overlapping earlier Chevron clearing footprints.

Table 6.2: RN 2908 Conservation Significant Taxa Records

Taxa	Pre-known Locations	New Locations	Interacting New Locations	Impacts on Taxa
Abutilon sp.	5	62	>15*	0

* A targeted search for Abutilon sp. conducted prior to the commencement of the archaeological investigations revealed numerous specimens located less than ten metres from a pre-existing vehicle track that is part of the Shire of Ashburton's Old Onslow Heritage Trail.

Furthermore, it should be noted that Condition 7(c) of this requirement notice requires the translocation of mangrove taxa, their survival rate to be monitored and the data reported to the EPA. Some translocations were performed to accommodate geotechnical investigations for the proposed pipeline shoreline crossing and the mangrove monitoring data is presented in Appendix 4 of this report.

Vegetation Management

Chevron implemented the management measures described in Section 7 of this report through site environmental management procedures, training and site induction processes, and the implementation of the Wheatstone Project permit to work system.

Compliance Summary

A review of the data in Appendix 4 and records collected by Chevron's Permit to Work system indicate that:

- Vegetation clearing did not exceed the maximum area authorised by RN 2908.
- Vegetation clearing did not occur outside the boundaries depicted in Plan 2908/4.
- Inspections were always conducted for conservation significant taxa prior to clearing any vegetation under the authority this requirement notice.
- Mangrove taxa were translocated instead of being cleared, and data recorded to enable the translocation survival rate to be reported to the EPA in this report.
- Stripped topsoil and vegetation was stockpiled and reinstated within an optimal timeframe, this typically being less than 30 days.
- All the applicable management measures described in Section 7 of this report were implemented to fulfil all the other conditions of the requirement notice.

6.2 Requirement Notice 3052

Requirement Notice 3052 authorised the clearing of native vegetation for the purpose of geotechnical investigations. Figure 1 depicts the location and spatial boundaries of the permit area.

Data Recording and Reporting

Part II of RN 3052 requires that certain records be kept (Condition 10) and that those records be reported to the EPA at or before the response to public submissions stage of the assessment (Condition 11). Figures depicting the extent of clearing and tables containing the recorded data required to be reported are presented in Appendix 5 of this report, which is being submitted to the EPA in November 2010.

Condition 7 of this requirement notice requires a pre-clearing inspection for conservation significant taxa to be completed by a flora specialist and that records and protective measures be taken in the event of any taxa being identified.

Chevron utilised its Permit to Work system to ensure these inspections were completed and protective measures implemented, however no conservation significant taxa were found during the pre-clearing inspections.

A summary of the required reporting data is provided in Table 6.3 below.

Table 6.3: RN 3052 Clearing Control

RN	Authorised Clearing Area (ha)	Work Pad Clearing (ha)	Track Clearing (ha)	Total Clearing (ha)	Cumulative Total Clearing Area (ha)
3052	5	0.0 #	0.42 #	0.42 #	3.60 *

Work completed during the requirement notice reporting period from the 4th of June 2010 to on or before the response to the public submissions is provided.
* Cumulative totals account for additional clearing overlapping earlier Chevron clearing footprints.

Vegetation Management

Chevron implemented the management measures described in Section 7 of this report through site environmental management procedures, training and site induction processes, and the implementation of the Wheatstone Project permit to work system.

Compliance Summary

A review of the data in Appendix 5 and records collected by Chevron's Permit to Work system indicate that:

- Vegetation clearing did not exceed the maximum area authorised by RN 3052.
- Vegetation clearing did not occur outside the boundaries depicted in Plan 3052/2.
- Inspections were always conducted for conservation significant taxa prior to clearing any vegetation under the authority this requirement notice.
- Stripped topsoil and vegetation was stockpiled and reinstated within an optimal timeframe, this typically being less than 30 days.
- The applicable management measures described in Section 7 of this report were implemented to fulfil all the other conditions of the requirement notice.

6.3 Requirement Notice 3165

Requirement Notice 3165 authorised the clearing of native vegetation for the purpose of geotechnical investigations within the proposed shared infrastructure corridor and camp site area for the Wheatstone Project. Figure 1 depicts the location and spatial boundaries of the permit area.

Data Recording and Reporting

Part III of RN 3165 requires that certain records be kept (Condition 10) and that those records be reported to the EPA at or before the response to public submissions stage of the assessment (Condition 11).

It should be noted that Condition 7 requires a pre-clearing inspection to be conducted for *priority flora* and that records and protective measures be taken if any are found.

Chevron elected however to conduct pre-clearing inspections for *Conservation Significant Taxa* (as per RN 2908, RN 3052 and RN 3846) as this definition includes EPBC Act listed flora and ensured a consistently high standard of pre-clearing inspection would be conducted across the entire Ashburton North area. Chevron utilised its Permit to Work system to ensure these inspections were completed and protective measures would be implemented in the event that such flora were identified.

A summary of the required reporting data is provided in Table 6.4 and Table 6.5 below.

Table 6.4: RN 3165 Clearing Control

RN	Authorised Clearing Area (ha)	Work Pad Clearing (ha)	Track Clearing (ha)	Total Clearing (ha)	Cumulative Total Clearing Area (ha)
3165	25	3.72 #	4.0 #	7.72 #	9.72 *

Work completed during the requirement notice reporting period from the 4th of June 2010 to on or before the response to the public submissions is provided.
* Cumulative totals account for additional clearing overlapping earlier Chevron clearing footprints.

Table 6.5: RN 3165 Conservation Significant Taxa Records

Taxa	Pre-known Locations	New Locations	Interacting New Locations	Impacts on Taxa
Eremophila forrestii (P3)	10	3	0	0
Abutilon uncinatum (P1)	1	1	0	0

Vegetation Management

Chevron implemented the management measures described in Section 7 of this report through site environmental management procedures, training and site induction processes, and the implementation of the Wheatstone Project permit to work system.

Compliance Summary

A review of the data in Appendix 5 and records collected by Chevron's Permit to Work system indicate that:

- Vegetation clearing did not exceed the maximum area authorised by RN 3165.
- Vegetation clearing did not occur outside the boundaries depicted in Plan 3165/3.
- Inspections were always conducted for conservation significant taxa prior to clearing any vegetation under the authority this requirement notice.
- Stripped topsoil and vegetation was stockpiled and reinstated within an optimal timeframe, this typically being less than 30 days.
- The management measures described in Section 7 of this report were implemented to fulfil all the other conditions of the requirement notice.

6.4 Requirement Notice 3846

Requirement Notice 3846 authorised the clearing of native vegetation for the purpose of geotechnical investigations within the proposed Wheatstone Project domestic gas pipeline corridor. Figure 1 depicts the location and spatial boundaries of the requirement notice area.

Data Recording and Reporting

Part III of RN 3846 requires that certain records be kept (Condition 10) and that those records be reported to the EPA at or before the response to public submissions stage of the assessment (Condition 11).

It should be noted that Condition 7 requires a pre-clearing inspection for *priority or undescribed flora* or *Eleocharis paplilosa* to be completed and that records and protective measures be taken in the event of any are identified.

Chevron utilised its Permit to Work system to ensure these inspections were completed and protective measures would be implemented, however no significant flora were found during the pre-clearing inspections.

A summary of the required reporting data is provided in Table 6.6 below.

Table 6.6: RN 3846 Clearing Control

RN	Authorised Clearing Area (ha)	Work Pad Clearing (ha)	Track Clearing (ha)	Total Clearing (ha)	Cumulative Total Clearing Area (ha)
3846	8.0	0.63 #	0.59 #	1.22 #	1.22 *

Work completed during the requirement notice reporting period from the 4th of June 2010 to on or before the response to the public submissions is provided.
* Cumulative totals account for additional clearing overlapping earlier Chevron clearing footprints.

Vegetation Management

Chevron implemented the management measures described in Section 7 of this report through site environmental management procedures, training and site induction processes, and the implementation of the Wheatstone Project permit to work system.

Compliance Summary

A review of the data in Appendix 8 and records collected by Chevron's Permit to Work system indicate that:

- Vegetation clearing did not exceed the maximum area authorised by RN 3846.
- Vegetation clearing did not occur outside the boundaries depicted in Plan 3846/1.
- Inspections were always conducted for conservation significant taxa prior to clearing any vegetation under the authority this requirement notice.
- Stripped topsoil and vegetation was stockpiled and reinstated within an optimal timeframe, this typically being less than 30 days.
- The management measures described in Section 7 of this report were implemented to fulfil all the other conditions of the requirement notice.

6.5 Requirement Notice 2915

Requirement Notice 2915 authorised the clearing of native nearshore (marine environment) vegetation for the purposes of constructing cored boreholes and undertaking static cone penetrometers (CPT) tests. Figure 1 depicts the location and spatial boundaries of the permit area.

Data Recording and Reporting

Part III of RN 2195 requires that certain records be kept (Condition 2) and that those records be reported to the EPA at or before the response to public submissions stage of the assessment (Condition 3).

A summary of the required reporting data is provided in Table 6.7 below.

Table 6.7: RN 2915 Clearing Control

RN	Authorised Clearing Area (ha)	Work Pad Clearing (ha)	Trenching Trial (ha)	Total Clearing (ha)	Cumulative Total Clearing Area (ha)
2195	1.0	0.004 #	0.0 #	0.004 #	0.142 *

Work completed during the requirement notice reporting period from the 4th of June 2010 to on or before the response to the public submissions is provided.
* Cumulative totals account for additional clearing overlapping earlier Chevron clearing footprints.

As 2915 applied to the clearing of vegetation below the high water mark, it did not include any requirement to complete a pre-clearing inspection for priority flora, report any identified priority flora, or retain and later respread stripped topsoil and vegetative material at the completion of investigative activities.

Vegetation Management

Chevron implemented the management measures described in Section 7 of this report through site environmental management procedures, training and site induction processes, and the implementation of the Wheatstone Project permit to work system.

Compliance Summary

A review of the data in Appendix 9 and records collected by Chevron's Permit to Work system indicate that:

- Vegetation clearing did not exceed the maximum area authorised by RN 2915.
- Vegetation clearing did not occur outside the boundaries depicted in Plan 2915/3.
- The management measures described in Section 7 of this report were implemented to fulfil all the other conditions of the requirement notice.

7.0 VEGETATION MANAGEMENT

All requirement notices issued by the EPA include conditions requiring an Assessment Sequence and Management Procedure to be implemented by the proponent.

Accordingly, Chevron Australia implemented management measures to:

- Avoid and minimise clearing;
- Reduce the impact of clearing on environmental values;
- Avoid impacts on Conservation Significant Taxa and other sensitivities;
- Maximise the potential for natural regeneration of native vegetation; and
- Minimise the potential for the introduction and spread of weeds.

Specific measures implemented during these investigations include:

- Implementation of an updated site induction program to ensure personnel are aware and of new regulatory requirements.
- Implementing a permit to work system that requires the completion of a checklist and signature of the Chevron site manager prior to the implementation of any off-track activities, excavations or clearing of vegetation.
- Using pre-existing access tracks or pre-cleared footprints whenever practicable;
- Selecting clearing footprints within areas of previously cleared, disturbed and/or degraded vegetation; and/or with minimal erosion risk;
- Performing pre-clearing inspections to avoid potential impacts on Conservation Significant Taxa and other environmental sensitivities;
- Translocating mangrove specimens at risk of damage from machinery and activities during the geotechnical investigations within RN 2908.
- As far as practicable, creating tracks by rolling over vegetation instead of scraping away topsoil and overlying vegetation;
- Avoiding the potential duplication of tracks by selecting alignments more likely to remain trafficable in the event of rainfall or high tides;
- Restricting operations where access is constrained by rainfall, flooding or tidal inundation; in order to protect soil structure, topsoil and vegetation;
- Relocating proposed clearing footprints to prevent direct or indirect impacts on tentatively identified protected flora, fauna habitat and declared plants;
- Using pegs and flag tape to demarcate the 10-metre activity exclusion buffer around environmental sensitivities near operational areas;

- Using pegs and flag tape to designate the status of closed tracks and pad sites in order to control ongoing access and maximise natural regeneration from topsoil;

- Stockpiling topsoil displaced when clearing work pads and grid lines, then re-spreading the topsoil and cleared vegetative material within the clearing footprint as soon as possible after the completion of drilling works. This reduced topsoil loss and maximised the successful germination of native seed within that topsoil.

- Inspecting and as required, cleaning down vehicles/equipment at weed hygiene stations established at site entrances/exits; and also the pre-inspection and clean-down of vehicles/equipment prior to their initial mobilisation to Onslow.

*Appendix 2 contains photographs depicting several of these measures.

8.0 CONCLUSIONS

8.1 Permit Boundaries

Chevron conducted its vegetation clearing entirely within authorised boundaries of the requirement notice in effect at the time the clearing was undertaken. Any activities undertaken outside of authorised permit boundaries utilised previously cleared or naturally bare ground, or existing vehicle access tracks that were in a condition that indicated regular use by the public or landholders.

8.2 Permit Clearing Area

A review of Chevron's recorded data confirms that the cumulative total vegetation clearing area did not exceed the maximum area authorised by the requirement notices in effect at the time the clearing was undertaken.

8.3 Conservation Significant Taxa

When required, all surveys were performed by experienced botanists and as a consequence, the pre-clearing inspections would look for conservation significant taxa, irrespective of whether this broader definition was stated in the requirement notice.

8.4 Mangrove Translocations and Monitoring

The requirements of condition 7c of RN 2908/4 were complied with as demonstrated by the data tables in Appendix 4.

8.5 Re-instatement of Topsoil and Vegetated Material

All requirement notices except for the offshore RN 2915 include a condition requiring Chevron to stockpile topsoil and cleared vegetation; then re-instate it upon completion of investigative works. This practice was consistently adopted within all onshore requirement notices (RN 2908, RN 3052, RN 3165 and 3846).

In all instances where topsoil and vegetation was stripped, it was always reinstated across the entire area from which it was taken within four weeks of the completion of the investigative activities.

8.6 Record Keeping and Reporting

In 2010, Chevron kept records as required by its requirement notices and these are presented in the appendices to this report. Botanical data was recorded in the field by a variety of botanical contractors using standard data entry forms, which were later submitted to Chevron personnel in the Perth office for collation, review and reporting.

The reported location, area and date of vegetation clearing and re-instatement was recorded by field personnel and documented in the Ashburton North "Data-Sphere" which is managed jointly by the Wheatstone Project environment and GIS teams.

9.0 REFERENCES

Chevron Australia (2010) Wheatstone Project Environmental Impact Statement and Environmental Review and Management Plan. July 2010.

Chevron Australia (2010) Wheatstone Project Environmental Impact Statement and Environmental Review and Management Plan. Technical Appendix I - Vegetation and Flora Survey of the Wheatstone Project Area. July 2010.

Environmental Protection Authority (2010a). Wheatstone Project – (Assessment No. 1754) Requirement to Undertake Geotechnical Investigations. Requirement Notices issued under section 40(2)(b) *Environmental Protection Act 1986* for Area 2915/3, 2908/3. 3052/1 and 3165/1 in correspondence to Chevron Australia dated 4 June 2010.

Environmental Protection Authority (2010b). Wheatstone Project (Assessment No. 1754) Requirement to Undertake Geotechnical Investigations and Archaeological Excavation. Requirement Notices issued under section 40(2)(b) *Environmental Protection Act 1986* for Area 2908/4, 3052/2 and 3165/2 in correspondence to Chevron Australia dated 18 June 2010.

Environmental Protection Authority (2010c). Wheatstone Project (Assessment No. 1754) Requirement to Undertake Geotechnical Investigations. Requirement Notice issued under section 40(2)(b) *Environmental Protection Act 1986* for Area 3165/3 in correspondence to Chevron Australia dated 17 September 2010.

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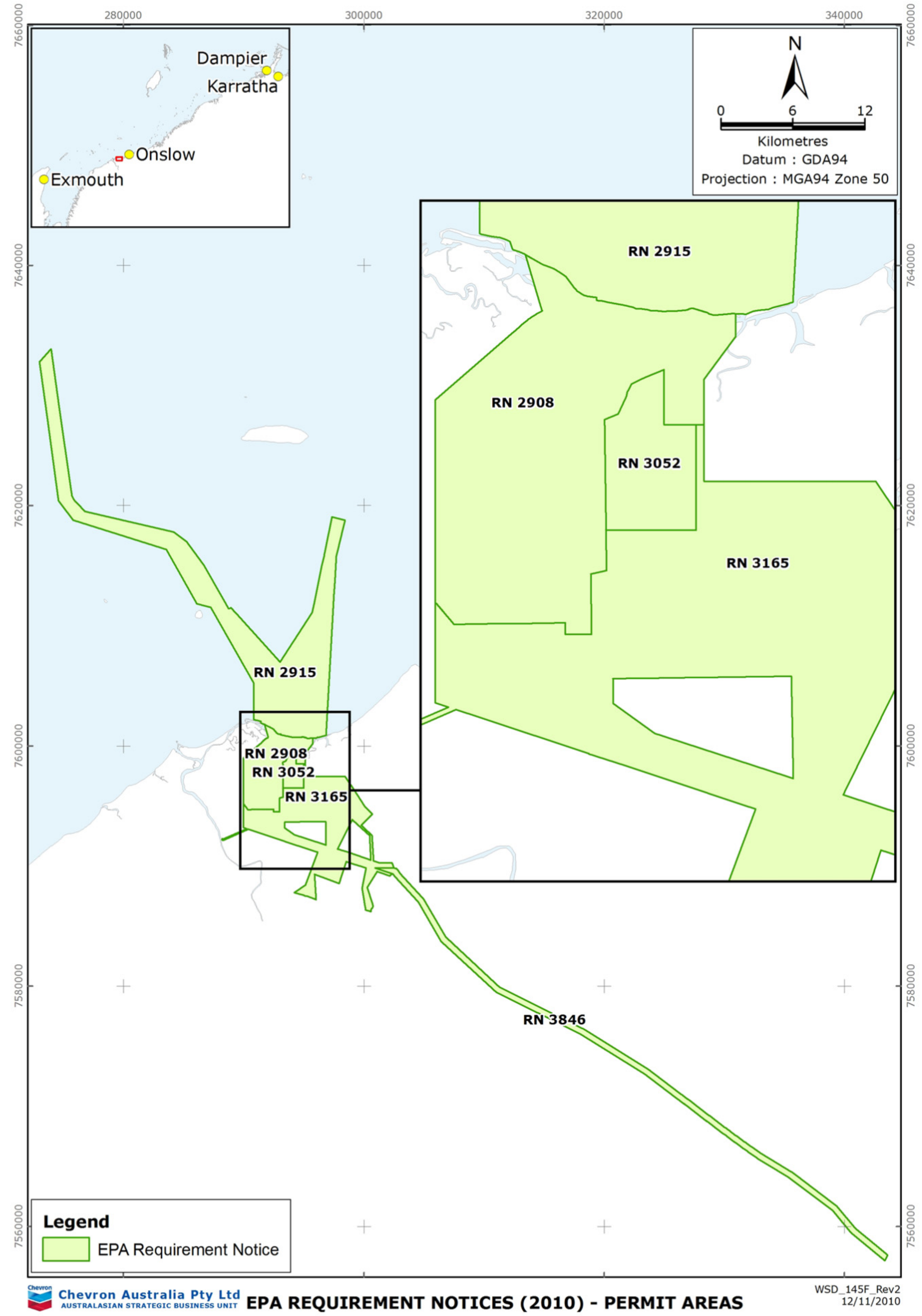
Outback Ecology (2010). Ashburton North Preliminary Mangrove Survival Monitoring Report. Unpublished. Updated worksheet received on 1st November 2010.

URS Australia (2010). Wheatstone Project: Intertidal Habitats of the Onslow Coastline. Unpublished report. May 2010.

URS Australia (2010). Wheatstone Project: Survey of Subtidal Habitats off Onslow, Western Australia. Unpublished report. May 2010.

APPENDIX 1: REQUIREMENT NOTICE BOUNDARIES


280000
300000
320000
340000
7660000
7640000
7620000
7600000
7580000
7560000
Dampier
Karratha
Onslow
Exmouth
N
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6
12
Kilometres
Datum : GDA94
Projection : MGA94 Zone 50
RN 2915
RN 2908
RN 3052
RN 3165
RN 3846
Legend
EPA Requirement Notice
Chevron Australia Pty Ltd
AUSTRALASIAN STRATEGIC BUSINESS UNIT
EPA REQUIREMENT NOTICES (2010) - PERMIT AREAS
WSD_145F_Rev2
12/11/2010

APPENDIX 2: SITE PHOTOGRAPHS

Photo # 1: Typical footprint of a geotechnical drilling rig at the Ashburton North site.

Photo # 2: Existing pastoral station tracks were used wherever possible to avoid creating new tracks.

Photo # 3: Typical drill pad access tracks across samphire mudflats.

Photo # 4: Typical geotechnical test pit activity.

Photo # 5: Drill pad access tracks such as this would provide access to multiple drill pads. They were closed and/or access restricted after drilling and pad rehabilitation was completed.

Photo # 6: Typical geophysics grid line, stripped with a backhoe.

Photo # 7: Pre-existing station access tracks and pre-cleared footprints were often utilised to avoid clearing.

Photo # 8: Chevron typically created tracks by 'rolling' vegetation (instead of stripping or scraping). This reduces topsoil loss and preserves rootstock, which improves the speed and success of regeneration.

Photo # 9: Re-spreading topsoil and cleared vegetative material within the clearing footprint allowed for the prompt natural germination of any viable native seed within the topsoil.

Photo # 10: Inspecting proposed clearing sites by a flora specialist (botanist) for the presence of priority flora, prior to undertaking clearing. Location data was recorded using a GPS. Above photo is of *Triumfetta echinata* seedlings.

Photo # 11: Using pegs and flagging tape to highlight the 10-metre activity exclusion buffer around environmental sensitivities (e.g. undescribed flora).

Photo # 12: Using pegs and flag tape to designate the status of closed tracks and pad sites, control ongoing access and maximise the speed and success of regeneration.

Photo # 13: Using Dura-Base mat to construct a temporary access over intertidal marshland. This prevented vehicles from bogging, which avoided clearing that would otherwise have resulted from repeated track widening and bog recovery works.

Photo # 14: Weed hygiene vehicle clean-down station

APPENDIX 3: VEGETATION TYPE CODES

Vegetation Type Codes

ID Code	Sub-Association Description (Species and Structure)	Vegetation Density
T1	*Tecticornia* spp. scattered low shrubs on mudflats	<2%
T2	*Avicennia marina* open scrub along tidal creeks	30-70%
CD1	*Acacia coriacea* subsp. *coriacea*, *Crotalaria cunninghamii* tall shrubland over *Spinifex longifolius*, (**Cenchrus ciliaris*) open tussock grassland on foredunes	20-60%
CD2	Acacia coriacea subsp. coriacea tall shrubland over Crotalaria cunninghamii, Trichodesma zeylanicum var. grandiflorum open shrubland over Triodia epactia open hummock grassland with *Cenchrus ciliaris open tussock grassland on near-coastal dunes	22-70%
ID1	*Grevillea stenobotrya* tall open shrubland over *Crotalaria cunninghamii*, *Trichodesma zeylanicum var. grandiflorum* open shrubland over *Triodia epactia* open hummock grassland on red sand dunes	14-50%
ID2	Grevillea stenobotrya tall open shrubland over Crotalaria cunninghamii, Hibiscus brachychlaenus open shrubland over Triodia schinzii, (T. epactia) open hummock grassland on red sand dunes	14-50%
ID3	*Acacia stellaticeps* shrubland over *Triodia epactia* hummock grassland in swales	40-100%
CS1	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland occurring broadly over sandy plains	30-70%
CS1/CS2	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland occurring broadly over sandy plains / *Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland occurring on sandy plains, particularly fringing claypans	30-70%/10-70%
CS1/CP1	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland occurring broadly over sandy plains / *Sporobolus mitchellii*, *Eriachne aff. benthamii*, *E. benthamii*, *Eulalia aurea* tussock grassland on low-lying clayey plains	30-70%
CS2	*Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland with **Cenchrus ciliaris* open tussock grassland occurring on sandy plains, particularly fringing claypans	10-70%
CS3	*Acacia tetragonophylla* scattered shrubs over *Scaevola pulchella*, *Indigofera monophylla* low open shrubland over *Triodia epactia* hummock grassland on areas of calcrete	32-80%
CS4	**Prosopis pallida*, *Acacia tetragonophylla*, *A. synchronicia* scattered tall shrubs over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* open tussock grassland in scalded areas	12-40%
CS4/CS1	**Prosopis pallida*, *Acacia tetragonophylla*, *A. synchronicia* scattered tall shrubs over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* open tussock grassland in scalded areas / *Acacia tetragonophylla* scattered shrubs over *Triodia epactia* hummock grassland occurring broadly over sandy plains	12-40%/30-70%
C1	Bare claypan	0%
C2	*Eriachne aff. benthamii* open tussock grassland in claypans	10-30%

ID Code	Sub-Association Description (Species and Structure)	Vegetation Density
C3	*Tecticornia* spp. low shrubland in saline claypans	10-30%
C3/C2	*Tecticornia* spp. low shrubland in saline claypans / *Eriachne aff. benthamii* open tussock grassland in claypans	10-30%
C3/CP1	*Tecticornia* spp. low shrubland in saline claypans / *Sporobolus mitchellii*, *Eriachne aff. benthamii*, *E. benthamii*, *Eulalia aurea* tussock grassland on low-lying clayey plains	10-30%/30-70%
CP1	*Sporobolus mitchellii*, *Eriachne aff. benthamii*, *E. benthamii*, *Eulalia aurea* tussock grassland on low-lying clayey plains	30-70%
CP2	**Prosopis pallida* scattered tall shrubs to tall open shrubland over *Acacia tetragonophylla*, **Vachellia farnesiana* shrubland over *Eulalia aurea*, *Chrysopogon fallax*, *Sporobolus mitchellii* tussock grassland within drainage depressions in low-lying claye	42-100%
CP3	*Acacia xiphophylla* tall shrubland over *Triodia epactia* open hummock grassland on clayey plains	20-60%
CP4	*Acacia xiphophylla* tall shrubland over *Triodia lanigera* open hummock grassland on elevated areas of clayey plains	20-60%
CP5/CP4	*Acacia xiphophylla* tall open scrub over *Triodia brizoides* open hummock grassland on elevated areas of clayey plains, particularly where the substrate was calcareous / *Acacia xiphophylla* tall shrubland over *Triodia lanigera* open hummock grassland on elevated areas of clayey plains	40-100%
IS1	*Corymbia hamersleyana* scattered low mallees over *Acacia ancistrocarpa*, *A. bivenosa* shrubland over *Triodia lanigera* hummock grassland occurring broadly over inland sandy plains	40-100%
IS2	*Acacia inaequilatera* tall open shrubland over *A. ancistrocarpa* open shrubland over *Triodia lanigera* open hummock grassland on slightly elevated areas of inland sandy plains	14-50%
H1	*Acacia inaequilatera* tall open shrubland over *Triodia lanigera*, *T. brizoides* open hummock grassland on stony hills	12-40%
D1	*Eucalyptus victrix* open forest over *Eulalia aurea*, **Cenchrus ciliaris* tussock grassland in tributary of Ashburton River	60-100%
D2	*Eucalyptus victrix* scattered low trees over *Acacia synchronicia*, *A. bivenosa* shrubland over *Triodia epactia* hummock grassland in broad ill-defined drainage through clayey plain	40-100%
D3	*Corymbia hamersleyana* scattered low mallees over *Acacia tumida var. pilbarensis*, *Grevillea wickhamii subsp. hispidula* tall open shrubland over *A. ancistrocarpa* open shrubland over *Triodia epactia*, *T. lanigera* open hummock grassland	14-50%
D4	*Eucalyptus victrix* low trees over *Acacia tetragonophylla*, *A. synchronica* shrubland and *Hibiscus brachychlaenus* shrubland over Tussock Grassland of **Cenchus ciliaris*	42-100%
ID4	*Grevillea stenobotrya* tall open shrubland with *Acacia stellaticeps* over *Triodia epactica* and **Cenchus ciliaris* open tussock grassland	12-40%
C4	**Prosopis pallida*, *Atriplex bunburyana*, *Triodia epactia* and **Cenchus ciliaris* open tussock Grassland.	10-30%
CS4/CP1	**Prosopis pallida*, *Acacia tetragonophylla*, *A. synchronicia* scattered tall shrubs over *Triodia epactia* very open hummock grassland and **Cenchrus ciliaris* open tussock grassland in scalded areas / *Sporobolus mitchellii*, *Eriachne aff. benthamii*, *E. benthamii*, *Eulalia aurea* tussock grassland on low-lying clayey plains	12-40%/30-70%
CS5	**Prosopis pallida*, *Acacia sclerophylla var. sclerophylla*, *A. tetragonophylla* scattered tall shrubs over *Triodia epactica* and	12-32%

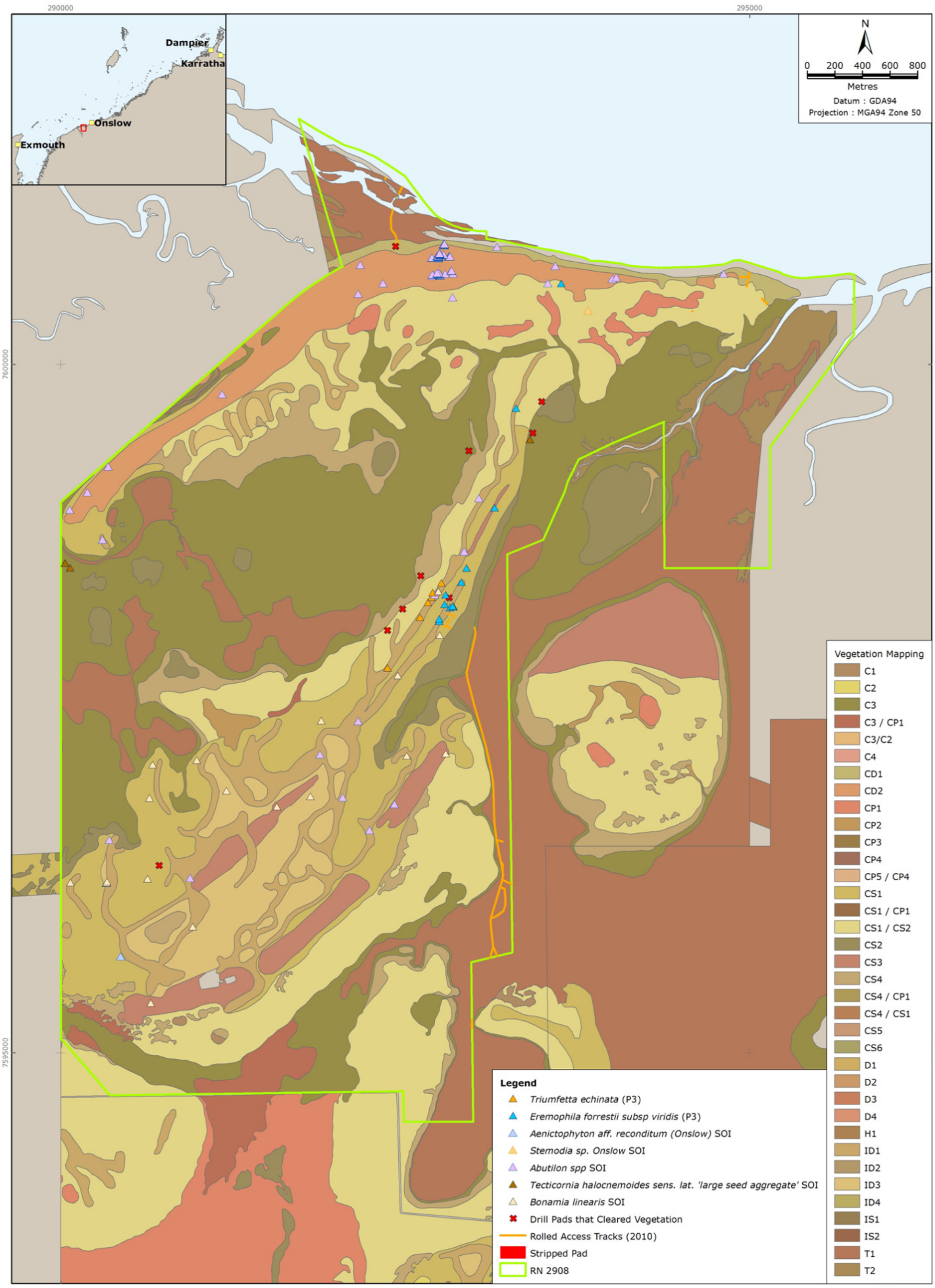
ID Code	Sub-Association Description (Species and Structure)	Vegetation Density
	Cenchus ciliaris open tussock grassland	
CS6	**Prosopis pallida*, *Acacia tetragonophylla*, *A. synchronicia* scattered tall shrubs over Triodia epactia very open hummock grassland and **Cenchrus ciliaris* open tussock grassland in scalded areas	4-30%
Beach	Bare	0%
Tidal Channel	Bare	0%
Ocean	Bare	0%
Cleared	Bare	0%
Macroalgae	Sandy substrate with sparse low patches of *Caulerpa*.	15%
Seagrass	Sandy substrate with sparsely distributed patches of *Halophila* and *Halodule*.	5%

** Refers to a weed species.*

APPENDIX 4: REQUIREMENT NOTICE 2908

Figures

Tables



2010 VEGETATION DISTURBANCE MAP - RN 2908

TABLE 4.2.1 - Records of Geotechnical Work Pad Clearing - RN 2908

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Area Cleared (m2)	Area Spread (m2)	Date Spread
B-353	05/06/2010	RN 2908/4	292955	7599367	C3	10-30%	140.00	140.00	
B-PZ2	20/06/2010	RN 2908/4	293422	7599498	C3	10-30%	20.03	20.03	
TP-944	25/07/2010	RN 2908/4	292606	7598464	CS4	12-40%	56.00	56.00	
B-C4	15/07/2010	RN 2908/4	292427	7600851	CD1	20-60%	324.00	324.00	
TP-943	25/07/2010	RN 2908/4	292364	7598067	CS1 / CS2	30-100%	95.80	95.80	
B-942	12/06/2010	RN 2908/4	292477	7598224	CS1 / CS2	30-100%	294.50	294.50	
B-PZ1	20/06/2010	RN 2908/4	293485	7599733	CS1 / CS2	30-100%	78.50	78.50	
B-911	12/06/2010	RN 2908/4	290706	7596356	CS1	30-70%	264.00	264.00	
B-MN3	05/06/2010	RN 2908/4	292813	7598300	CS1	30-70%	320.00	320.00	
						Sum Total	**0.1592 ha**	**0.1592 ha**	

TABLE 4.2.2 - Records of Archaeological Work Pad Clearing - RN 2908

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Area Cleared (m2)	Area Spread (m2)	Date Spread
Tram Trench 1	31/08/2010	RN 2908/4	292237	7599877	C3	10-30%	3.84	3.84	11/09/2010
South Gate	31/08/2010	RN 2908/4	292744	7600680	CD2	22-70%	3.00	3.00	11/09/2010
TP#20	31/08/2010	RN 2908/4	292799	7600692	CD2	22-70%	0.25	0.25	11/09/2010
TP#11	31/08/2010	RN 2908/4	292789	7600698	CD2	22-70%	0.25	0.25	11/09/2010
Well Excavation	31/08/2010	RN 2908/4	292798	7600700	CD2	22-70%	2.56	2.56	11/09/2010
SQ#01 West	31/08/2010	RN 2908/4	292741	7600701	CD2	22-70%	0.25	0.25	11/09/2010
TP#10	31/08/2010	RN 2908/4	292787	7600701	CD2	22-70%	0.25	0.25	11/09/2010
TP15	31/08/2010	RN 2908/4	292815	7600701	CD2	22-70%	0.42	0.42	11/09/2010
TP14	31/08/2010	RN 2908/4	292826	7600704	CD2	22-70%	0.19	0.19	11/09/2010
Tram Sleepers	31/08/2010	RN 2908/4	292752	7600705	CD2	22-70%	9.88	9.88	11/09/2010
Excv Sq-T	31/08/2010	RN 2908/4	292744	7600705	CD2	22-70%	5.86	5.86	11/09/2010
TP#03 (West)	31/08/2010	RN 2908/4	292732	7600706	CD2	22-70%	0.25	0.25	11/09/2010
TP#08	31/08/2010	RN 2908/4	292787	7600706	CD2	22-70%	0.25	0.25	11/09/2010
TP12	31/08/2010	RN 2908/4	292795	7600709	CD2	22-70%	0.38	0.38	11/09/2010
TP#07	31/08/2010	RN 2908/4	292786	7600710	CD2	22-70%	0.25	0.25	11/09/2010
TP#19	31/08/2010	RN 2908/4	292820	7600711	CD2	22-70%	0.25	0.25	11/09/2010
Feature 98	31/08/2010	RN 2908/4	292754	7600712	CD2	22-70%	5.68	5.68	11/09/2010
TP#9	31/08/2010	RN 2908/4	292755	7600712	CD2	22-70%	0.26	0.26	11/09/2010
TP13	31/08/2010	RN 2908/4	292827	7600718	CD2	22-70%	0.16	0.16	11/09/2010
TP#06	31/08/2010	RN 2908/4	292784	7600718	CD2	22-70%	0.25	0.25	11/09/2010
Trench 4b	31/08/2010	RN 2908/4	292746	7600719	CD2	22-70%	12.01	12.01	11/09/2010
TP#17	31/08/2010	RN 2908/4	292807	7600720	CD2	22-70%	0.25	0.25	11/09/2010
TP#13	31/08/2010	RN 2908/4	292816	7600721	CD2	22-70%	0.26	0.26	11/09/2010
TP#05	31/08/2010	RN 2908/4	292784	7600722	CD2	22-70%	0.25	0.25	11/09/2010
Trench 4a	31/08/2010	RN 2908/4	292749	7600722	CD2	22-70%	2.97	2.97	11/09/2010

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Area Cleared (m2)	Area Spread (m2)	Date Spread
TP#01	31/08/2010	RN 2908/4	292766	7600725	CD2	22-70%	0.25	0.25	11/09/2010
TP#02	31/08/2010	RN 2908/4	292768	7600725	CD2	22-70%	0.25	0.25	11/09/2010
TP#03	31/08/2010	RN 2908/4	292778	7600726	CD2	22-70%	0.25	0.25	11/09/2010
TP#04	31/08/2010	RN 2908/4	292783	7600727	CD2	22-70%	0.25	0.25	11/09/2010
TP#18	31/08/2010	RN 2908/4	292810	7600727	CD2	22-70%	0.25	0.25	11/09/2010
North Gate	31/08/2010	RN 2908/4	292762	7600811	CD2	22-70%	6.08	6.08	11/09/2010
Jetty Area	31/08/2010	RN 2908/4	292765	7600873	CD1	20-60%	21.13	21.13	11/09/2010
Jetty East	31/08/2010	RN 2908/4	292805	7600875	CD1	20-60%	19.97	19.97	11/09/2010
						Sum Total	**0.0098 ha**	**0.0098 ha**	

TABLE 4.2.3 - Records of Access Track Clearing – RN 2908/4

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Track Type	Width (m)	Area Cleared (m2)
B-942	12/06/2010	RN 2908/3	292468	7598230	CS4	12-40%	LV	0.60	0.86
B-942	12/06/2010	RN 2908/3	292470	7598229	CS1 / CS2	30-100%	LV	0.60	1.34
C-915	25/07/2010	RN 2908/3	292368	7598086	CS1 / CS2	30-100%	Exc/LV/Argo	0.40	4.15
ES-62 to 64	14/07/2010	RN 2908/3	293090	7597208	T1	<2%	MB/Argo	2.55	3022.94
ES-62 to 64	14/07/2010	RN 2908/4	292973	7597876	C3	10-30%	MB/Argo	2.55	1115.04
C11,9,7,6	22/06/2010	RN 2908/4	292468	7601267	T1	<2%	MB/Argo	3.00	199.07
C11,9,7,6	22/06/2010	RN 2908/4	292397	7601010	T1	<2%	MB/Argo	3.00	680.97
C11,9,7,6	22/06/2010	RN 2908/4	292355	7601402	beach	0%	MB	0.00	0.00
C11,9,7,6	22/06/2010	RN 2908/4	292471	7601370	beach	0%	MB/Argo	0.00	0.00
C11,9,7,6	22/06/2010	RN 2908/4	292412	7601192	tidal channel	0%	MB/Argo	0.00	0.00
C11,9,7,6	22/06/2010	RN 2908/4	292443	7600893	CD1	20-60%	MB/Argo	3.00	95.54
C4	01/07/2010	RN 2908/4	292428	7600876	CD1	20-60%	MB/Argo	3.00	4.10
C-941/ ES-191	01/07/2010	RN 2908/4	294583	7600386	CS1 / CS2	30-100%	LV/Argo	0.60	2.65
C-851,852,ES-161,65,162	12/07/2010	RN 2908/4	293190	7596207	T1	<2%	MB/Argo	3.00	2089.63
C-854, ES-92	12/07/2010	RN 2908/4	293129	7595851	T1	<2%	MB/Argo	3.00	481.46
ES-65	12/07/2010	RN 2908/4	293225	7596065	T1	<2%	Argo	0.45	128.48
ES-92	12/07/2010	RN 2908/4	293154	7595737	T1	<2%	Argo	0.45	33.45
ES-161	14/07/2010	RN 2908/4	293208	7596352	T1	<2%	Argo	0.45	40.29
ES-162	14/07/2010	RN 2908/4	293199	7596201	T1	<2%	Argo	0.45	8.93
ES-192	14/07/2010	RN 2908/4	294937	7600633	CD1	20-60%	Argo	0.45	52.89
ES-192	14/07/2010	RN 2908/4	294982	7600575	CS1 / CS2	30-100%	Argo	0.45	9.71
ES-194	14/07/2010	RN 2908/4	295120	7600443	CD1	20-60%	Argo	0.45	6.51
ES-194	14/07/2010	RN 2908/4	295102	7600463	CS1 / CS2	30-100%	Argo	0.45	17.91
C-854, ES-92	15/07/2010	RN 2908/4	293127	7595731	T1	<2%	MB/Argo	3.00	253.27

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Track Type	Width (m)	Area Cleared (m2)
ES-193	15/07/2010	RN 2908/4	295063	7600669	beach	0%	Argo	0.00	0.00
ES-193	15/07/2010	RN 2908/4	294999	7600652	CD1	20-60%	Argo	0.45	15.31
C-878	19/07/2010	RN 2908/4	293238	7596241	T1	<2%	MB	3.00	217.64
C-948	23/07/2010	RN 2908/4	292812	7598186	ID1	14-50%	LV	0.60	6.35
C-948	23/07/2010	RN 2908/4	292827	7598183	CS1	30-70%	LV	0.60	11.27
C-949	23/07/2010	RN 2908/4	292853	7598172	CS1	30-70%	LV	0.60	6.27
C-950	24/07/2010	RN 2908/4	292787	7598096	CS1	30-70%	LV	0.60	11.56
C-951	24/07/2010	RN 2908/4	292812	7598093	CS1	30-70%	LV	0.60	25.65
C-952	24/07/2010	RN 2908/4	292815	7598132	CS1	30-70%	LV	0.60	17.94
TP-943	25/07/2010	RN 2908/4	292366	7598077	CS1 / CS2	30-100%	Exc	1.00	9.65
TP-944	25/07/2010	RN 2908/4	292618	7598457	CS4	12-40%	Exc	1.00	14.92
								Sum Total	**0.8586 ha**

TABLE 4.2.4 - Records of Mangrove Translocations – RN 2908

Location Identifier	Corner	Easting	Northing	Plants Translocated ---- (s= seedlings; p= propagules)	Extraction Method (PVC Pipe / Hand Removal)	Date Translocated (DD/MM/YYYY)	Monitoring Results				
							2 Weeks	6 Weeks	12 Weeks	26 Weeks	52 Weeks
							Date: 14/07/2010 (by C.K.)	Date: 12/08/2010 (by M.T)	Date: 19/10/2010 (by C.K.)	Date:	Date:
Beach East (MTA06)	1	292407	7601045	58s / 13p	All PVC pipe	26/06/2010	9s / 31p	10s / 30p	5s / 7p		
	2	292416	7601043								
	3	292417	7601047								
	4	292408	7601049								
Beach West (MTA05)	1	292386	7601064	28s / 67p	All PVC Pipe	26/06/2010	23s / 40p	8s / 24p	5s / 11p		
	2	292377	7601063								
	3	292376	7601072								
	4	292387	7601071								
Mid Way to Water (MTA04)	1	292385	7601000	35s / 3p	All PVC Pipe	25/06/2010	34s / 3p	26s / 2p	30s / 3p		
	2	292377	7601000								
	3	292378	7601008								
	4	292385	7601008								
The Spit (MTA02)	1	292476	7601261	23s / 6p	All PVC pipe	24/06/2010	23s / 4p	18s / 3p	18s / 3p		
	2	292473	7601253								
	3	292493	7601253								
	4	292488	7601248								
The Spit (MTA01)	1	292393	7601345	25s / 0p	All PVC pipe	24/06/2010	24s / 0p	24s / 0p	24s / 0p		
	2	292381	7601349								
	3	292378	7601340								
	4	292391	7601336								

TABLE 4.3.5 - Records of Conservation Significant Taxa – RN 2908

Taxa	Status	Easting (GDA94)	Northing (GDA94)	# Individuals
Abutilon sp	undescribed	292699	7600651	1
Abutilon sp	undescribed	292753	7600646	1
Abutilon sp	undescribed	292756	7600644	1
Abutilon sp	undescribed	292781	7600872	1
Abutilon sp	undescribed	292786	7600872	1
Abutilon sp	undescribed	292778	7600866	1
Abutilon sp	undescribed	292781	7600864	1
Abutilon sp	undescribed	292756	7600803	1
Abutilon sp	undescribed	292754	7600801	1
Abutilon sp	undescribed	292754	7600799	1
Abutilon sp	undescribed	292753	7600794	1
Abutilon sp	undescribed	292699	7600642	1
Abutilon sp	undescribed	292746	7600784	1
Abutilon sp	undescribed	292742	7600782	1
Abutilon sp	undescribed	292741	7600782	1
Abutilon sp	undescribed	292741	7600781	1
Abutilon sp	undescribed	292741	7600779	1
Abutilon sp	undescribed	292741	7600775	1
Abutilon sp	undescribed	292741	7600768	1
Abutilon sp	undescribed	292739	7600786	1
Abutilon sp	undescribed	292734	7600782	1
Abutilon sp	undescribed	292696	7600775	1
Abutilon sp	undescribed	292708	7600649	1
Abutilon sp	undescribed	292696	7600773	1
Abutilon sp	undescribed	292747	7600805	1
Abutilon sp	undescribed	292817	7600782	1
Abutilon sp	undescribed	292820	7600782	1
Abutilon sp	undescribed	292822	7600782	1
Abutilon sp	undescribed	292825	7600782	1
Abutilon sp	undescribed	292780	7600796	1
Abutilon sp	undescribed	292747	7600661	1
Abutilon sp	undescribed	292756	7600655	1
Abutilon sp	undescribed	292792	7600656	1
Abutilon sp	undescribed	292848	7600656	1
Abutilon sp	undescribed	292832	7600677	1
Abutilon sp	undescribed	292837	7600680	1
Abutilon sp	undescribed	292820	7600780	1
Abutilon sp	undescribed	292822	7600780	1
Abutilon sp	undescribed	292751	7600805	1
Abutilon sp	undescribed	292732	7600782	1
Abutilon sp	undescribed	292739	7600784	1
Abutilon sp	undescribed	292742	7600782	3
Abutilon sp	undescribed	292746	7600782	2
Abutilon sp	undescribed	292742	7600779	1
Abutilon sp	undescribed	292741	7600773	1
Abutilon sp	undescribed	292694	7600773	3

Abutilon sp	undescribed	292783	7600866	1
Abutilon sp	undescribed	292779	7600868	1
Abutilon sp	undescribed	292744	7600650	2
Abutilon sp	undescribed	292741	7600653	1
Abutilon sp	undescribed	292741	7600655	1
Abutilon sp	undescribed	292739	7600655	1
Abutilon sp	undescribed	292739	7600657	2
Abutilon sp	undescribed	292735	7600657	1
Abutilon sp	undescribed	292734	7600662	1
Abutilon sp	undescribed	292780	7600872	1
Abutilon sp	undescribed	292786	7600871	1
Abutilon sp	undescribed	292756	7600801	1
Abutilon sp	undescribed	292754	7600797	1
Abutilon sp	undescribed	292754	7600792	1
Abutilon sp	undescribed	292815	7600780	1
Abutilon sp	undescribed	292818	7600780	1

APPENDIX 5: REQUIREMENT NOTICE 3052

Figures

Tables

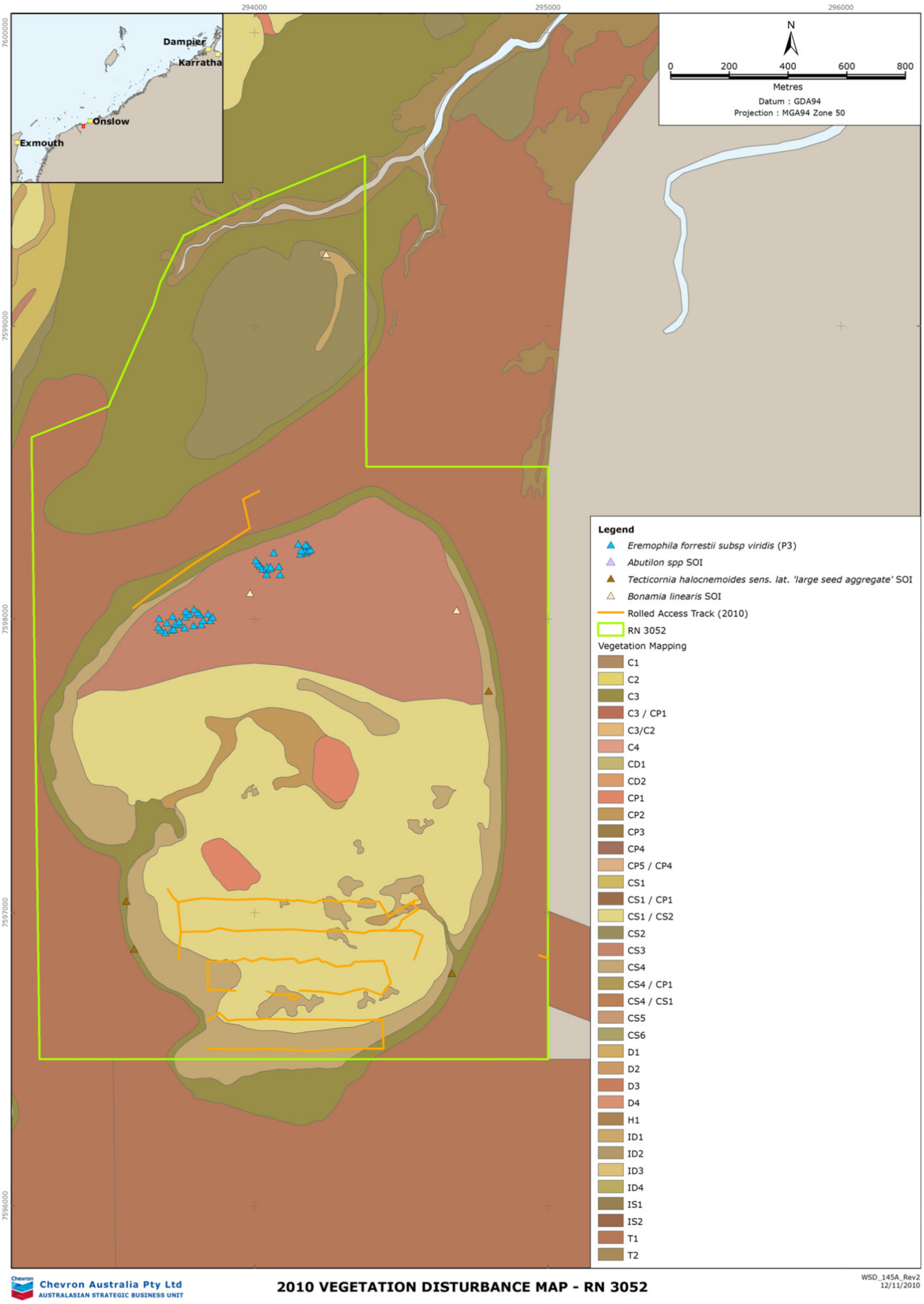

Dampier
Karratha
Onslow
Exmouth
N
0 200 400 600 800
Metres
Datum : GDA94
Projection : MGA94 Zone 50
Legend
Eremophila forrestii subsp viridis (P3)
Abutilon spp SOI
Tecticornia halocnemoides sens. lat. 'large seed aggregate' SOI
Bonamia linearis SOI
Rolled Access Track (2010)
RN 3052
Vegetation Mapping
C1
C2
C3
C3 / CP1
C3/C2
C4
CD1
CD2
CP1
CP2
CP3
CP4
CP5 / CP4
CS1
CS1 / CP1
CS1 / CS2
CS2
CS3
CS4
CS4 / CP1
CS4 / CS1
CS5
CS6
D1
D2
D3
D4
H1
ID1
ID2
ID3
ID4
IS1
IS2
T1
T2
Chevron Australia Pty Ltd
AUSTRALASIAN STRATEGIC BUSINESS UNIT
2010 VEGETATION DISTURBANCE MAP - RN 3052
WSD_145A_Rev2
12/11/2010

TABLE 5.2.1 - Records of Track Clearing - RN 3052

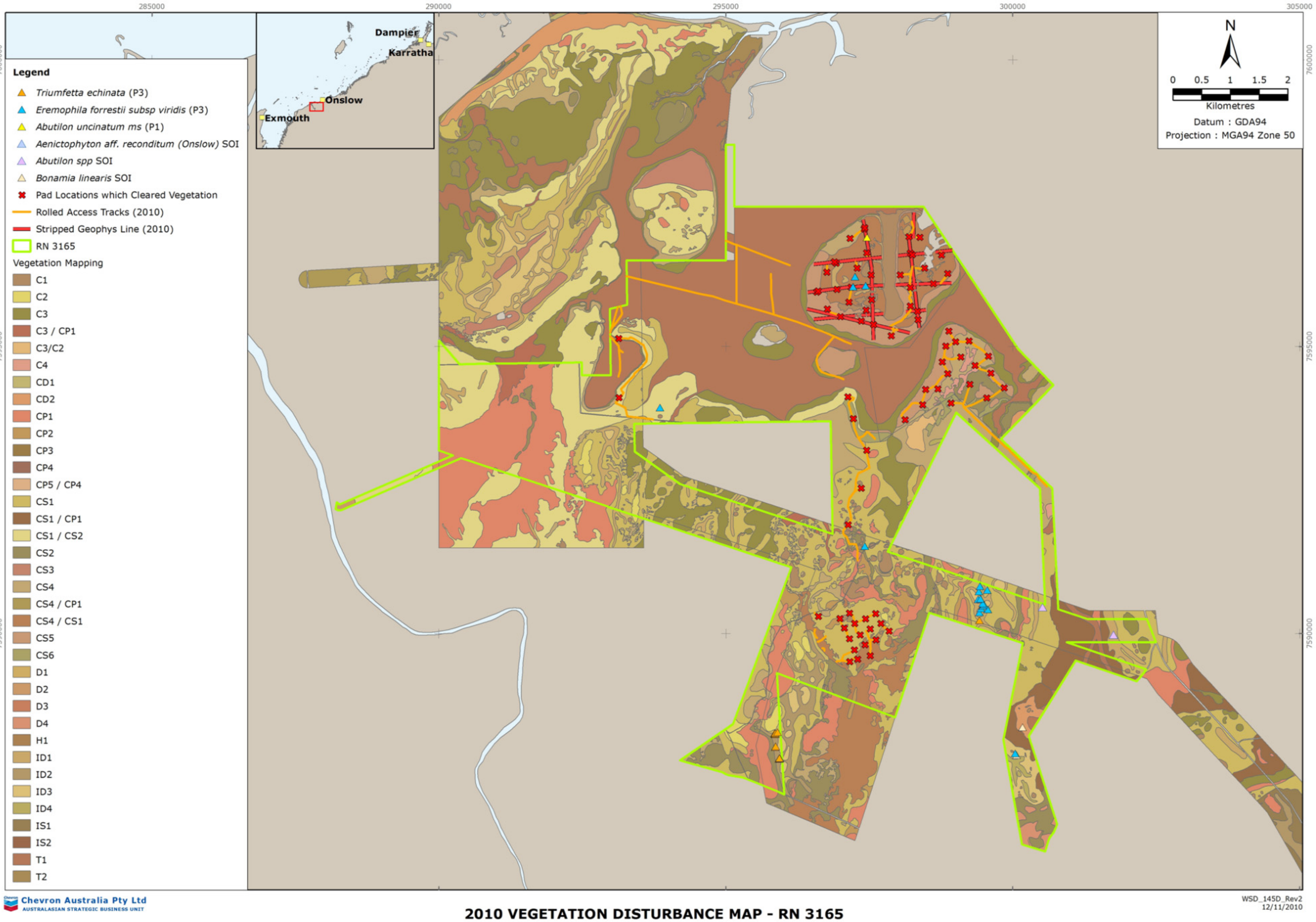
Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Track Type	Width (m)	Area Cleared (m2)
C-945	13/07/2010	RN 3052/2	293977	7598340	T1	<2%	MB	3.00	791.85
C-945	13/07/2010	RN 3052/2	293739	7598152	C3	10-30%	MB	3.00	1137.87
ES-163 to 190	10/07/2010	RN 3052/2	294428	7596535	C3	10-30%	Argo	0.45	42.59
ES-163 to 190	10/07/2010	RN 3052/2	294173	7596527	CS4	12-40%	Argo	0.45	303.82
ES-163 to 190	10/07/2010	RN 3052/2	294035	7596638	CS4	12-40%	Argo	0.45	7.04
ES-163 to 190	11/07/2010	RN 3052/2	294134	7596722	CS4	12-40%	Argo	0.45	61.83
ES-163 to 190	10/07/2010	RN 3052/2	293841	7596787	CS4	12-40%	Argo	0.45	108.98
ES-163 to 190	10/07/2010	RN 3052/2	294454	7596747	CS4	12-40%	Argo	0.45	8.57
ES-163 to 190	10/07/2010	RN 3052/2	294145	7596635	CS1 / CS2	30-100%	Argo	0.45	241.25
ES-163 to 190	11/07/2010	RN 3052/2	294054	7596727	CS1 / CS2	30-100%	Argo	0.45	11.38
ES-163 to 190	10/07/2010	RN 3052/2	294025	7596844	CS1 / CS2	30-100%	Argo	0.45	123.09
ES-163 to 190	10/07/2010	RN 3052/2	294198	7596839	CS1 / CS2	30-100%	Argo	0.45	316.98
ES-227 to 233	23/07/2010	RN 3052/2	293742	7596863	CS4	12-40%	Argo	0.45	20.52
ES-227 to 233	23/07/2010	RN 3052/2	293929	7596938	CS1 / CS2	30-100%	Argo	0.45	306.97
ES-234,235,245	24/07/2010	RN 3052/2	294271	7596943	CS4	12-40%	Argo	0.45	23.50
ES-234,235,245	24/07/2010	RN 3052/2	294542	7597027	CS1 / CS2	30-100%	Argo	0.45	13.42
ES-234,235,245	24/07/2010	RN 3052/2	294331	7596934	CS1 / CS2	30-100%	Argo	0.45	143.89
ES-234,235,245	24/07/2010	RN 3052/2	294549	7597020	CP2	42-100%	Argo	0.45	7.20
ES-236 to 241	22/07/2010	RN 3052/2	294244	7597042	CS4	12-40%	Argo	0.45	11.71
ES-236 to 241	22/07/2010	RN 3052/2	294104	7597041	CS4	12-40%	Argo	0.45	11.65
ES-236 to 241	22/07/2010	RN 3052/2	293973	7597045	CS1 / CS2	30-100%	Argo	0.45	212.15
ES-242,243	25/07/2010	RN 3052/2	294272	7597039	CS4	12-40%	Argo	0.45	14.08
ES-242,243	25/07/2010	RN 3052/2	294384	7597038	CS4	12-40%	Argo	0.45	24.47
ES-242,243	25/07/2010	RN 3052/2	294492	7597008	CS4	12-40%	Argo	0.45	17.59

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Track Type	Width (m)	Area Cleared (m2)
ES-242,243	25/07/2010	RN 3052/2	294533	7597034	CS1 / CS2	30-100%	Argo	0.45	12.69
ES-242,243	25/07/2010	RN 3052/2	294353	7597037	CS1 / CS2	30-100%	Argo	0.45	59.68
ES-242,243	25/07/2010	RN 3052/2	294515	7597022	CP2	42-100%	Argo	0.45	6.79
ES-242,243	25/07/2010	RN 3052/2	294460	7596989	CP2	42-100%	Argo	0.45	15.27
ES-246	25/07/2010	RN 3052/2	294560	7596928	CS1 / CS2	30-100%	Argo	0.45	90.54
Marsh DCP's	27/07/2010	RN 3052/2	294985	7596849	T1	<2%	Argo	0.45	14.49
								Sum Total	**0.416 ha**

APPENDIX 6: REQUIREMENT NOTICE 3165

Figures

Tables



2010 VEGETATION DISTURBANCE MAP - RN 3165

TABLE 6.2.1 - Records of Geotechnical Work Pad Clearing - RN 3165

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Area Cleared (m2)	Area Spread (m2)	Date Spread*
B-660	04/06/2010	RN 3165/1	297054	7590090	0%	C1	0.00	0.00	6/07/2010
TP-884	04/06/2010	RN 3165/1	297145	7589914	30-70%	CS1	60.00	60.00	7/06/2010
B-661	04/06/2010	RN 3165/1	297334	7589975	30-70%	CS1	240.00	240.00	6/07/2010
TP-880	04/06/2010	RN 3165/1	297244	7590177	30-70%	CS1	65.98	65.98	20/07/2010
TP-879	04/06/2010	RN 3165/1	296986	7590263	30-70%	CS1	50.00	50.00	7/06/2010
TP-877	04/06/2010	RN 3165/1	297600	7590344	30-70%	CS1	38.76	38.76	7/06/2010
B-662	05/06/2010	RN 3165/1	297608	7589894	42-100%	CP2	110.81	110.81	18/07/2010
B-665	07/06/2010	RN 3165/1	297507	7589616	12-40%/30-70%	CS4 / CS1	160.01	160.01	6/07/2010
TP-885	07/06/2010	RN 3165/1	297415	7589806	12-40%/30-70%	CS4 / CS1	69.39	69.39	8/06/2010
TP-881	07/06/2010	RN 3165/1	297510	7590079	30-70%	CS1	96.00	96.00	7/06/2010
TP-889	08/06/2010	RN 3165/1	297288	7589559	12-40%/30-70%	CS4 / CS1	69.94	69.94	8/06/2010
B-659	08/06/2010	RN 3165/1	297697	7590170	30-70%	CS1	160.06	160.06	24/07/2010
B-658	09/06/2010	RN 3165/1	297429	7590256	30-70%	CS1	360.00	360.00	24/07/2010
B-657	09/06/2010	RN 3165/1	297153	7590355	30-70%	CS1	340.05	340.05	24/07/2010
B-664	10/06/2010	RN 3165/1	297241	7589716	30-70%	CS1	170.00	170.00	24/07/2010
E050a	15/06/2010	RN 3165/1	297828	7590036	30-70%	CS1	660.00	660.00	6/07/2010
E049a	15/06/2010	RN 3165/1	296600	7590301	30-70%	CS1	510.00	510.00	6/07/2010
E051a	18/06/2010	RN 3165/2	297153	7589510	30-70%	CS1	754.95	754.95	11/08/2010
B-775	22/06/2010	RN 3165/2	298335	7595620	12-40%/30-70%	CS4 / CS1	278.48	278.48	23/08/2010
B-871	22/06/2010	RN 3165/2	297118	7591890	30-70%	CS1	151.65	151.65	26/07/2010
B-777	23/06/2010	RN 3165/2	298607	7596096	12-40%/30-70%	CS4 / CS1	526.57	526.57	23/08/2010
B-873	23/06/2010	RN 3165/2	297448	7593188	30-70%	CS1	105.00	105.00	26/07/2010
B-781	24/06/2010	RN 3165/2	298185	7596916	12-40%/30-70%	CS4 / CS1	201.35	201.35	15/08/2010
B-780	25/06/2010	RN 3165/2	298244	7596605	12-40%/30-70%	CS4 / CS1	354.17	354.17	15/08/2010
B-875	25/06/2010	RN 3165/2	297117	7594126	30-100%	CS1 / CS2	240.00	240.00	26/07/2010

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Area Cleared (m2)	Area Spread (m2)	Date Spread*
B-774	26/06/2010	RN 3165/2	297565	7595387	12-32%	CS5	300.01	300.01	
TP-872	26/06/2010	RN 3165/2	297350	7592530	30-70%	CS1	198.00	198.00	26/07/2010
TP-874	26/06/2010	RN 3165/2	297212	7593742	4-30%	CS6	110.02	110.02	26/07/2010
B-772	27/06/2010	RN 3165/2	296995	7595521	12-32%	CS5	109.14	109.14	15/08/2010
B-853	27/06/2010	RN 3165/2	293122	7595144	30-100%	CS1 / CS2	193.82	193.82	21/07/2010
TP-745	28/06/2010	RN 3165/2	298344	7595466	12-32%	CS5	106.05	106.05	15/08/2010
B-856	28/06/2010	RN 3165/2	293126	7594111	12-40%	CS4	150.01	150.01	27/07/2010
B-761	28/06/2010	RN 3165/2	297414	7597074	12-40%	CS4	210.25	210.25	15/08/2010
TP-747	28/06/2010	RN 3165/2	298865	7596273	12-40%/30-70%	CS4 / CS1	169.44	169.44	15/08/2010
TP-778	28/06/2010	RN 3165/2	298458	7596370	12-40%/30-70%	CS4 / CS1	132.65	132.65	15/08/2010
TP-744	29/06/2010	RN 3165/2	297876	7595189	12-32%	CS5	105.69	105.69	15/08/2010
B-768	29/06/2010	RN 3165/2	296604	7595968	12-32%	CS5	266.71	266.71	15/08/2010
B-765	29/06/2010	RN 3165/2	296887	7596474	12-40%/30-70%	CS4 / CS1	319.51	319.51	15/08/2010
TP-779	29/06/2010	RN 3165/2	298748	7596603	12-40%/30-70%	CS4 / CS1	319.00	319.00	23/08/2010
TP-750	29/06/2010	RN 3165/2	298375	7596907	12-40%/30-70%	CS4 / CS1	48.00	48.00	23/08/2010
TP-748	30/06/2010	RN 3165/2	298033	7596251	12-40%/30-70%	CS4 / CS1	157.51	157.51	15/08/2010
TP-749	30/06/2010	RN 3165/2	298208	7596631	12-40%/30-70%	CS4 / CS1	126.35	126.35	15/08/2010
TP-776	30/06/2010	RN 3165/2	298207	7596036	42-100%	CP2	209.49	209.49	15/08/2010
TP-769	01/07/2010	RN 3165/2	297535	7595818	0%	C1	0.00	0.00	15/08/2010
TP-746	01/07/2010	RN 3165/2	298213	7595707	12-32%	CS5	114.08	114.08	15/08/2010
B-767	01/07/2010	RN 3165/2	297178	7596041	12-40%/30-70%	CS4 / CS1	359.94	359.94	15/08/2010
TP-741	02/07/2010	RN 3165/2	296576	7595951	12-32%	CS5	158.78	158.78	15/08/2010
TP-770	02/07/2010	RN 3165/2	297139	7595773	12-40%/30-70%	CS4 / CS1	101.26	101.26	15/08/2010
TP-742	02/07/2010	RN 3165/2	296932	7595997	14-50%	ID1	111.82	111.82	15/08/2010
TP-738	03/07/2010	RN 3165/2	297406	7597048	12-40%	CS4	130.14	130.14	15/08/2010
TP-764	03/07/2010	RN 3165/2	297277	7596367	12-40%/30-70%	CS4 / CS1	203.79	203.79	15/08/2010
TP-763	03/07/2010	RN 3165/2	297445	7596639	12-40%/30-70%	CS4 / CS1	151.22	151.22	15/08/2010

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Area Cleared (m2)	Area Spread (m2)	Date Spread*
TP-762	04/07/2010	RN 3165/2	297152	7596885	12-40%	CS4	212.01	212.01	15/08/2010
TP-766	04/07/2010	RN 3165/2	296761	7596299	12-40%/30-70%	CS4 / CS1	183.38	183.38	15/08/2010
TP-739	04/07/2010	RN 3165/2	296914	7596456	12-40%/30-70%	CS4 / CS1	85.69	85.69	15/08/2010
TP-743	05/07/2010	RN 3165/2	297436	7595636	0%	C1	0.00	0.00	15/08/2010
TP-773	05/07/2010	RN 3165/2	297352	7595449	12-32%	CS5	166.39	166.39	15/08/2010
TP-771	05/07/2010	RN 3165/2	296762	7595650	12-32%	CS5	239.97	239.97	15/08/2010
TP-740	05/07/2010	RN 3165/2	297524	7596251	12-40%/30-70%	CS4 / CS1	127.89	127.89	15/08/2010
TP-BP4-14	07/10/2010	RN 3165/3	298920	7594017	12-40%	CS4	218.15	218.15	14/10/2010
TP-BP4-13	08/10/2010	RN 3165/3	299544	7594105	10-70%	CS2	225.00	225.00	14/10/2010
TP-BP4-10	08/10/2010	RN 3165/3	299249	7594342	10-70%	CS2	396.82	396.82	15/10/2010
TP-BP4-12	08/10/2010	RN 3165/3	299848	7594280	12-32%	CS5	225.00	225.00	14/10/2010
TP-BP4-11	09/10/2010	RN 3165/3	299612	7594538	12-32%	CS5	300.01	300.01	15/10/2010
TP-BP4-07	09/10/2010	RN 3165/3	299337	7594671	12-40%	CS4	225.00	225.00	14/10/2010
TP-BP4-06	10/10/2010	RN 3165/3	299572	7594834	12-32%	CS5	299.99	299.99	15/10/2010
TP-BP4-02	10/10/2010	RN 3165/3	298999	7595084	12-40%	CS4	254.99	254.99	15/10/2010
TP-BP4-03	10/10/2010	RN 3165/3	299235	7595101	12-40%	CS4	396.61	396.61	15/10/2010
TP-BP4-09	11/10/2010	RN 3165/3	298861	7594528	12-32%	CS5	270.00	270.00	14/10/2010
TP-BP4-08	11/10/2010	RN 3165/3	298768	7594732	12-32%	CS5	400.00	400.00	14/10/2010
TP-BP4-04	11/10/2010	RN 3165/3	298827	7595011	12-32%	CS5	400.01	400.01	14/10/2010
TP-BP4-17	12/10/2010	RN 3165/3	298422	7593985	12-32%	CS5	320.00	320.00	14/10/2010
TP-BP4-16	12/10/2010	RN 3165/3	298478	7594252	12-32%	CS5	537.56	537.56	14/10/2010
TP-BP4-15	12/10/2010	RN 3165/3	298691	7594262	12-32%	CS5	224.99	224.99	14/10/2010
TP-BP4-18	13/10/2010	RN 3165/3	298120	7593724	12-32%	CS5	600.00	600.00	14/10/2010
TP-BP4-01	13/10/2010	RN 3165/3	298879	7595270	12-32%	CS5	500.00	500.00	14/10/2010
TP-BP4-05	13/10/2010	RN 3165/3	299088	7594821	12-40%	CS4	399.99	399.99	14/10/2010
Grid Line F	22/06/2010	RN 3165/2	298295	7595979	0%	C1	0.00	0.00	23/08/2010
Grid Line F	22/06/2010	RN 3165/2	298319	7595770	12-40%/30-70%	CS4 / CS1	674.31	674.31	23/08/2010

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Area Cleared (m2)	Area Spread (m2)	Date Spread*
Grid Line B2	23/06/2010	RN 3165/2	298345	7596088	0%	C1	0.00	0.00	23/08/2010
Grid Line B2	23/06/2010	RN 3165/2	298497	7596093	12-40%/30-70%	CS4 / CS1	490.05	490.05	23/08/2010
Grid Line F	24/06/2010	RN 3165/2	298203	7596783	12-40%/30-70%	CS4 / CS1	535.65	535.65	23/08/2010
Grid Line A2/ B-780	25/06/2010	RN 3165/2	298228	7596605	12-40%/30-70%	CS4 / CS1	14.42	14.42	21/08/2010
Grid Line C1/ B-774	26/06/2010	RN 3165/2	297731	7595345	12-32%	CS5	593.09	593.09	23/08/2010
Grid Line F	26/06/2010	RN 3165/2	298235	7596506	12-40%/30-70%	CS4 / CS1	347.52	347.52	23/08/2010
Grid Line C1/ B-772	27/06/2010	RN 3165/2	297281	7595451	12-32%	CS5	1016.32	1016.32	23/08/2010
Grid Line F	28/06/2010	RN 3165/2	298351	7595490	12-32%	CS5	77.73	77.73	23/08/2010
Grid Line F	28/06/2010	RN 3165/2	298343	7595562	12-40%/30-70%	CS4 / CS1	174.58	174.58	23/08/2010
Grid Line A1	29/06/2010	RN 3165/2	297388	7596523	12-40%/30-70%	CS4 / CS1	431.83	431.83	21/08/2010
Grid Line A1/ B-765	29/06/2010	RN 3165/2	297076	7596491	12-40%/30-70%	CS4 / CS1	665.23	665.23	21/08/2010
Grid Line E	29/06/2010	RN 3165/2	297541	7596310	12-40%/30-70%	CS4 / CS1	794.39	794.39	21/08/2010
Grid Line E	29/06/2010	RN 3165/2	297547	7596071	14-50%	ID1	44.51	44.51	21/08/2010
Grid Line E to Xroads	29/06/2010	RN 3165/2	297553	7595827	0%	C1	0.00	0.00	21/08/2010
Grid Line E to Xroads	29/06/2010	RN 3165/2	297550	7595954	0%	C1	0.00	0.00	21/08/2010
Grid Line E to Xroads	29/06/2010	RN 3165/2	297552	7595876	0%	C1	0.00	0.00	21/08/2010
Grid Line E to Xroads	29/06/2010	RN 3165/2	297551	7595914	12-40%/30-70%	CS4 / CS1	184.99	184.99	21/08/2010
Grid Line E to Xroads	29/06/2010	RN 3165/2	297548	7596036	14-50%	ID1	76.80	76.80	21/08/2010
Grid Line E/ TP-769	29/06/2010	RN 3165/2	297553	7595816	0%	C1	0.00	0.00	21/08/2010
Grid Line E/ TP-769	29/06/2010	RN 3165/2	297554	7595766	0%	C1	0.00	0.00	21/08/2010
Grid Line E/ TP-769	29/06/2010	RN 3165/2	297561	7595518	12-32%	CS5	426.91	426.91	21/08/2010
Grid Line E/ TP-769	29/06/2010	RN 3165/2	297556	7595710	12-40%/30-70%	CS4 / CS1	246.23	246.23	21/08/2010
Grid Line B2/ TP-741	02/07/2010	RN 3165/2	296633	7595971	12-32%	CS5	94.15	94.15	23/08/2010
Grid Line B2/ TP-741	02/07/2010	RN 3165/2	296847	7595998	12-40%/30-70%	CS4 / CS1	660.33	660.33	23/08/2010
Grid Line B2/ TP-741	02/07/2010	RN 3165/2	296936	7596010	14-50%	ID1	238.56	238.56	23/08/2010
Grid Line A1	04/07/2010	RN 3165/2	296825	7596466	12-40%/30-70%	CS4 / CS1	217.04	217.04	21/08/2010
Grid Line B2	06/07/2010	RN 3165/2	298005	7596076	12-32%	CS5	166.98	166.98	23/08/2010

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Area Cleared (m2)	Area Spread (m2)	Date Spread*
Grid Line B2	06/07/2010	RN 3165/2	298866	7596106	12-32%	CS5	236.44	236.44	23/08/2010
Grid Line B2	06/07/2010	RN 3165/2	296502	7595954	12-32%	CS5	267.79	267.79	23/08/2010
Grid Line B2	06/07/2010	RN 3165/2	298089	7596079	12-40%/30-70%	CS4 / CS1	413.76	413.76	23/08/2010
Grid Line B2	06/07/2010	RN 3165/2	298684	7596100	12-40%/30-70%	CS4 / CS1	206.37	206.37	23/08/2010
Grid Line B2	06/07/2010	RN 3165/2	298771	7596103	12-40%/30-70%	CS4 / CS1	97.89	97.89	23/08/2010
Grid Line B2	06/07/2010	RN 3165/2	297704	7596065	12-40%/30-70%	CS4 / CS1	121.30	121.30	23/08/2010
Grid Line B2	06/07/2010	RN 3165/2	297351	7596049	12-40%/30-70%	CS4 / CS1	632.46	632.46	23/08/2010
Grid Line B2	06/07/2010	RN 3165/2	297608	7596060	14-50%	ID1	214.14	214.14	23/08/2010
Grid Line B2	06/07/2010	RN 3165/2	297539	7596057	14-50%	ID1	27.09	27.09	23/08/2010
Grid Line A1	08/07/2010	RN 3165/2	296631	7596446	12-32%	CS5	344.69	344.69	21/08/2010
Grid Line A1	08/07/2010	RN 3165/2	297612	7596545	12-40%/30-70%	CS4 / CS1	356.32	356.32	21/08/2010
Grid Line A1	08/07/2010	RN 3165/2	296746	7596458	12-40%/30-70%	CS4 / CS1	61.04	61.04	21/08/2010
Grid Line A2	08/07/2010	RN 3165/2	298113	7596595	12-40%/30-70%	CS4 / CS1	387.17	387.17	21/08/2010
Grid Line A2	08/07/2010	RN 3165/2	298352	7596616	12-40%/30-70%	CS4 / CS1	364.22	364.22	21/08/2010
Grid Line A3	08/07/2010	RN 3165/2	298800	7596662	12-40%/30-70%	CS4 / CS1	524.96	524.96	21/08/2010
Grid Line E	10/07/2010	RN 3165/2	297568	7595246	12-32%	CS5	455.28	455.28	21/08/2010
Grid Line E	10/07/2010	RN 3165/2	297425	7597035	12-40%	CS4	33.77	33.77	21/08/2010
Grid Line E	10/07/2010	RN 3165/2	297413	7597104	12-40%	CS4	134.71	134.71	21/08/2010
Grid Line E	10/07/2010	RN 3165/2	297462	7596816	12-40%/30-70%	CS4 / CS1	743.42	743.42	21/08/2010
Grid Line E	10/07/2010	RN 3165/2	297400	7597177	12-40%/30-70%	CS4 / CS1	125.01	125.01	21/08/2010
Grid Line E	10/07/2010	RN 3165/2	297486	7596676	42-100%	CP2	128.21	128.21	21/08/2010
Grid Line D1	14/07/2010	RN 3165/2	297341	7595543	0%	C1	0.00	0.00	23/08/2010
Grid Line D1	14/07/2010	RN 3165/2	297189	7595531	12-32%	CS5	1865.73	1865.73	23/08/2010
Grid Line D1	14/07/2010	RN 3165/2	297728	7595571	12-40%/30-70%	CS4 / CS1	56.42	56.42	23/08/2010
Grid Line D2	14/07/2010	RN 3165/2	298396	7595629	12-32%	CS5	314.65	314.65	23/08/2010
Grid Line D2	14/07/2010	RN 3165/2	298311	7595623	12-40%/30-70%	CS4 / CS1	230.63	230.63	23/08/2010
Grid Line D2	14/07/2010	RN 3165/2	298234	7595617	42-100%	CP2	39.05	39.05	23/08/2010

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Area Cleared (m2)	Area Spread (m2)	Date Spread*
Grid Line C1	18/07/2010	RN 3165/2	296701	7595588	12-32%	CS5	1027.75	1027.75	23/08/2010
Grid Line C2	18/07/2010	RN 3165/2	297934	7595299	12-32%	CS5	24.52	24.52	23/08/2010
Grid Line C3	18/07/2010	RN 3165/2	298098	7595263	12-32%	CS5	386.07	386.07	23/08/2010
Grid Line G	04/08/2010	RN 3165/2	298272	7597112	12-40%/30-70%	CS4 / CS1	788.70	788.70	23/08/2010
Grid Line F	05/08/2010	RN 3165/2	298362	7595398	12-32%	CS5	248.48	248.48	23/08/2010
Grid Line F	05/08/2010	RN 3165/2	298279	7596120	12-40%/30-70%	CS4 / CS1	371.01	371.01	23/08/2010
						Sum Total	**3.72 ha**	**3.72 ha**	

TABLE 6.2.2 - Records of Track Clearing - RN 3165

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Track Type	Width (m)	Area Cleared (m2)
B-657	09/06/2010	RN 3165/1	297225	7590281	30-70%	CS1	LV	0.60	124.28
B-659	07/06/2010	RN 3165/1	297703	7590161	30-70%	CS1	LV	0.60	7.12
B-661	04/06/2010	RN 3165/1	297327	7590008	30-70%	CS1	LV	0.60	22.73
B-662	04/06/2010	RN 3165/1	297598	7589903	12-40%/30-70%	CS4 / CS1	LV	0.60	49.34
B-662	04/06/2010	RN 3165/1	297553	7589892	30-70%	CS1	LV	0.60	9.29
B-662	04/06/2010	RN 3165/1	297603	7589901	42-100%	CP2	LV	0.60	5.65
B-662/ ES-225	04/06/2010	RN 3165/1	297505	7589885	12-40%/30-70%	CS4 / CS1	LV	0.60	13.49
B-662/ ES-225	04/06/2010	RN 3165/1	297473	7589971	30-70%	CS1	LV	0.60	96.94
B-664	10/06/2010	RN 3165/1	297097	7589641	30-70%	CS1	LV	0.60	188.81
B-665	05/06/2010	RN 3165/1	297524	7589733	12-40%/30-70%	CS4 / CS1	LV	0.60	130.25
B-665/ ES-225	05/06/2010	RN 3165/1	297515	7589858	12-40%/30-70%	CS4 / CS1	LV	0.60	21.31
E049	15/06/2010	RN 3165/1	296544	7590361	0%	cleared	LV	0.00	0.00
E049	15/06/2010	RN 3165/1	296572	7590331	30-70%	CS1	LV	0.60	47.56
E050	16/06/2010	RN 3165/1	297802	7590069	30-70%	CS1	LV	0.60	48.30
E050	16/06/2010	RN 3165/1	297755	7590113	42-100%	CP2	LV	0.60	48.83
ES-221/TP-879	04/06/2010	RN 3165/1	297045	7590102	0%	C1	Exc	0.00	0.00
ES-221/TP-879	04/06/2010	RN 3165/1	297018	7590160	30-70%	CS1	Exc	1.00	118.22
ES-221/TP-879	04/06/2010	RN 3165/1	296993	7590234	42-100%	CP2	Exc	1.00	38.41
Heritage Avoidance	08/06/2010	RN 3165/1	296713	7589734	12-40%/30-70%	CS4 / CS1	LV	0.60	44.69
TP-877,880/B-658/ES-220,222	04/06/2010	RN 3165/1	297602	7590344	30-70%	CS1	Exc	1.00	4.40
TP-877,880/B-658/ES-220,222	04/06/2010	RN 3165/1	297520	7590305	30-70%	CS1	Exc	1.00	177.37
TP-877,880/B-658/ES-220,222	04/06/2010	RN 3165/1	297404	7590245	30-70%	CS1	LV/Exc	1.00	346.19

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Track Type	Width (m)	Area Cleared (m2)
TP-881/ES-223	07/06/2010	RN 3165/1	297511	7590071	30-70%	CS1	Exc	1.00	14.41
TP-884	04/06/2010	RN 3165/1	297146	7589914	30-70%	CS1	Exc	1.00	2.24
TP-884	04/06/2010	RN 3165/1	297126	7589959	30-70%	CS1	Exc	1.00	97.16
TP-885/ ES-225	07/06/2010	RN 3165/1	297472	7589817	12-40%/30-70%	CS4 / CS1	Exc	1.00	107.87
TP-889/E051/ES-226	08/06/2010	RN 3165/1	296932	7589510	12-40%/30-70%	CS4 / CS1	Exc/LV	1.00	14.15
TP-889/E051/ES-226	08/06/2010	RN 3165/1	297039	7589523	30-70%	CS1	Exc/LV	1.00	201.67
TP-889/ES-226	08/06/2010	RN 3165/1	297289	7589558	12-40%/30-70%	CS4 / CS1	Exc	1.00	3.16
TP-889/ES-226	08/06/2010	RN 3165/1	297276	7589559	12-40%/30-70%	CS4 / CS1	Exc	1.00	24.73
TP-889/ES-226	08/06/2010	RN 3165/1	297205	7589555	30-70%	CS1	Exc	1.00	117.79
B-660/ES-221/TP-879	03/06/2010	RN 3165/2	297068	7590088	0%	C1	Argo after LV	0.00	0.00
B-660/ES-221/TP-879	03/06/2010	RN 3165/2	297091	7590046	30-70%	CS1	Argo after LV	0.00	0.00
B-662/ ES-225	04/06/2010	RN 3165/2	297505	7589885	12-40%/30-70%	CS4 / CS1	Argo after LV	0.00	0.00
B-662/ ES-225	04/06/2010	RN 3165/2	297473	7589971	30-70%	CS1	Argo after LV	0.00	0.00
B-665/ ES-225	05/06/2010	RN 3165/2	297515	7589858	12-40%/30-70%	CS4 / CS1	Argo after LV	0.00	0.00
B-765	29/06/2010	RN 3165/2	296887	7596472	12-40%/30-70%	CS4 / CS1	LV	0.60	0.30
B-781	24/06/2010	RN 3165/2	298260	7597045	12-40%/30-70%	CS4 / CS1	LV/Exc	1.00	276.87
B-853	26/06/2010	RN 3165/2	293796	7593723	0%	cleared	LV	0.00	0.00
B-853	26/06/2010	RN 3165/2	293117	7594059	12-40%	CS4	LV	0.60	54.64
B-853	26/06/2010	RN 3165/2	293427	7594543	30-100%	CS1 / CS2	LV	0.60	697.82
B-853	26/06/2010	RN 3165/2	293348	7595160	30-100%	CS1 / CS2	LV	0.60	265.61
B-853	26/06/2010	RN 3165/2	293695	7593735	30-100%	CS1 / CS2	LV	0.60	43.09
B-853	26/06/2010	RN 3165/2	293625	7594845	30-100%	CS1 / CS2	LV	0.60	271.33
B-853	26/06/2010	RN 3165/2	293486	7593760	30-70%	CS1	LV	0.60	80.72
B-853	26/06/2010	RN 3165/2	293242	7593936	30-70%	CS1	LV	0.60	44.86
B-853	26/06/2010	RN 3165/2	293606	7593745	30-70%	CS1	LV	0.60	64.13
B-856	27/06/2010	RN 3165/2	293145	7594106	12-40%	CS4	LV	0.60	4.97

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Track Type	Width (m)	Area Cleared (m2)
B-856	27/06/2010	RN 3165/2	293152	7594101	30-100%	CS1 / CS2	LV	0.60	4.60
B-871	22/06/2010	RN 3165/2	297297	7591267	0%	cleared	LV	0.00	0.00
TP-877,880/B-658/ES-220,222	04/06/2010	RN 3165/2	297103	7591678	10-70%	CS2	LV	0.60	224.30
B-871	22/06/2010	RN 3165/2	297230	7591554	12-40%	CS4	LV	0.60	25.37
B-871	22/06/2010	RN 3165/2	297044	7591770	30-70%	CS1	LV	0.60	74.98
B-871	22/06/2010	RN 3165/2	297294	7591355	30-70%	CP1	LV	0.60	102.43
B-871	22/06/2010	RN 3165/2	297094	7591856	30-70%	CS1	LV	0.60	48.75
B-871	22/06/2010	RN 3165/2	297175	7592047	0%	C1	LV	0.00	0.00
B-873	23/06/2010	RN 3165/2	297468	7593077	30-70%	CS1	LV	0.60	893.99
B-873	23/06/2010	RN 3165/2	297467	7593510	12-32%	CS5	LV	0.60	24.28
B-875/ TP-874	25/06/2010	RN 3165/2	297376	7593306	12-40%	CS4	LV	0.60	103.96
B-875/ TP-874	25/06/2010	RN 3165/2	297217	7594108	30-100%	CS1 / CS2	LV	0.60	104.81
B-875/ TP-874	25/06/2010	RN 3165/2	297435	7593216	30-70%	CS1	LV	0.60	26.82
B-875/ TP-874	25/06/2010	RN 3165/2	297301	7593419	4-30%	CS6	LV	0.60	637.86
B-875/ TP-874	25/06/2010	RN 3165/2	293060	7595499	<2%	T1	MB/Argo	3.00	1192.89
C-854, ES-92	15/07/2010	RN 3165/2	293081	7595068	<2%	T1	MB/Argo	3.00	886.71
C-854, ES-92	12/07/2010	RN 3165/2	293155	7594710	<2%	T1	MB	3.00	1436.85
C-855	15/07/2010	RN 3165/2	293134	7594979	<2%	T1	MB	3.00	183.97
C-855/ ES-92	15/07/2010	RN 3165/2	293397	7596195	<2%	T1	MB	3.00	775.85
C-878	19/07/2010	RN 3165/2	295362	7595697	<2%	T1	MB	3.00	11402.19
C-878	19/07/2010	RN 3165/2	296771	7595038	<2%	T1	MB	3.00	1081.46
C-878	20/07/2010	RN 3165/2	296649	7595277	10-30%	C3	MB	3.00	89.46
C-878	19/07/2010	RN 3165/2	296613	7594637	10-30%	C3	MB	3.00	2381.84
C-878	20/07/2010	RN 3165/2	296667	7594559	12-32%	CS5	MB	3.00	13.35
C-878	20/07/2010	RN 3165/2	295793	7595911	<2%	T1	MB	3.00	2115.41
D-947	19/07/2010	RN 3165/2	296762	7596381	12-40%/30-70%	CS4 / CS1	Excavator	1.00	158.17

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Track Type	Width (m)	Area Cleared (m2)
ES-199/ TP-766	04/07/2010	RN 3165/2	297462	7596586	12-40%/30-70%	CS4 / CS1	Excavator	1.00	95.36
ES-201/ TP-763	03/07/2010	RN 3165/2	297284	7596965	12-40%	CS4	Excavator	1.00	289.40
ES-202/ TP-762	04/07/2010	RN 3165/2	298348	7596908	12-40%/30-70%	CS4 / CS1	Excavator	1.00	49.34
ES-204/ TP-750	29/06/2010	RN 3165/2	298399	7596356	12-40%/30-70%	CS4 / CS1	Excavator	1.00	108.77
ES-207/ TP-778	28/06/2010	RN 3165/2	298322	7596366	42-100%	CP2	Excavator	1.00	46.23
ES-207/ TP-778	28/06/2010	RN 3165/2	298106	7596261	12-40%/30-70%	CS4 / CS1	Excavator	1.00	131.16
ES-208/ TP-748	30/06/2010	RN 3165/2	298199	7596258	42-100%	CP2	Excavator	1.00	56.13
ES-208/ TP-748	30/06/2010	RN 3165/2	298211	7596154	12-40%/30-70%	CS4 / CS1	LV/Exc	1.00	186.12
ES-209/ TP-776	26/06/2010	RN 3165/2	298207	7596050	42-100%	CP2	LV/Exc	1.00	21.60
ES-209/ TP-776	26/06/2010	RN 3165/2	298228	7596263	42-100%	CP2	LV/Exc	1.00	149.04
ES-209/ TP-776	26/06/2010	RN 3165/2	298204	7596044	42-100%	CP2	LV/Exc	1.00	0.03
ES-209/ TP-776	26/06/2010	RN 3165/2	298805	7596183	12-40%/30-70%	CS4 / CS1	Excavator	1.00	203.88
ES-210/ TP-747	28/06/2010	RN 3165/2	298230	7595708	12-32%	CS5	Excavator	1.00	22.61
ES-211/ TP-746	01/07/2010	RN 3165/2	298226	7595811	12-32%	CS5	LV/Exc	1.00	209.27
ES-211/ TP-746	26/06/2010	RN 3165/2	298194	7596004	12-40%/30-70%	CS4 / CS1	LV/Exc	1.00	20.51
ES-211/ TP-746	26/06/2010	RN 3165/2	298207	7595963	42-100%	CP2	LV/Exc	1.00	143.46
ES-211/ TP-746	26/06/2010	RN 3165/2	298204	7596044	42-100%	CP2	LV/Exc	1.00	0.03
ES-211/ TP-746	26/06/2010	RN 3165/1	298351	7595468	12-32%	CS5	Excavator	1.00	4.45
ES-212/ TP-745	28/06/2010	RN 3165/1	297920	7595251	12-32%	CS5	Excavator	1.00	141.11
ES-213/ TP-744	29/06/2010	RN 3165/1	297494	7595671	0%	C1	Excavator	0.00	0.00
ES-215/ TP-743	05/07/2010	RN 3165/1	297552	7595681	12-40%/30-70%	CS4 / CS1	Excavator	1.00	8.08
ES-215/ TP-743	05/07/2010	RN 3165/1	298120	7595516	12-32%	CS5	LV/Exc	1.00	470.98
ES-215/ TP-743	26/06/2010	RN 3165/1	297972	7595409	12-40%/30-70%	CS4 / CS1	LV/Exc	1.00	116.11
ES-215/ TP-743	26/06/2010	RN 3165/1	296876	7595578	12-32%	CS5	Excavator	1.00	259.82
ES-217/ TP-771	05/07/2010	RN 3165/1	297168	7595901	12-40%/30-70%	CS4 / CS1	Excavator	1.00	247.42
ES-218/ TP-770	02/07/2010	RN 3165/1	297535	7596249	12-40%/30-70%	CS4 / CS1	Excavator	1.00	13.91

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Track Type	Width (m)	Area Cleared (m2)
ES-219/ TP-740	05/07/2010	RN 3165/1	297045	7590102	0%	C1	Argo after Exc	0.00	0.00
ES-221/TP-879	04/06/2010	RN 3165/1	297018	7590160	30-70%	CS1	Argo after Exc	0.00	0.00
ES-221/TP-879	04/06/2010	RN 3165/1	296993	7590234	42-100%	CP2	Argo after Exc	0.00	0.00
ES-221/TP-879	04/06/2010	RN 3165/1	297415	7589806	12-40%/30-70%	CS4 / CS1	Argo	0.45	0.34
ES-225	17/07/2010	RN 3165/1	298737	7596632	12-40%/30-70%	CS4 / CS1	Excavator	1.00	47.61
ES-226/ TP-779	29/06/2010	RN 3165/1	293170	7594924	<2%	T1	Argo	0.45	37.91
ES-92	12/07/2010	RN 3165/1	293140	7595492	<2%	T1	Argo	0.45	205.72
ES-92	12/07/2010	RN 3165/1	297965	7595293	12-32%	CS5	LV	0.60	30.36
Geophysics Access	12/08/2010	RN 3165/1	297912	7595304	12-32%	CS5	LV	0.60	18.77
Geophysics Access	12/08/2010	RN 3165/1	296664	7589884	12-40%/30-70%	CS4 / CS1	Argo after LV	0.00	0.00
Heritage Avoidance	02/06/2010	RN 3165/1	296550	7589983	12-40%/30-70%	CS4 / CS1	Argo after LV	0.00	0.00
Heritage Avoidance	02/06/2010	RN 3165/1	296713	7589734	12-40%/30-70%	CS4 / CS1	Argo after LV	0.00	0.00
Heritage Avoidance	08/06/2010	RN 3165/1	296730	7589940	30-70%	CS1	Argo after LV	0.00	0.00
Heritage Avoidance	02/06/2010	RN 3165/1	296546	7589993	30-70%	CS1	Argo after LV	0.00	0.00
Heritage Avoidance	02/06/2010	RN 3165/1	295185	7596736	<2%	T1	Argo	0.45	924.03
Marsh DCP's	27/07/2010	RN 3165/2	295075	7596814	<2%	T1	Argo	0.45	72.47
Marsh DCP's	27/07/2010	RN 3165/2	297415	7597057	12-40%	CS4	Excavator	1.00	11.08
TP-738	03/07/2010	RN 3165/2	296910	7596467	12-40%/30-70%	CS4 / CS1	Excavator	1.00	15.69
TP-739	04/07/2010	RN 3165/2	296580	7595961	12-32%	CS5	Excavator	1.00	9.29
TP-741	02/07/2010	RN 3165/2	296933	7596006	14-50%	ID1	Excavator	1.00	7.78
TP-742	27/07/2010	RN 3165/2	298217	7596631	12-40%/30-70%	CS4 / CS1	Excavator	1.00	7.67
TP-749	30/06/2010	RN 3165/2	297274	7596443	12-40%/30-70%	CS4 / CS1	Excavator	1.00	140.35
TP-764	03/07/2010	RN 3165/2	297548	7595821	0%	C1	Excavator	0.00	0.00
TP-769	01/07/2010	RN 3165/2	297349	7595438	12-32%	CS5	Excavator	1.00	5.21
TP-773	05/07/2010	RN 3165/2	297296	7592500	30-70%	CS1	LV	0.60	69.47
TP-872	26/06/2010	RN 3165/2	297520	7590305	30-70%	CS1	Argo after Exc	0.00	0.00

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Track Type	Width (m)	Area Cleared (m2)
TP-877,880/B-658/ES-220,222	04/06/2010	RN 3165/2	297404	7590245	30-70%	CS1	Argo after LV/Exc	0.00	0.00
TP-877,880/B-658/ES-220,222	04/06/2010	RN 3165/2	297511	7590071	30-70%	CS1	Argo after Exc	0.00	0.00
TP-881/ES-223	07/06/2010	RN 3165/2	297126	7589959	30-70%	CS1	Argo after Exc	0.00	0.00
TP-884/ES-224	04/06/2010	RN 3165/2	297472	7589817	12-40%/30-70%	CS4 / CS1	Argo after Exc	0.00	0.00
TP-885/ ES-225	07/06/2010	RN 3165/2	296932	7589510	12-40%/30-70%	CS4 / CS1	Argo ~LV/Exc	0.00	0.00
TP-889/E051/ES-226	08/06/2010	RN 3165/2	297039	7589523	30-70%	CS1	Argo ~LV/Exc	0.00	0.00
TP-889/E051/ES-226	08/06/2010	RN 3165/2	297276	7589559	12-40%/30-70%	CS4 / CS1	Argo after Exc	0.00	0.00
TP-889/ES-226	08/06/2010	RN 3165/2	297205	7589555	30-70%	CS1	Argo after Exc	0.00	0.00
TP-889/ES-226	08/06/2010	RN 3165/2	299692	7593419	10-30%	C3	Excavator/ LV	1.00	147.26
BP4 Main Track	07/10/2010	RN 3165/3	299959	7593169	12-40%	CS4	Excavator/ LV	1.00	1133.41
BP4 Main Track	07/10/2010	RN 3165/1	299411	7593684	12-40%	CS4	Excavator/ LV	1.00	738.41
BP4 Main Track	07/10/2010	RN 3165/1	300401	7592780	4-30%	CS6	Excavator/ LV	1.00	49.93
BP4 Main Track	07/10/2010	RN 3165/1	298923	7595192	12-32%	CS5	Excavator/ LV	1.00	157.40
BP4-01	13/10/2010	RN 3165/1	298986	7595112	12-40%	CS4	Excavator/ LV	1.00	47.74
BP4-01	13/10/2010	RN 3165/1	299117	7595081	12-40%	CS4	Excavator/ LV	1.00	219.22
BP4-02	10/10/2010	RN 3165/1	299545	7594865	12-32%	CS5	Excavator/ LV	1.00	64.98
BP4-03	10/10/2010	RN 3165/1	299384	7594991	12-40%	CS4	Excavator/ LV	1.00	346.71
BP4-03	10/10/2010	RN 3165/1	298907	7595025	12-32%	CS5	Excavator/ LV	1.00	145.79
BP4-04	11/10/2010	RN 3165/1	298978	7595078	12-40%	CS4	Excavator/ LV	1.00	32.46
BP4-04	11/10/2010	RN 3165/1	298849	7594795	12-32%	CS5	Excavator/ LV	1.00	126.67
BP4-05	13/10/2010	RN 3165/1	298995	7594791	12-40%	CS4	Excavator/ LV	1.00	175.95
BP4-05	13/10/2010	RN 3165/1	299382	7594661	10-30%	C4	Excavator/ LV	1.00	46.14
BP4-06	10/10/2010	RN 3165/1	299559	7594823	12-32%	CS5	Excavator/ LV	1.00	10.85
BP4-06	10/10/2010	RN 3165/1	299476	7594748	12-40%	CS4	Excavator/ LV	1.00	214.00
BP4-06	10/10/2010	RN 3165/1	299410	7594622	10-30%	C4	Excavator/ LV	1.00	103.67

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	% Cover	Veg Code	Track Type	Width (m)	Area Cleared (m2)
BP4-07	09/10/2010	RN 3165/1	299481	7594592	10-70%	CS2	Excavator/ LV	1.00	106.12
BP4-07	09/10/2010	RN 3165/1	299570	7594565	12-32%	CS5	Excavator/ LV	1.00	81.17
BP4-07	09/10/2010	RN 3165/1	298810	7594868	12-32%	CS5	Excavator/ LV	1.00	268.44
BP4-08	11/10/2010	RN 3165/1	298825	7594630	12-32%	CS5	Excavator/ LV	1.00	209.50
BP4-09	11/10/2010	RN 3165/1	299200	7594168	10-70%	CS2	Excavator/ LV	1.00	315.80
BP4-10	08/10/2010	RN 3165/3	299138	7594003	12-40%	CS4	Excavator/ LV	1.00	16.24
BP4-10	08/10/2010	RN 3165/3	299151	7594029	12-40%	CS4	Excavator/ LV	1.00	40.83
BP4-10	08/10/2010	RN 3165/3	299726	7594375	10-70%	CS2	Excavator/ LV	1.00	10.07
BP4-11	09/10/2010	RN 3165/3	299623	7594509	12-32%	CS5	Excavator/ LV	1.00	329.79
BP4-11	09/10/2010	RN 3165/3	299696	7594168	10-70%	CS2	Excavator/ LV	1.00	320.84
BP4-12	08/10/2010	RN 3165/3	299833	7594271	12-32%	CS5	Excavator/ LV	1.00	22.89
BP4-12	08/10/2010	RN 3165/3	299390	7594030	10-70%	CS2	Excavator/ LV	1.00	321.24
BP4-13	08/10/2010	RN 3165/3	299173	7593948	12-40%	CS4	Excavator/ LV	1.00	55.44
BP4-13	08/10/2010	RN 3165/3	299208	7593958	12-40%	CS4	Excavator/ LV	1.00	17.01
BP4-13	08/10/2010	RN 3165/3	299230	7593964	4-30%	CS6	Excavator/ LV	1.00	28.07
BP4-13	08/10/2010	RN 3165/3	299034	7594015	12-40%	CS4	Excavator/ LV	1.00	208.40
BP4-14	07/10/2010	RN 3165/3	298663	7594287	12-32%	CS5	Excavator/ LV	1.00	56.03
BP4-15	12/10/2010	RN 3165/3	298687	7594370	12-32%	CS5	Excavator/ LV	1.00	475.16
BP4-16	12/10/2010	RN 3165/3	298447	7594109	12-32%	CS5	Excavator/ LV	1.00	282.27
BP4-17	12/10/2010	RN 3165/3	298175	7593928	12-32%	CS5	Excavator/ LV	1.00	514.51
BP4-18	13/10/2010	RN 3165/3	297225	7590281	30-70%	CS1	LV	0.60	124.28
								Sum Total	**3.99 ha**

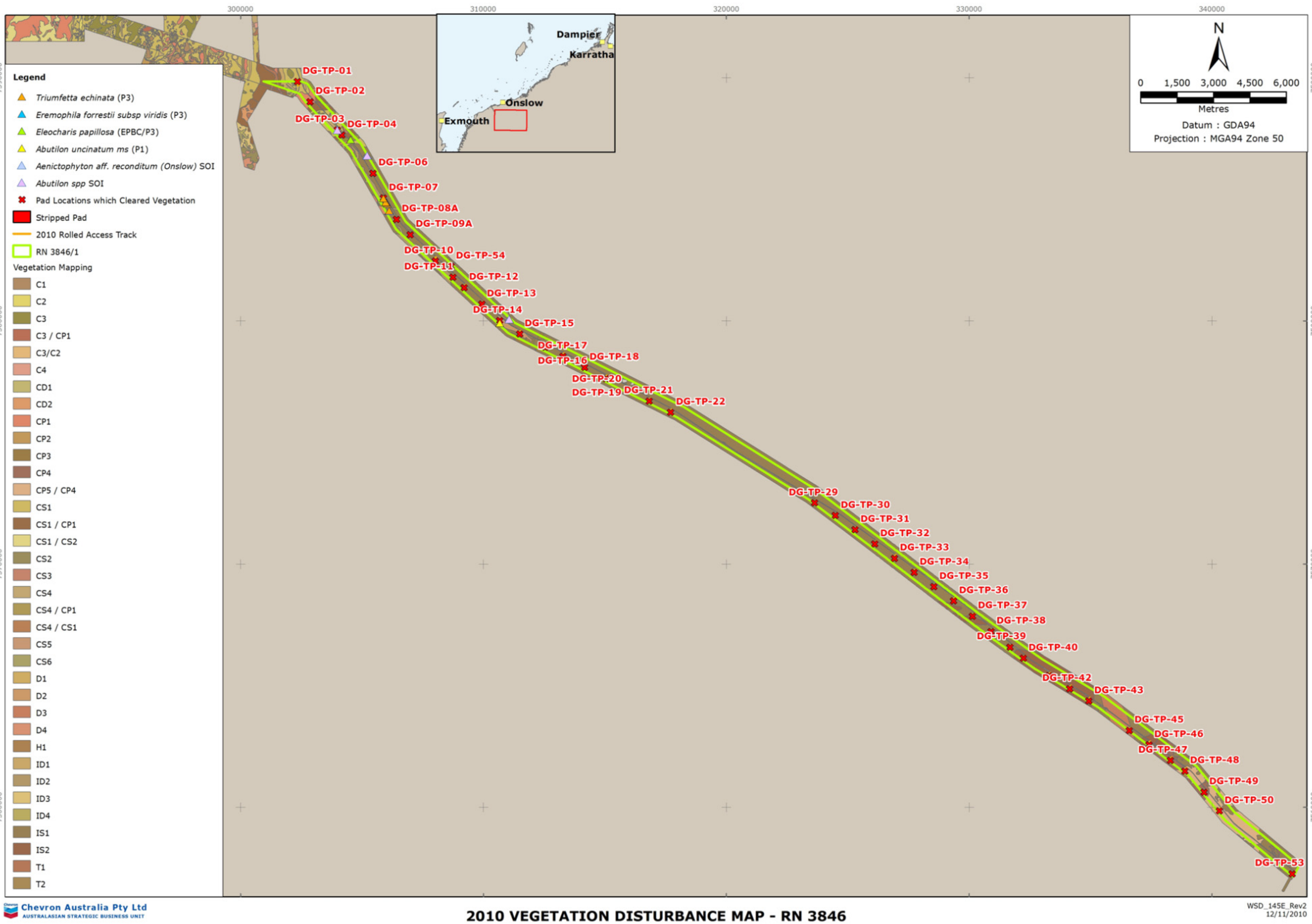
TABLE 6.2.3 - Records of Conservation Significant Taxa – RN 3165

Priority Taxa	Status	Easting (GDA94)	Northing (GDA94)	# Individuals
Eremophila forrestii subsp viridis	P3	297216	7596043	1
Eremophila forrestii subsp viridis	P3	297435	7596062	1
Eremophila forrestii subsp viridis	P3	297252	7596215	15
Abutilon uncinatum	P1	297457	7596903	1

APPENDIX 7: REQUIREMENT NOTICE 3846

Figures

Tables



2010 VEGETATION DISTURBANCE MAP - RN 3846

TABLE 7.2.1 - Records of Geotechnical Work Pad Clearing - RN 3846

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Area Cleared (m2)	Area Spread (m2)	Date Spread*
DG-TP-32	19/10/2010	RN 3846/1	326102	7570833	IS1	40-100%	299	299	19/10/2010
DG-TP-04	22/10/2010	RN 3846/1	304169	7587646	CS1 / CP1	30-100%	100	100	22/10/2010
DG-TP-53	14/10/2010	RN 3846/1	343286	7557273	IS1	40-100%	119	119	14/10/2010
DG-TP-50	14/10/2010	RN 3846/1	340285	7559860	CP5 / CP4	40-100%	138	138	14/10/2010
DG-TP-49	15/10/2010	RN 3846/1	339653	7560633	CP4	20-60%	75	75	15/10/2010
DG-TP-48	15/10/2010	RN 3846/1	338867	7561500	CP5 / CP4	40-100%	160	160	15/10/2010
DG-TP-47	15/10/2010	RN 3846/1	338269	7561936	CP4	20-60%	300	300	15/10/2010
DG-TP-46	15/10/2010	RN 3846/1	337389	7562579	IS2	14-50%	150	150	15/10/2010
DG-TP-45	16/10/2010	RN 3846/1	336581	7563170	D3	14-50%	120	120	16/10/2010
DG-TP-43	18/10/2010	RN 3846/1	334919	7564382	IS2	14-50%	80	80	18/10/2010
DG-TP-42	16/10/2010	RN 3846/1	334125	7564884	IS2	14-50%	170	170	16/10/2010
DG-TP-41	16/10/2010	RN 3846/1	333278	7565415	IS2	14-50%	225	225	16/10/2010
DG-TP-40	16/10/2010	RN 3846/1	332216	7566136	IS2	14-50%	500	500	16/10/2010
DG-TP-39	18/10/2010	RN 3846/1	331667	7566593	IS1	40-100%	150	150	18/10/2010
DG-TP-38	18/10/2010	RN 3846/1	330894	7567236	IS1	40-100%	150	150	18/10/2010
DG-TP-37	18/10/2010	RN 3846/1	330128	7567871	IS1	40-100%	65	65	18/10/2010
DG-TP-36	18/10/2010	RN 3846/1	329345	7568494	IS1	40-100%	66	66	18/10/2010
DG-TP-35	18/10/2010	RN 3846/1	328535	7569078	IS1	40-100%	55	55	18/10/2010
DG-TP-34	18/10/2010	RN 3846/1	327724	7569664	IS1	40-100%	64	64	18/10/2010
DG-TP-33	18/10/2010	RN 3846/1	326913	7570248	IS1	40-100%	75	75	18/10/2010
DG-TP-31	19/10/2010	RN 3846/1	325291	7571418	IS1	40-100%	44	44	19/10/2010
DG-TP-30	19/10/2010	RN 3846/1	324477	7571999	IS1	40-100%	52	52	19/10/2010
DG-TP-29	19/10/2010	RN 3846/1	323620	7572517	IS1	40-100%	60	60	19/10/2010
DG-TP-22	19/10/2010	RN 3846/1	317695	7576238	IS1	40-100%	119	119	19/10/2010
DG-TP-21	19/10/2010	RN 3846/1	316811	7576706	IS1	40-100%	112	112	19/10/2010

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Area Cleared (m2)	Area Spread (m2)	Date Spread*
DG-TP-20	19/10/2010	RN 3846/1	315922	7577166	IS1	40-100%	144	144	19/10/2010
DG-TP-19	19/10/2010	RN 3846/1	315035	7577625	IS1	40-100%	130	130	19/10/2010
DG-TP-18	20/10/2010	RN 3846/1	314147	7578084	IS1	40-100%	112	112	20/10/2010
DG-TP-17	20/10/2010	RN 3846/1	313258	7578543	IS1	40-100%	200	200	20/10/2010
DG-TP-16	20/10/2010	RN 3846/1	312524	7578923	IS1	40-100%	210	210	20/10/2010
DG-TP-15	21/10/2010	RN 3846/1	311479	7579463	D2	40-100%	150	150	21/10/2010
DG-TP-14	21/10/2010	RN 3846/1	310657	7580012	D2	40-100%	75	75	21/10/2010
DG-TP-13	21/10/2010	RN 3846/1	309924	7580692	IS1	40-100%	150	150	21/10/2010
DG-TP-12	21/10/2010	RN 3846/1	309190	7581372	IS1	40-100%	50	50	21/10/2010
DG-TP-11	21/10/2010	RN 3846/1	308728	7581797	IS1	40-100%	120	120	21/10/2010
DG-TP-10	21/10/2010	RN 3846/1	308018	7582457	IS1	40-100%	120	120	21/10/2010
DG-TP-09A	22/10/2010	RN 3846/1	306984	7583547	IS1	40-100%	75	75	22/10/2010
DG-TP-08A	22/10/2010	RN 3846/1	306418	7584181	IS1	40-100%	400	400	22/10/2010
DG-TP-07	22/10/2010	RN 3846/1	305882	7585049	ID2	14-50%	300	300	22/10/2010
DG-TP-06	22/10/2010	RN 3846/1	305453	7586071	IS1	40-100%	150	150	22/10/2010
DG-TP-03	23/10/2010	RN 3846/1	303983	7587851	ID1	14-50%	75	75	23/10/2010
DG-TP-02	23/10/2010	RN 3846/1	302863	7589011	CP1	30-70%	100	100	23/10/2010
DG-TP-01	23/10/2010	RN 3846/1	302338	7589842	C3	10-30%	100	100	23/10/2010
DG-TP-54	21/10/2010	RN 3846/1	308649	7582246	IS1	40-100%	180	180	21/10/2010
						Sum Total	**0.6289 ha**	**0.6289 ha**	

*Note that Chevron only respread clearing locations that were stripped of topsoil and vegetation. Within RN 3846/1 this was limited to test pits pads, as all track clearing occurred through the rolling of the backhoe and light vehicle over (and whenever possible, around) vegetation.

TABLE 7.2.2 - Records of Access Track Clearing - RN 3846

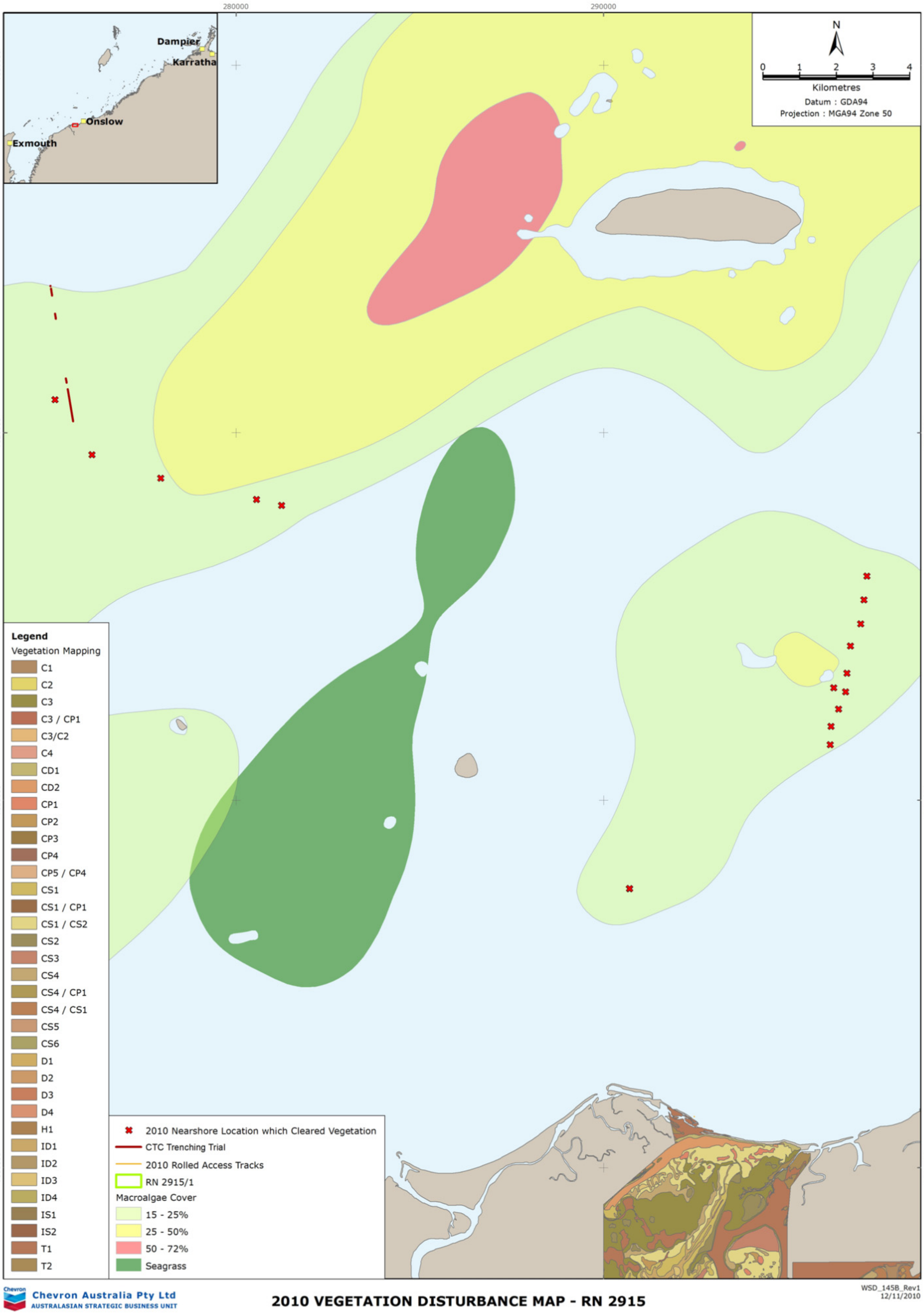
Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Track Type	Width (m)	Area Cleared (m2)
DG-TP-01	23/10/2010	RN 3846/1	302361	7589847	C3	10-30%	Back-Hoe	1.1	39.27
DG-TP-02	23/10/2010	RN 3846/1	302880	7589019	CP1	30-70%	Back-Hoe	1.1	25.71
DG-TP-03	23/10/2010	RN 3846/1	304018	7587848	ID1	14-50%	Back-Hoe	1.1	72.36
DG-TP-04	22/10/2010	RN 3846/1	304209	7587673	CS1 / CP1	30-100%	Back-Hoe	1.1	92.46
DG-TP-06	22/10/2010	RN 3846/1	305435	7586059	IS1	40-100%	Back-Hoe	1.1	22.73
DG-TP-06	22/10/2010	RN 3846/1	305419	7586054	cleared	0%	Back-Hoe	0.0	0.00
DG-TP-07	22/10/2010	RN 3846/1	305918	7585092	IS1	40-100%	Back-Hoe	1.1	102.14
DG-TP-07	22/10/2010	RN 3846/1	305885	7585066	ID2	14-50%	Back-Hoe	1.1	15.18
DG-TP-08	22/10/2010	RN 3846/1	306461	7584170	IS1	40-100%	Back-Hoe	1.1	82.02
DG-TP-53	14/10/2010	RN 3846/1	343283	7557267	IS1	40-100%	Back-Hoe	1.1	5.48
DG-TP-50	14/10/2010	RN 3846/1	340333	7559903	CP5 / CP4	40-100%	Back-Hoe	1.1	154.45
DG-TP-49	15/10/2010	RN 3846/1	339720	7560646	CP4	20-60%	Back-Hoe	1.1	157.32
DG-TP-48	15/10/2010	RN 3846/1	338899	7561562	CP5 / CP4	40-100%	Back-Hoe	1.1	147.73
DG-TP-47	15/10/2010	RN 3846/1	338285	7562010	CP4	20-60%	Back-Hoe	1.1	162.04
DG-TP-47	15/10/2010	RN 3846/1	338346	7562047	cleared	0%	Back-Hoe	0.0	0.00
DG-TP-46	15/10/2010	RN 3846/1	337420	7562645	IS2	14-50%	Back-Hoe	1.1	138.20
DG-TP-46	15/10/2010	RN 3846/1	337448	7562700	cleared	0%	Back-Hoe	0.0	0.00
DG-TP-45	16/10/2010	RN 3846/1	336613	7563233	D3	14-50%	Back-Hoe	1.1	147.39
DG-TP-43	18/10/2010	RN 3846/1	334958	7564448	IS2	14-50%	Back-Hoe	1.1	156.64
DG-TP-42	16/10/2010	RN 3846/1	334160	7564945	IS2	14-50%	Back-Hoe	1.1	144.32
DG-TP-41	16/10/2010	RN 3846/1	333314	7565484	IS2	14-50%	Back-Hoe	1.1	157.44
DG-TP-41	16/10/2010	RN 3846/1	333359	7565525	cleared	0%	Back-Hoe	0.0	0.00
DG-TP-40	16/10/2010	RN 3846/1	332259	7566200	IS2	14-50%	Back-Hoe	1.1	148.84
DG-TP-39	18/10/2010	RN 3846/1	331712	7566657	IS1	40-100%	Back-Hoe	1.1	166.69
DG-TP-38	18/10/2010	RN 3846/1	330941	7567292	IS1	40-100%	Back-Hoe	1.1	153.57

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Track Type	Width (m)	Area Cleared (m2)
DG-TP-37	18/10/2010	RN 3846/1	330174	7567932	IS1	40-100%	Back-Hoe	1.1	163.24
DG-TP-36	18/10/2010	RN 3846/1	329372	7568569	IS1	40-100%	Back-Hoe	1.1	171.59
DG-TP-35	18/10/2010	RN 3846/1	328580	7569134	IS1	40-100%	Back-Hoe	1.1	157.46
DG-TP-34	18/10/2010	RN 3846/1	327746	7569740	IS1	40-100%	Back-Hoe	1.1	189.54
DG-TP-33	18/10/2010	RN 3846/1	326948	7570310	IS1	40-100%	Back-Hoe	1.1	154.86
DG-TP-32	19/10/2010	RN 3846/1	326165	7570885	IS1	40-100%	Back-Hoe	1.1	139.62
DG-TP-31	19/10/2010	RN 3846/1	325328	7571480	IS1	40-100%	Back-Hoe	1.1	157.66
DG-TP-30	19/10/2010	RN 3846/1	324514	7572065	IS1	40-100%	Back-Hoe	1.1	161.92
DG-TP-29	19/10/2010	RN 3846/1	323654	7572576	IS1	40-100%	Back-Hoe	1.1	152.66
DG-TP-22	19/10/2010	RN 3846/1	317725	7576302	IS1	40-100%	Back-Hoe	1.1	143.93
DG-TP-21	19/10/2010	RN 3846/1	316849	7576768	IS1	40-100%	Back-Hoe	1.1	149.31
DG-TP-20	19/10/2010	RN 3846/1	315952	7577232	IS1	40-100%	Back-Hoe	1.1	153.10
DG-TP-19	19/10/2010	RN 3846/1	315071	7577685	IS1	40-100%	Back-Hoe	1.1	141.31
DG-TP-18	20/10/2010	RN 3846/1	314159	7578163	IS1	40-100%	Back-Hoe	1.1	184.24
DG-TP-17	20/10/2010	RN 3846/1	313288	7578608	IS1	40-100%	Back-Hoe	1.1	148.38
DG-TP-16	20/10/2010	RN 3846/1	312544	7578990	IS1	40-100%	Back-Hoe	1.1	144.19
DG-TP-15	21/10/2010	RN 3846/1	311510	7579533	D2	40-100%	Back-Hoe	1.1	161.07
DG-TP-14	21/10/2010	RN 3846/1	310706	7580060	D2	40-100%	Back-Hoe	1.1	167.38
DG-TP-13	21/10/2010	RN 3846/1	309972	7580748	IS1	40-100%	Back-Hoe	1.1	146.37
DG-TP-12	21/10/2010	RN 3846/1	309235	7581425	IS1	40-100%	Back-Hoe	1.1	140.18
DG-TP-11	21/10/2010	RN 3846/1	308782	7581843	IS1	40-100%	Back-Hoe	1.1	150.56
DG-TP-54	21/10/2010	RN 3846/1	308608	7582200	IS1	40-100%	Back-Hoe	1.1	118.74
DG-TP-54	21/10/2010	RN 3846/1	308583	7582149	pre-cleared	0%	Back-Hoe	0.0	0.00
DG-TP-10	21/10/2010	RN 3846/1	308023	7582537	IS1	40-100%	Back-Hoe	1.1	167.79
DG-TP-09	22/10/2010	RN 3846/1	306991	7583574	IS1	40-100%	Back-Hoe	1.1	56.22
								Sum Total	**0.5913 ha**

APPENDIX 8: REQUIREMENT NOTICE 2915

Figures

Tables



2010 VEGETATION DISTURBANCE MAP - RN 2915

TABLE 8.2.1 - Records of Work Pad Clearing - RN 2915

Location ID	Date Cleared	Permit #	Easting (MGA50)	Northing (MGA50)	Veg Code	% Cover	Area Cleared (m2)
MC326	20/06/2010	RN 2915/3	296159	7611517	MA	15-25%	5
MC328	22/06/2010	RN 2915/3	296388	7612486	MA	15-25%	5
N9	22/06/2010	RN 2915/3	281234	7618025	MA	15-25%	5
MC338	23/06/2010	RN 2915/3	296583	7612955	MA	15-25%	5
N10	28/06/2010	RN 2915/3	280553	7618188	MA	15-25%	5
N11	30/06/2010	RN 2915/3	277943	7618764	MA	15-25%	5
N13	25/07/2010	RN 2915/3	275065	7620901	MA	15-25%	5
						Sum Total	**0.0035 ha**

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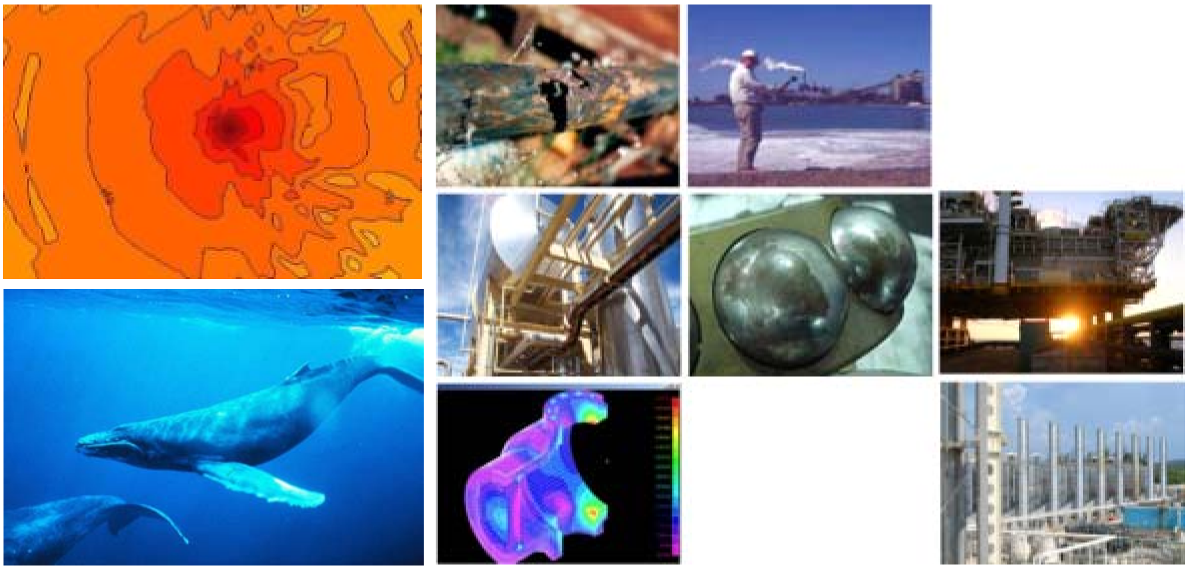
Appendix FL

Underwater Environmental Noise Assessment for Marine Mammals: Wheatstone Piling

This report documents the outcomes of the underwater noise model and the assessed impact on humpback whales, dolphins and dugongs from the piling activities associated with the development. Possible physical injury and possible behavioural disturbance by marine fauna are the two environmental impacts of underwater noise that were considered in the assessment. These two effects result in the determination of three zones of interest. These zones were defined by the dual criteria of Peak Sound Pressure Level (SPL peak) and Sound Exposure Level (SEL) and are as follows: Zone of Possible Physical Injury; Zone of Possible Temporary Threshold Shift (TTS); and Zone of Possible Behavioural Disturbance. Pile driving barges where modelled at various Work Points (WP) for the proposed Wheatstone port facility development. It was assumed that two piling barges would be operating simultaneously. Two piling scenarios were modelled. As SEL criteria was applied to define the zones of possible physical injury and possible TTS - onset, the received SEL depends on the animals exposure time to the piling noise, and therefore so do the estimated furthest distance from source to the zones. For humpback whales, dolphins and dugongs the piling activities could cause physical injury up to 400 m range and TTS - onset up to in 2600 m range if they are exposed to a complete piling operation as defined in the scenarios modelled. The furthest distance from the piling activity source to the zone of behavioural disturbance is 6 km.

SVT ENGINEERING CONSULTANTS

UNDERWATER ENVIRONMENTAL NOISE ASSESSMENT FOR MARINE MAMMALS: WHEATSTONE PILING



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EXECUTIVE SUMMARY

SVT was commissioned by RPS to perform an underwater noise assessment for the piling activities associated with the Wheatstone port facility development. This report documents the outcomes of the underwater noise model and the assessed impact on humpback whales, dolphins and dugongs from the piling activities associated with the development.

Assessment Criteria

Possible physical injury and possible behavioural disturbance by marine fauna are the two environmental impacts of underwater noise that were considered in the assessment. These two effects result in the determination of three areas or zones of interest. These areas or zones are as follows:

1. **Zone of Possible Physical Injury**. In this zone there is a possibility that the animal may suffer physical injury and/or permanent hearing damage or permanent hearing threshold shift (PTS).
2. **Zone of Possible Temporary Threshold Shift**. In this zone there is a possibility that the animal may experience temporary threshold shift (TTS).
3. **Zone of Possible Behavioural Disturbance.** In this zone there is a possibility that the animal may experience auditory masking/ and/or behavioural change and/or avoid the area.

Dual criteria of Peak Sound Pressure Level (SPL peak) and Sound Exposure Level (SEL) were recommended by *Southall et al* [1] to define the three zones.

Table E-1 provides the noise assessment criteria that were used to determine impacts on humpback whales, dolphins and dugongs. More details can be seen in Section 3.

Table E-1 Received threshold levels of Peak Sound Pressure Level (SPL peak), RMS Sound Pressure Level (SPL (rms)) and Sound Exposure Level (SEL) above which there would be a possibility of physical injury or behavioural disturbance or TTS-onset for humpback whales, dolphins and dugongs. M_{lf}: Marine mammal low-frequency weighting; M_{mf}: Marine mammal mid-frequency weighting; flat: flat frequency weighting.

Metric	Possible Physical Injury		Possible TTS - onset		Possible Behavioural Disturbance	
	Humpback Whales	Dolphins and Dugongs	Humpback Whales	Dolphins and Dugongs	Humpback Whales	Dolphins and Dugongs
SPL peak (dB re 1μPa)	230 (flat)	230 (flat)	-	-	-	-
SPL (rms) (dB re 1μPa)	-	-	-	-	120 (flat)	120 (flat)
SEL (dB re 1μPa^2.s)	198 (M_{lf})	198 (M_{mf})	183 (M_{lf})	183 (M_{mf})	-	-

[1] *Southall et al*, Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

Modelling Scenarios

Pile driving barges where modelled at various Work Points (WP) for the proposed Wheatstone port facility development. It was assumed that two piling barges would be operating simultaneously. Two piling scenarios were modelled: piling with source locations at WP114 and WP106 and piling with source locations at WP103 and WP102 (see Table 5-1 for detailed locations).

Modelling Results

Two modelling scenarios were modelled in this study. Each scenario was modelled using Highest Astronomical Tide (HAT) of 3 meters.

Table E-2 and Table E- 3 summarise the maximum distances between noise sources and the zones of possible physical injury, possible behavioural disturbance and possible TTS-onset respectively for humpback whales, dolphins and dugongs.

Table E-2 Furthest distances to zones of possible physical injury and TTS onset for humpback whales, dolphins and dugong, against the exposure duration to the piling noise.

Modelling Scenarios	Furthest Distance from Source to Zone of Physical Injury (m)							
	Humpback Whales				Dolphins and Dugongs			
	With the exposure duration of							
	10 minutes	0.5 h	1 h	3 h	10 minutes	0.5 h	1 h	3 h
Pile Driving – Wheatstone port facility development	50	100	250	400	50	100	250	400
	Furthest Distance from Source to Zone of TTS-onset (m)							
Pile Driving – Wheatstone port facility development	650	1250	1800	2600	650	1250	1800	2600

Table E- 3 Furthest distances to zones of Possible Behavioural Disturbance for humpback whales, dolphins and dugong, against the exposure duration to the piling noise.

Modelling Scenarios	Furthest Distance from Source to Zone of Possible Behavioural Disturbance (km)	
	Whales	Dolphins and Dugongs
Pile Driving – Wheatstone port facility development	6	6

As SEL criteria was applied to define the zones of possible physical injury and possible TTS - onset, the received SEL depends on the animals exposure time to the piling noise, and therefore so do the estimated furthest distance from source to the zones. Table E-2 shows that for humpback whales, dolphins and dugongs the piling activities could cause physical injury up to 400 m range and TTS - onset up to in a 2600 m if they are exposed to a complete piling operation as defined in the scenarios modelled. As is shown in Table E- 3, the furthest distance from the piling activity source to the zone of behavioural disturbance is 6 km.

TABLE OF CONTENTS

1. INTRODUCTION

SVT was commissioned by RPS to undertake an underwater environmental noise impact assessment for the piling activities associated with the jetty and wharf construction of the proposed Wheatstone port facility development. This report documents the outcomes of the underwater noise model and the expected impact on humpback whales, dolphins and dugongs as a result of piling activities for the port facility development. These species have been selected because humpbacks are seasonally abundant and some individuals move into shallow water with calves. Dugongs and dolphins because they are occassionally observed in nearshore waters off the proposed plant site.

1.1 Background

The proposed Wheatstone port facility development is located at Ashburton North, approximately 12 km south-west of Onslow, Western Australia. The facility forms part of the downstream component of the Wheatstone LNG development, as shown in Figure 1-1. The facility development will consist of the wharf and access jetty construction, for which piling activities will be involved.

1.2 Aim

The aim of this study was to assess the impact of underwater noise on humpback whales, dolphins and dugongs, as a result of the piling activities associated with the jetty and wharf construction of the proposed Wheatstone port facility development.

1.3 Scope

The scope of this work covers the modelling of the underwater noise from the piling activities associated with the Wheatstone port construction activities as well as the assessment of the impact on humpback whales, dolphins and dugongs as a result of the piling activities.

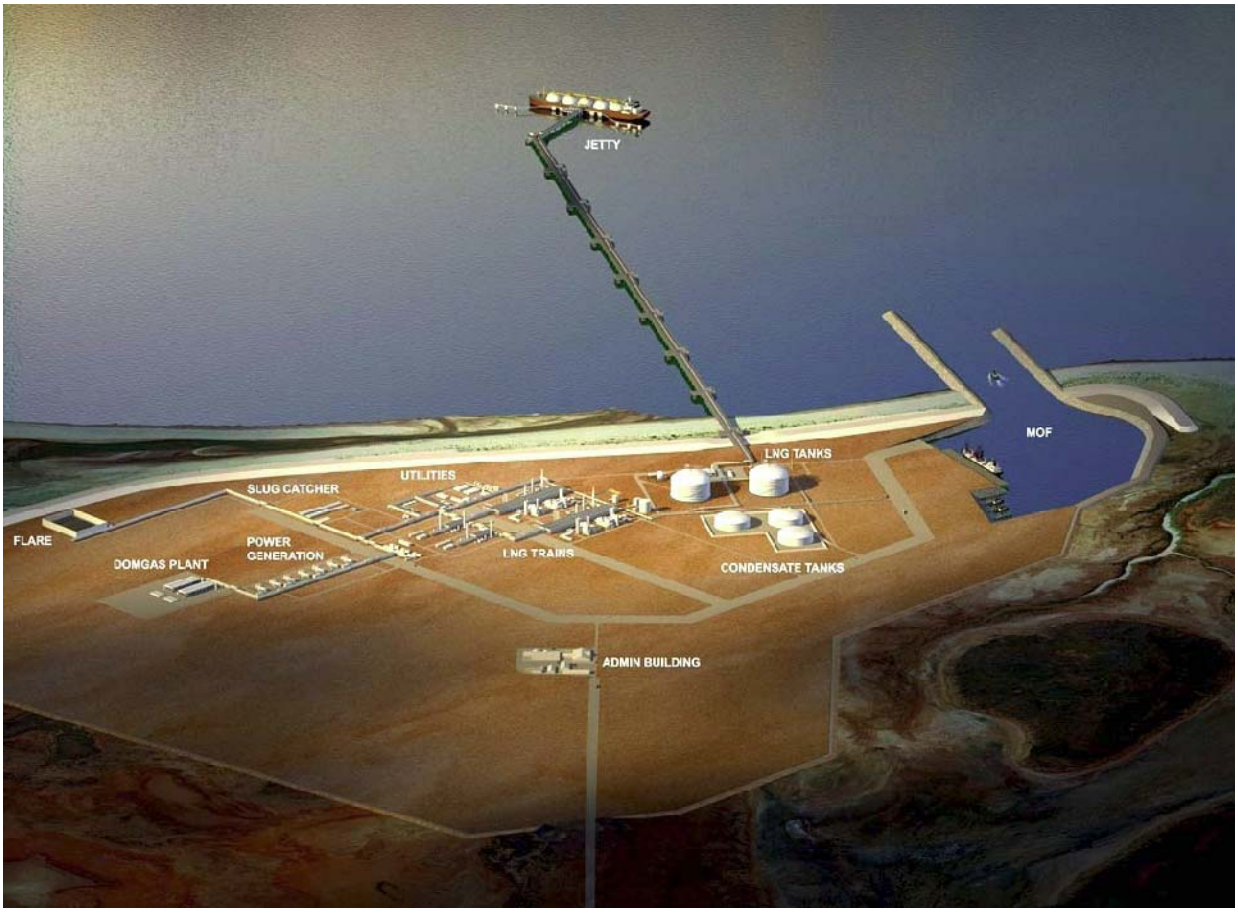

Figure 1-1 Illustrative representation of downstream infrastructure[2] (Note: this is illustrative only and does not represent final layout of facilities).

[2] Wheatstone Project – Environmental Scoping Document. Chevron Australia Pty Ltd. 2nd June 2009.

2. NOISE SOURCES

2.1 Pile Driving

Pile driving operations involve hammering a pile into the seabed. The noise emanating from a pile during a piling operation is a function of its material type, its size, the force applied to it and the characteristics of the substrate into which it is being driven.

The action of hammering a pile into the sea bed (Figure 2-1) will excite bendy waves[3] in the pile that will propagate along the length of the pile and then into the seabed. The transverse component of the wave will create compressional waves that will propagate into the ocean while the compressional component of the bendy wave will propagate into the seabed. There will also be some transmission of the airborne acoustic wave into the sea.

It can be expected that most of the energy from the hammering action of the pile driver will transfer into the seabed. Once in the seabed, the energy will then propagate outwards as compressional and shear waves. Some of the energy may be transferred into Rayleigh waves, which are seismic waves that form on the water/seabed interface, but it is expected that this will be a small portion of the total wave energy.

Piles can be driven using various methods such as vibration, gravity and hammer. The method that is used is dependent on the size of the pile and the substrate into which the pile is being driven. It is planned that hydraulic impact hammers with diameters of between 915 mm and 1200 mm will be used for pile driving operations in this development project. It is expected that one pile driving evolution will take up to 3 hours. The noise that is generated by an impact hammer hitting the top of the pile is short in duration lasting approximately 90 ms and can therefore be described as impulsive noise.

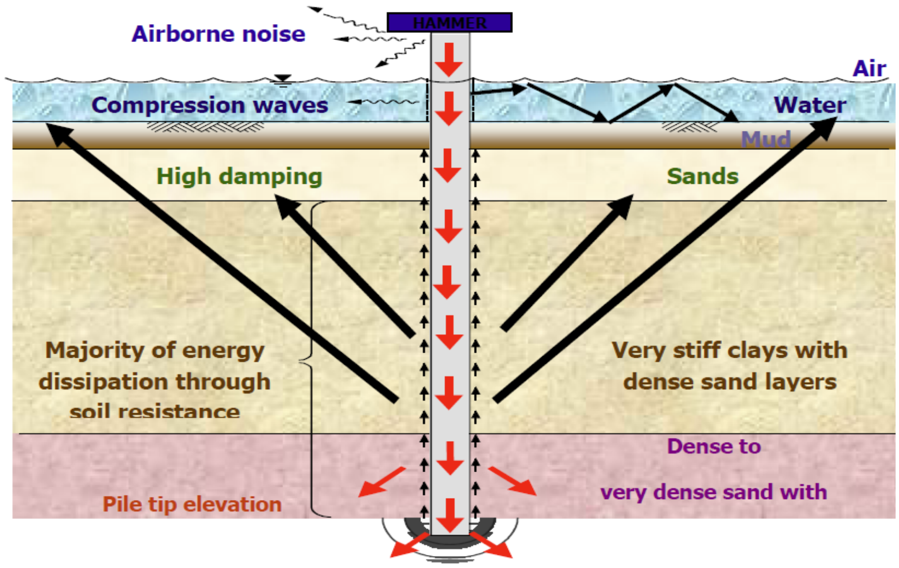

Figure 2-1 Energy transfer modes which occur when a pile is being driven into the seabed [4]

[3] Bendy wave is a wave that comprises of a compression wave and a transverse wave.

[4] S. Theiss et al, "Development of Guidance on the effects of Pile Driving on Fish', TRB ACD40, 2006

3. ASSESSMENT CRITERIA

Unlike airborne noise, where impact levels on humans have been regulated, assessment criteria levels for underwater environmental noise impacts have not been defined in regulation except in the case of underwater noise impacts on cetaceans from seismic surveys, where the EPBC Act Policy Statement 2.1 applies. As a result, assessment levels in this report are determined from peer reviewed and widely accepted literature.

A variety of units are used in underwater acoustics to define steady-state and impulsive signals. Some of the important definitions are as follows:

- **Sound Pressure Level (SPL) Root Mean Square (RMS) units dB re 1 µPa**. The rms pressure is the decibel value of the root mean of the squared pressure over a defined period of a signal.
- **Sound Pressure Level Peak units dB re 1 µPa (0-Pk)**. Peak pressure is the maximum recorded pressure and is measured from the mean of the signal to the maximum excursion from the mean.
- **Sound Pressure Level Peak to Peak units dB re 1 µPa (Pk-Pk)**. Peak to Peak sound pressure is the algebraic difference between the maximum positive and maximum negative instantaneous peak pressure.
- **Sound Exposure Level (SEL) units dB re 1 µPa^2.s**. Sound exposure level is a measure of energy with the dB level of the time integral of the squared-instantaneous sound pressure normalized to a 1-s period. For impulsive signals, such as pile driving noise and marine blasting noise, the averaging time is a significant consideration. Impulsive signals are better described by a measure of Sound Exposure Level (SEL) and a measure of the signal peak pressure.

3.1 Zones of Interest

For underwater noise impacts on marine fauna, two effects are of interest, namely physical injury and behavioural disturbance. These two effects result in the determination of three areas or zones of interest for underwater noise assessments. These areas or zones are as follows:

1) **Zone of Possible Physical Injury**. In this area there is a possibility that the animal may suffer physical/auditory injury and/ or permanent hearing damage or hearing threshold shift (PTS).

2) **Zone of Possible Temporary Threshold Shift (TTS).** In this area there is a possibility that the animal may suffer TTS.

3) **Zone of Possible Behavioural Disturbance.** In this area there is a possibility that the animal may experience hearing masking and/or behavioural change and/or avoid the area.

   Behavioural responses of marine animals to underwater noise encompass all behavioural reactions and responses. Here are some different levels of responses to the underwater noise that marine animals have: 1) some of these responses will be reflex responses that an animal would exhibit regardless of the noise stimulus; 2) some of these responses (such as alert responses or some avoidance) reflect an animal's awareness, and animals might experience hearing masking at this response level; 3) sub-lethal responses encompass the full range of observable symptoms of acute or chronic stress in individual animals that can disable an individual animal but do not kill the animal. Sub-lethal responses include increased respiration (for example, increased surfacing rates in aquatic mammals), reductions in an animal's foraging activity and foraging success, reduced body condition and reduced growth rates (which can result from reduced foraging success, but can also indicate physiological stress), reduced fecundity and reduced reproductive success (which can result from any of the other sub-lethal responses). The behavioural disturbance concerned in this study is based on animals' behavioural responses to underwater noise at some stages of the second response level.

3.2 Cetaceans and Dugongs

3.2.1 Auditory Sensitivity

Cetaceans (whales, dolphins) and dugongs have typical mammalian ears that consist of a middle ear and cochlea. Ears are the organs most sensitive to pressure and, therefore, to injury. Severe damage to the ears can include damage of the tympanic membrane, fracture of the ossicles, cochlear damage, haemorrhage, and cerebrospinal fluid leakage into the middle ear.

As low-frequency cetaceans, humpback whales produce a complex set of vocalised song patterns. The spectrum of the patterns has been measured to be between 20 and 24000 Hz with maximum peak to peak source level of 184 dB re 1 µPa @ 1 m[5]. In the absence of more detailed information on the hearing of humpback whales from the literature, it can be assumed that this bandwidth and source level is indicative of the whales' auditory bandwidth and auditory sensitivities.

Dolphins are mid-frequency cetaceans, which have hearing over a wide range of low to very high frequencies (see Figure 3-1 for typical audiograms from bottlenose dolphins). According to combined available research results, mid-frequency cetaceans have lower and upper frequency limits of nominal hearing at approximately 150 Hz to 160 kHz respectively[6].

[5] Whitlow *et al*, 'Acoustic properties of humpback whale songs', JASA, 120(2), Aug 2006.

[6] Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

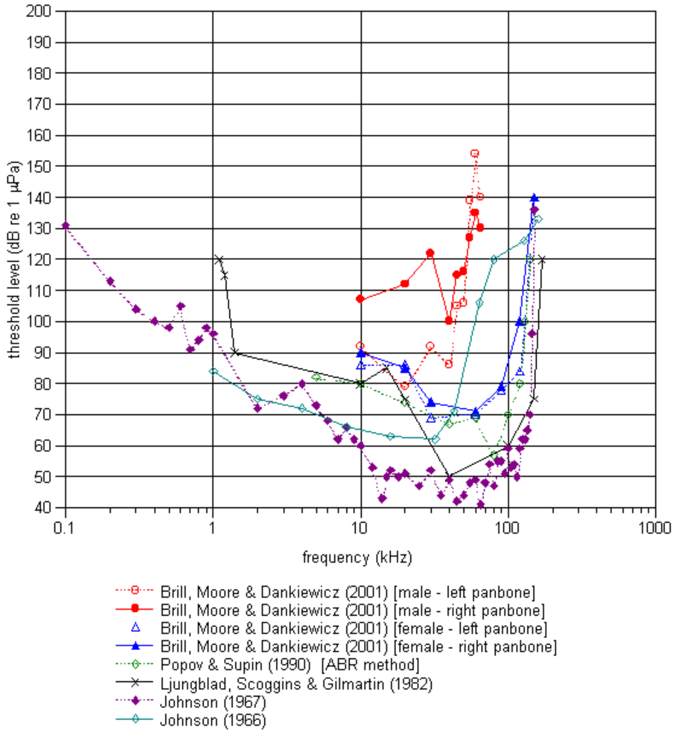

Figure 3-1 Bottlenose Dolphin Audiograms[7].

There is a lack of scientific data regarding the auditory bandwidths of dugongs. However if it is assumed that the auditory bandwidths of manatees are similar to that of dugongs, then it can be assumed that dugongs are also mid-frequency marine species as the manatee's auditory bandwidth has been found to be between 10 Hz and 50 KHz as shown in Figure 3-2. For the purposes of this assessment dugongs will be classed as mid-frequency cetaceans.

---

7 Nedwell,, J.R., et al., "Fish and Marine Mammal Audiograms: A summary of available information,"Subacoustech Report No. 534R0214, September 2004, p.90.

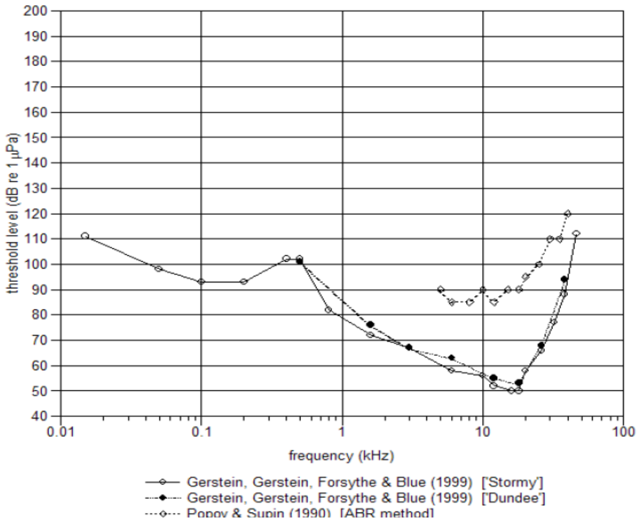

Figure 3-2 Manatee Audiogram[8]

3.2.2 Assessment of Noise Impacts

There is lack of scientific data specific to sirenians (i.e. dugongs) for determining injury and behavioural disturbance as a result of underwater noise, therefore the criteria for mid-frequency cetaceans were applied to dugongs in this assessment study. The criteria that will be used for the assessment of cetaceans and dugongs are given in Table 3-1 . A dual-criterion approach (i.e. SPL peak and SEL) was used for both zones of possible physical injury and possible behavioural disturbance. The following technical notes should be considered regarding the assessment criteria:

- The injury criteria for marine mammal groups and signal types (i.e. single pulses, multi-pulses and non-pulses) are divided into received SPL peak and SEL. These criteria mark the expected onset of permanent threshold shift (PTS). The onset of PTS was derived by *Southall et al* from measured or assumed onset of temporary threshold shift (TTS) levels and expected TTS growth range estimates for each marine mammal group[9]. Accordingly, Southall *et al*[10] defined physical injury criteria based on experiments conducted on mid frequency cetaceans (i.e. beluga whales and bottlenose dolphins). Due to the lack of data for low frequency cetaceans (i.e. humpback whales), the data for mid frequency mammals is recommended by Southall *et al* to be used for low frequency cetaceans.
- The behavioural disturbance criteria for single pulses and multi-pulses recommended by both Southall *et al*[11] are based on observational data predominately from seismic surveys. It must be noted that observational data is by no means conclusive. Additionally, seismic pulses on which the criteria are based are different both in spectrum and time to that of a pile driving pulse. However, as there is no data available that can be used to determine the criteria for pile driving, the criteria for seismic surveys will be used.

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[8] Nedwell,, J.R., et al., “Fish and Marine Mammal Audiograms: A summary of available information,”Subacoustech Report No. 534R0214, September 2004.

[9] Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

[10] Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

[11] Southall *et al* also considers observational data from other transient sources such as explosions

- The SEL criteria in Table 3-1 for possible physical injury are M-weighted based on M-weighting functions for low-, mid-, and high-frequency cetaceans shown in Figure 3-3[12].

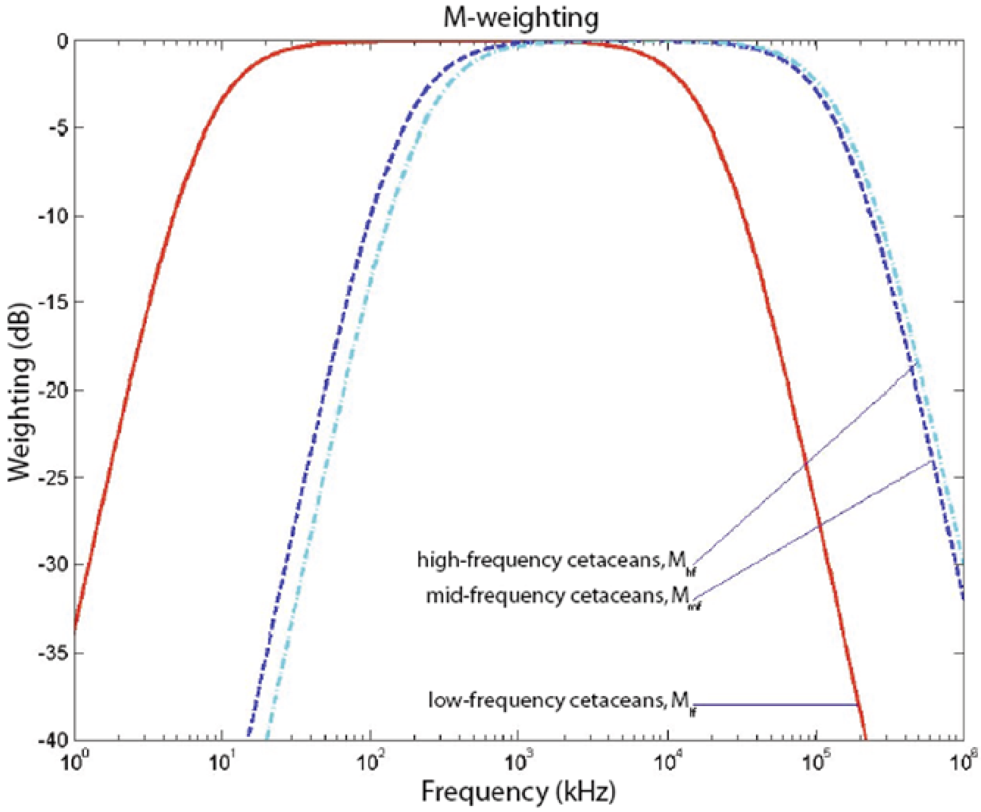


Figure 3-3 The M-weighting functions for low-frequency (M_{lf}), mid-frequency (M_{mf}), and high-frequency (M_{hf}) cetaceans.

3.2.3 Summary of Levels of Possible Physical Injury and Behavioural Change

Based on information in the preceding sections, the SPL peak, SEL and SPL rms values that are of interest with regard to their effects of noise on humpback whales, dolphins and dugongs are given in Table 3-1 .

[12] Aquatic Mammals, Volume 33, Number 4, 2007, ISSN 0167-5427

Table 3-1 Received threshold levels of Peak Sound Pressure Level (SPL peak), RMS Sound Pressure Level (SPL (rms)) and Sound Exposure Level (SEL) above which there would be a possibility of physical injury or behavioural disturbance or TTS-onset for humpback whales, dolphins and dugongs. M_{lf}: Marine mammal low-frequency weighting; M_{mf}: Marine mammal mid-frequency weighting; flat: flat frequency weighting.

Metric	Possible Physical Injury		Possible Onset of TTS		Possible Behavioural Disturbance	
	Humpback Whales	Dolphins and Dugongs	Humpback Whales	Dolphins and Dugongs	Humpback Whales	Dolphins and Dugongs
SPL peak (dB re 1µPa)	230 (flat)	230 (flat)	-	-	-	-
SPL (rms) (dB re 1µPa)	-	-	-	-	120 (flat)	120 (flat)
SEL (dB re 1µPa^2.s)	198 (M_{lf})	198 (M_{mf})	183 (M_{lf})	183 (M_{mf})		

4. METHODOLOGY

4.1 Underwater Noise Modelling

Underwater noise propagation models use bathymetric data, geoacoustic information and oceanographic parameters as inputs to produce estimates of the acoustic field in the water column at any depth and distance from the source. The accuracy of the environmental information used in the model is critical for the modelling prediction. For example, the geoacoustic parameters of the seabed, particularly the seabed layer structure, the compressional and shear sound velocities for each layer material, and the corresponding sound attenuation coefficients can significantly affect the acoustic propagation and can therefore affect the accuracy of the model predictions.

4.1.1 Model Selection

Various numerical techniques are used for the development of underwater acoustic propagation models, including wavenumber integration, ray theory, normal modes, parabolic equation (PE) and finite differences/finite elements. When determining which model is to be used for the modelling prediction, it is necessary to define the application for which it is to be used and the type of underwater environment it is going to model. For this model, the underwater environment has the following characteristics:

- strong range dependence
- shallow water ocean environment
- differing bottom types.

Parabolic Equation (PE) models are by nature capable of making predictions in environmental conditions that are range dependent, in shallow water and have changing bottom types. As a result, a PE model called the Monterey Miami Parabolic Equation (MMPE) model was selected. This model was selected because it has been benchmark tested for shallow water environment[13].

4.1.2 Data and Model Limitations

The following data and model limitations need to be noted:

1. **Rough Surface Scattering**. Acoustics wave scattering due to the roughness of sea surface and seabed is not accounted for in the model.
2. **Salinity and Sound Speed Profiles**. The water depth in the modelling area is relatively shallow. It can therefore be assumed that the water column is isothermal. Additionally, salinity will have negligible effect on the sound speed profile. Variation in the model's sound speed profile has been limited to the effects of water column pressure.

[13] Shallow Water Acoustic Modelling (SWAM 99) Workshop.

3. **Seabed**. The seabed was taken as half-space in the model, and its properties were taken as the same as the top layer sediment properties.

4.1.3 Model Environmental Inputs

The following environmental conditions were inputted into the model:

Tide level

In this study, the Highest Astronomical Tide (HAT) was used for the coastal area of Ashburton North, south-west of Onslow, representing the worst case scenario. HAT was 3 m higher than the Lowest Astronomical Tide (LAT) (i.e. chart datum)[14].

Seabed Types

Based on geophysical survey data supplied to SVT by RPS, the seabed in the nearshore survey area off Ashburton North is predominantly covered by soft sediment, assumably uncemented shelly sandy silts of various thickness with limestone base. Small patches of hard substrate, most likely limestone or hard rock, randomly distribute in the area. In terms of the seabed types for the modelling a sandy seabed type was entered to represent the soft sediment from the geophysical surveys. For the small patches of hard rock and inland area, basalt was selected to represent the seabed type. The geoacoustic properties of the seabed types used in the model are as described in Table 4-1.

Table 4-1 Geoacoustic properties used in the model for each seabed type

Type	Sound speed (m/s)	Density (g/cm^3)	Compressional Attenuation (dB/m/kHz)	Shear Attenuation (dB/m/kHz)	Shear Speed (m/s)
Fine to medium sand	1774.0	2.050	0.374	0	0
Bassalt	5250.0	2.700	0.1	0.2	1500

Sound Speed Profile

The sound speed profile in the near shore of Ashburton North is assumed to be isothermal with a constant temperature of 23 ^{0}C and a constant salinity of 35 ppt. This is estimated to be representative of the water temperature in the shallow water environment of the Pilbara area.

4.1.4 Model Contour Depth

The model produces horizontal contours for any depth as well as vertical plots showing depth versus range for any bearing. It is not practical to provide plots for each depth and for each bearing (i.e. 360 for each scenario). As a result only a selected number of graphs are provided in this report.

[14] Macedon Gas Development Subtidal Marine Ecology Survey, URS, 26 March 2010

5. MODEL INPUT

5.1 Noise Source Locations

Figure 5-1 presents the locations of various Work Points (WP) for the proposed Wheatstone port facility development. Pile driving barges are expected to be operating at WPs in the proposed development area as shown in the figure, and two piling barges are assumed to be operating simultaneously. Four source locations were selected to represent two piling operational scenarios: piling with source locations WP114 and WP106 and piling with WP103 and WP102 (see Table 5-1 for detailed locations).

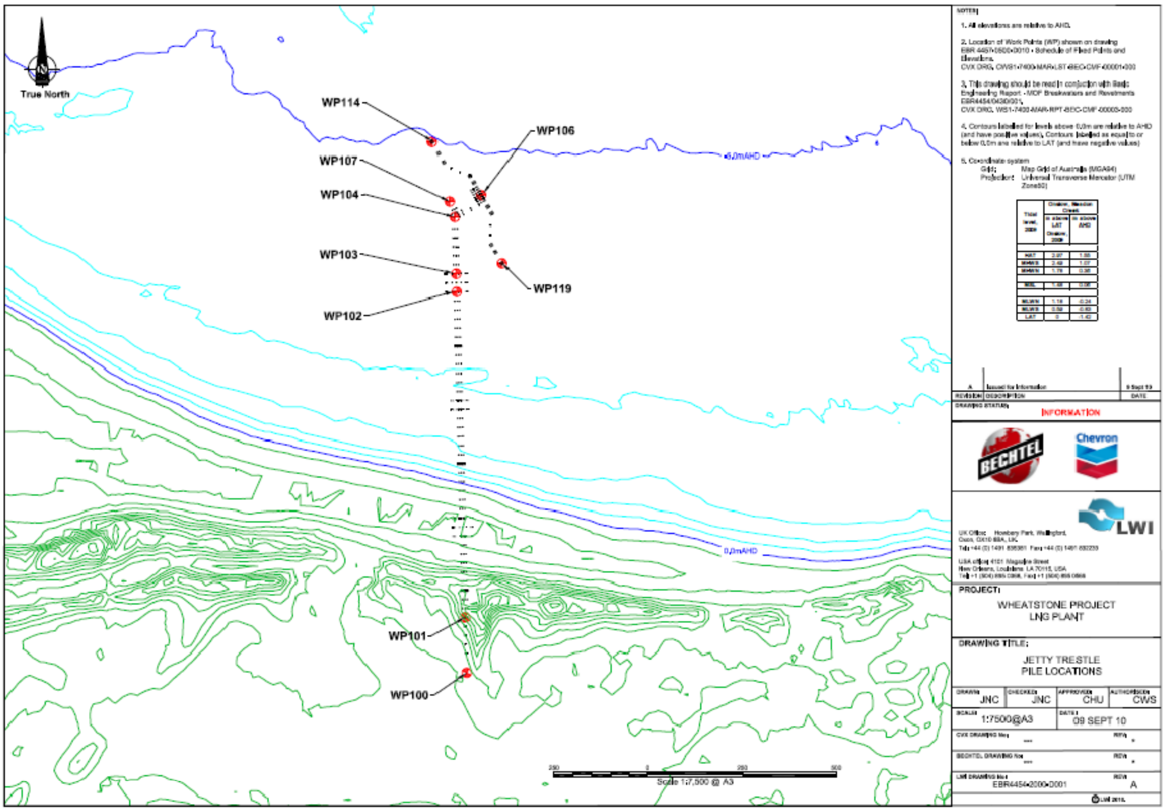


Figure 5-1 Locations of Work Points (WP) in the proposed Wheatstone port facility development.

Table 5-1 Noise sources and their locations

Source	Easting (m)	Northing (m)
Pile Driving 1 – WP114	293604.67	7601859.88
Pile Driving 2 – WP106	293735.27	7601718.63
Pile Driving 3 – WP103	293692.47	7600598.39
Pile Driving 1 – WP102	293696.34	7600451.77

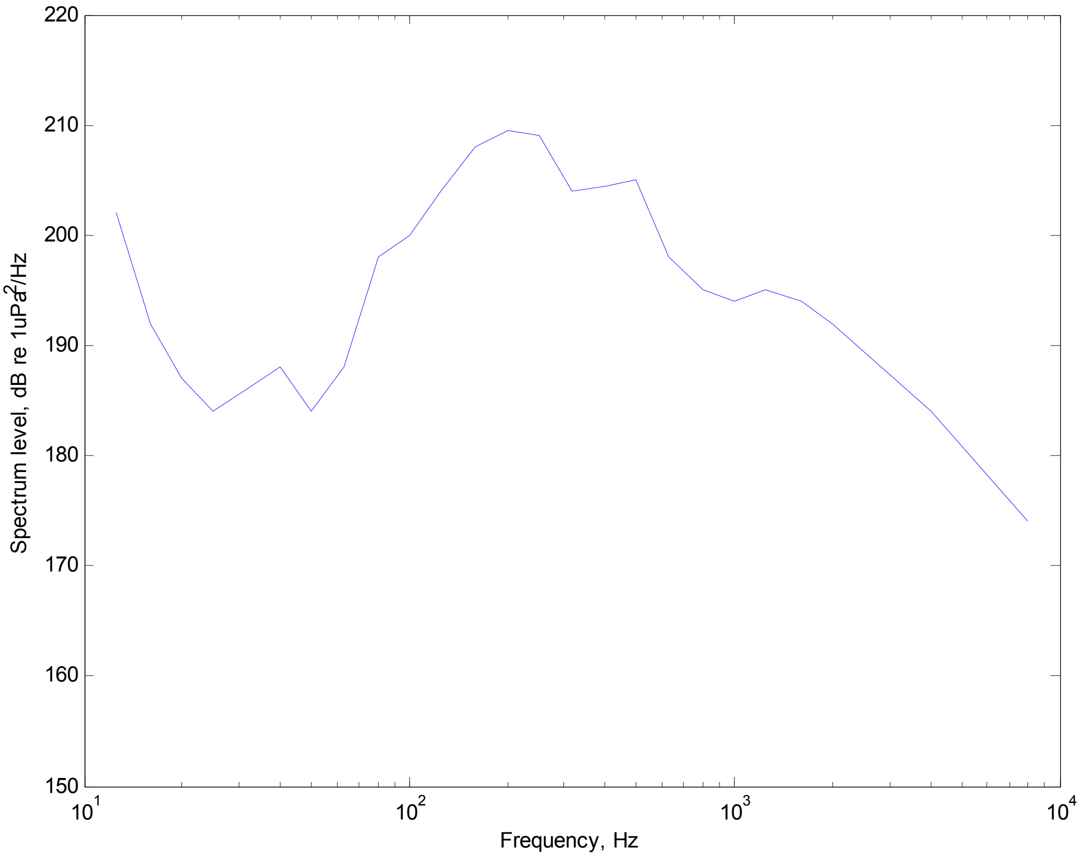
5.2 Modelling Source Depths and Characteristics

The depths of piling noise sources were determined by estimating their acoustic centre, as listed in Table 5-2. The source spectrum levels of the piling noise source used in the model are given in Figure 5-2. The frequency range used in the model was from 63 Hz to 2 kHz, which covers the expected frequency range of the major noise energy produced by the construction activities.

Table 5-2 Piling noise source depths.

Source	Water Depth (Chart datum + 3 m for HAT)	Source Depth
Pile Driving 1 – WP114	9.3 m	4.65 m above seabed
Pile Driving 2 – WP106	9.2 m	4.6 m above seabed
Pile Driving 3 – WP103	8.6 m	4.3 m above seabed
Pile Driving 1 – WP102	8.5 m	4.25 m above seabed

Figure 5-2 Source spectrum characteristics of Pile Driving



6. MODELLING RESULTS

The contour plots shown in this section are for a receiver depth of 2 m below the sea surface. The scenarios under the Highest Astronomical Tide (HAT) of 3 meters were modelled as it represents the worst case scenario.

6.1 SEL Contours for Piling Noise Sources

It is expected that 2 pile barges will be operating simultaneously in the proposed Wheatstone port facility development area, and the maximum separation of the two pile barges are assumed to be a minimum distance of 1 km apart.

Figure 6-1and Figure 6-2 show the contours of predicted SEL for one 3 hours of piling[15] for the two modelling scenarios (i.e. two piling operations occurring simultaneously at locations of WP114 and WP106, and two piling operations occurring simultaneously at WP103 and WP102) with flat-frequency weighting.

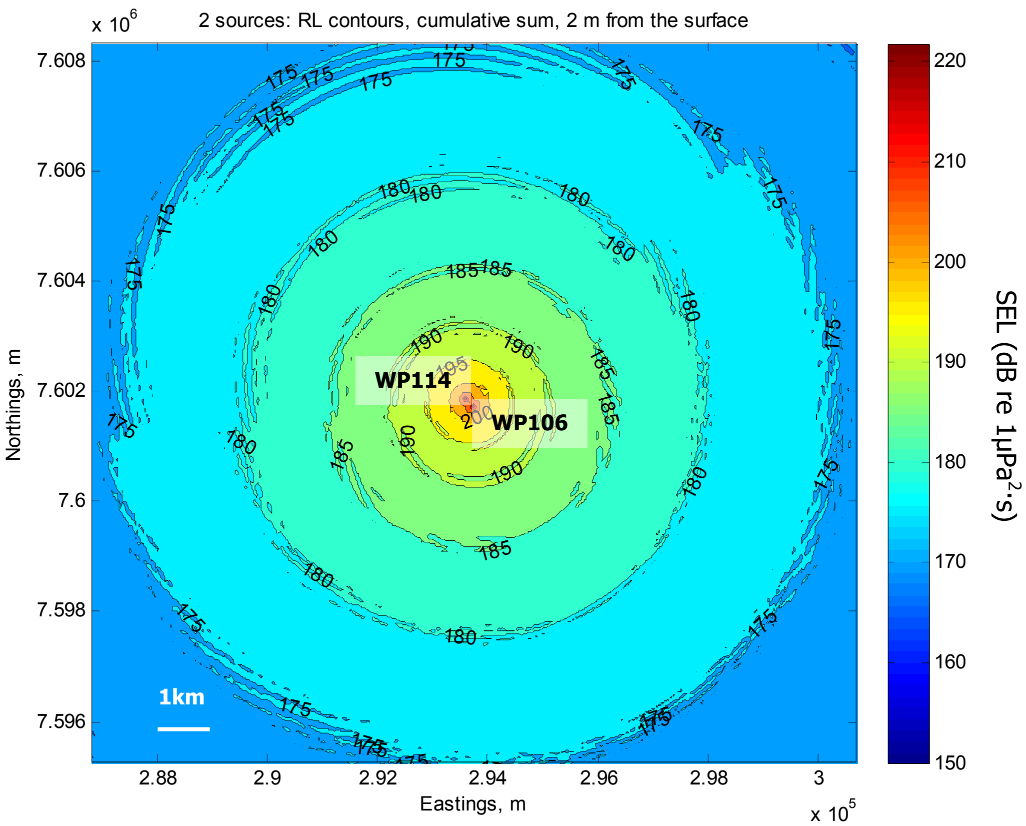


Figure 6-1 Contours showing predicted SEL of one piling evolution of 3 hours from 2 piling barges operating simutaneously at WP114 and WP106 with flat-frequency weighting. The noise contour is 2 m below the sea surface

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[15] This equates to 21600 pulses (2 piling barges X 3 hours X 60 minutes/hour X 60 Seconds/Minute X 1 pules/second) in total that an animal can be exposed to over a 3 hour piling operation. This implies that 43 dB (i.e. 10log(21600)) has been added to the SEl for one pulse.

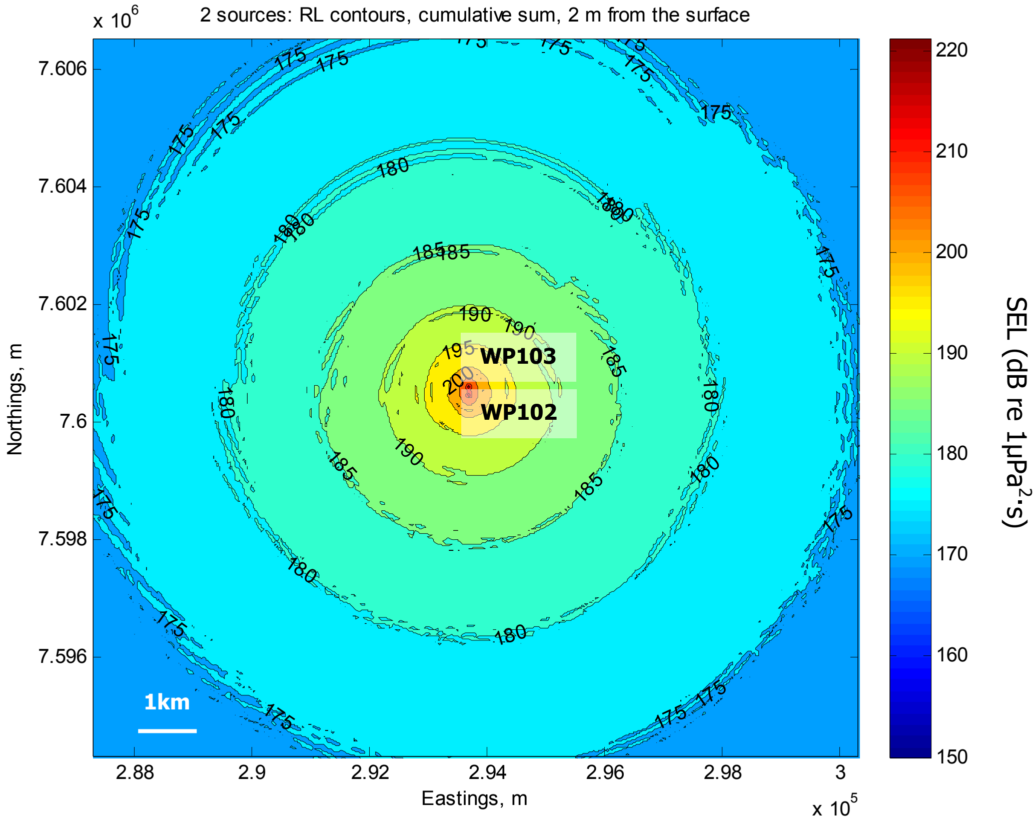

Figure 6-2 Contours showing predicted SEL of one piling evolution of 3 hours from 2 piling barges operating simultaneously at WP103 and WP102 with flat-frequency weighting. The noise contour is 2 m below the sea surface

6.2 Zones of Possible Behavioural Disturbance, TTS onset and Possible Physical Injury

Zones of possible physical injury, possible behavioural disturbance and TTS-onset for humpback whales, dolphins and dugongs were assessed based on criteria listed in Table 3-1 . Peak pressure levels for pile driving noise were estimated from the modelling results using an empirical formula[16].

The two modelling scenarios have similar noise propagation environmental conditions, and therefore the modelling outcomes are similar for the zone estimates. Table 6-1Table E-2, Table 6-2 and Table 6-2 summarise the maximum distances between noise sources and the zones of possible physical injury, possible behavioural disturbance and TTS-onset for humpback whales, dolphins and dugongs.

As SEL criteria were applied to define the zones of possible physical injury and possible TTS-onset, the received SEL depends on the exposure duration to the piling noise, and therefore so do the estimated furthest distance from sources to the zones.

[16] SPL_{peak}=SEL+10*log(T_1/T_2)+18, where T_1=1s and T_2=duration of impulsive signal.

It can be seen from Table 6-1 that for humpback whales, dolphins and dugongs the piling activities could cause physical injury up to 400 m, and TTS-onset up to 2600 m from the piling operation if they were exposed to a complete piling operation as defined in the modelled scenarios. As shown in Table 6-2, the furthest distance from piling noise source to the zone of behavioural disturbance is 6 km, which is based on a precautionary SPL behavioural disturbance criterion of 120 dB re 1μPa rms.

Table 6-1 Furthest distances to zones of possible physical injury and TTS onset for humpback whales, dolphins and dugong, against the exposure duration to the piling noise.

Modelling Scenarios	Furthest Distance from Source to Zone of Physical Injury (m)							
	Humpback Whales				Dolphins and Dugongs			
	With the exposure duration of							
	10 minutes	0.5 h	1 h	3 h	10 minutes	0.5 h	1 h	3 h
Pile Driving – Wheatstone port facility development	50	100	250	400	50	100	250	400
	Furthest Distance from Source to Zone of TTS-onset (m)							
Pile Driving – Wheatstone port facility development	650	1250	1800	2600	650	1250	1800	2600

Table 6-2 Furthest distances to zones of possible behavioural disturbance for humpback whales, dolphins and dugong, against the exposure duration to the piling noise.

Modelling Scenarios	Furthest Distance from Source to Zone of Behavioral Disturbance (km)	
	Humpback Whales	Dolphins and Dugongs
Pile Driving – Wheatstone port facility development	6	6

APPENDIX A : ACRONYMS

Acronym	Definition
EPBC	The Environment Protection and Biodiversity Conservation
HAT	Highest Astronomical Tide
LAT	Lowest Astronomical Tide
LNG	Liquified Natural Gas
MMPE	Monterey Miami Parabolic Equation
PE	Parabolic Equation
RMS	Root Mean Square
SEL	Sound Exposure Level
SPL	Sound Pressure Level
WP	Work Points

Appendix FM

Seagrass Dynamics and the Consequences of Seagrass Loss on Marine Megafauna: A Briefing Note

This document aims to clarify the predicted project impact on seagrasses including the percentage and spatial extent of anticipated seagrass losses; both permanent and temporary, and any impacts to marine megafauna resulting from these losses. Additionally a short account of the site selection, optimisation and management measures employed by Chevron to reduce impacts has been included. The Wheatstone Project is predicted to cause up to 10 ha of permanent (100%) loss of seagrass within the proposed Trunkline footprint as a result of physical damage from burial under rock armour during the installation of the pipeline. Additionally an area of approximately 2963 ha of seagrass is predicted to be affected by the dredge plume. Within this area a temporary loss of up to 50% of the above ground biomass is anticipated. Although the Zone of Influence associated with the dredge plume is extensive, no discernible impacts to seagrasses are predicted within this Zone. The seagrass disturbed, (predominantly Halophila sp.), will return within a period of one to three years, further there are three major seagrass patches within the study area (although low densities of seagrass occur extensively throughout the study area), one of which is outside the areas of predicted impacts and the other two of which will not have contiguous loss such that habitat will be unavailable for faunal usage. Species least at risk were determined to be dugongs, bottlenose dolphins and turtles. Species considered at a higher risk of displacement included green sawfish and Indo-Pacific humpback dolphins. However, even for species at a higher risk, the area of available displacement is insignificant when compared with the area of available habitat in the study area. The short-term displacement area is 100 times less than the available habitat and the long term displacement is 1000 times smaller. Management to reduce impact includes site selection, dredge optimisation, monitoring of seagrass and sensitive receptors, and adaptive management.

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1.0 INTRODUCTION

This briefing note on seagrasses of the Wheatstone Project area has been prepared to address concerns raised by the Department of Sustainability, Environment, Water, Population and Community (DSEWPaC) regarding the ecological significance of impacts predicted from the Project to seagrasses and to marine fauna dependent on this habitat. As a result, this document aims to clarify the predicted project impact on seagrasses including the percentage and spatial extent of anticipated seagrass losses; both permanent and temporary, and any impacts to marine megafauna resulting from these losses. Additionally a short account of the site selection, optimisation and management measures employed by Chevron to reduce impacts has been included.

Supporting this briefing note are two appendices. Appendix A provides a comprehensive account of seagrass resilience and recovery in tropical marine environments. The purpose of this document is to describe the dynamic nature of tropical seagrasses in the Project area and to illustrate the mechanisms for recovery following natural and dredging disturbance events. Appendix B describes the potential displacement of marine fauna from impacts to seagrasses and other marine habitats in the Project area. Combined, these appendices provide Chevron with a strong basis for predicting the potential effects of seagrass impacts on megafauna in the Project area. A succinct synthesis of the findings from both appendices is given in this briefing note.

2.0 IMPACT PREDICTION

Predicted seagrass losses associated with the Wheatstone dredging program are detailed in Appendix FN (*BPPH Loss Assessment Report*) and summarised here. The Wheatstone Project is predicted to cause up to 10 ha of permanent (100%) loss of seagrass within the proposed Trunkline footprint as a result of physical damage from burial under rock armour during the installation of the pipeline. The approximate location is shown in Figure 1. However, this is a worst case scenario as the base-case is for the pipeline to be covered with sand, not rock armour. If sand is used to cover the pipeline then the seagrass loss is predicted to be temporary, as seagrass is predicted to recolonise these areas from seed stock (Appendix FN).

Additionally an area of approximately 1481.5 ha of seagrass is predicted to be affected by the dredge plume. Within this area a temporary loss of up to 50% of the above ground biomass is anticipated (refer to Section 2.1 for further discussion). This area of seagrass lies within the Zone of Moderate Impact (partial mortality) as shown in Figure 1. Definition of the zones of impact is found in Table 1.

Table 1: Impact classification categories

Zone	Definitions
Zone of High Impact	An area within which key receptors are predicted to suffer total or substantial mortality (> 50%), and where loss of structural function is predicted to occur.
Zone of Moderate Impact	An area within which key receptors are predicted to suffer partial mortality (up to 50 percent loss close to the channel and <1 per-cent loss at the extremes). Mortality will occur within the area, but will not include all individuals. The outer border will be drawn so that no mortality will be predicted to occur immediately outside of this zone.
Zone of Influence	Outside the outer boundary of the Zone of Partial Mortality there may be influence from the dredge plume at low levels (for example sub-lethal impacts on key receptors, turbidity may be visible or very light sedimentation may occur) but this is predicted to be unlikely to have any material and/or measurable impact on the key receptors.
No Impact	Beyond the outer boundary of the Zone of Influence, there will be an unbounded area where there is no detectable influence on turbidity and sedimentation rates from the dredging and placement.

Although the Zone of Influence associated with the dredge plume is extensive (see Figure 1), no discernible impacts to seagrasses are predicted within this Zone (Figure 1, Draft EIS/ERMP Section 8.3 and Appendix FN). Within this Zone the frequency and intensity of turbidity will not be at levels that will induce seagrass mortality.

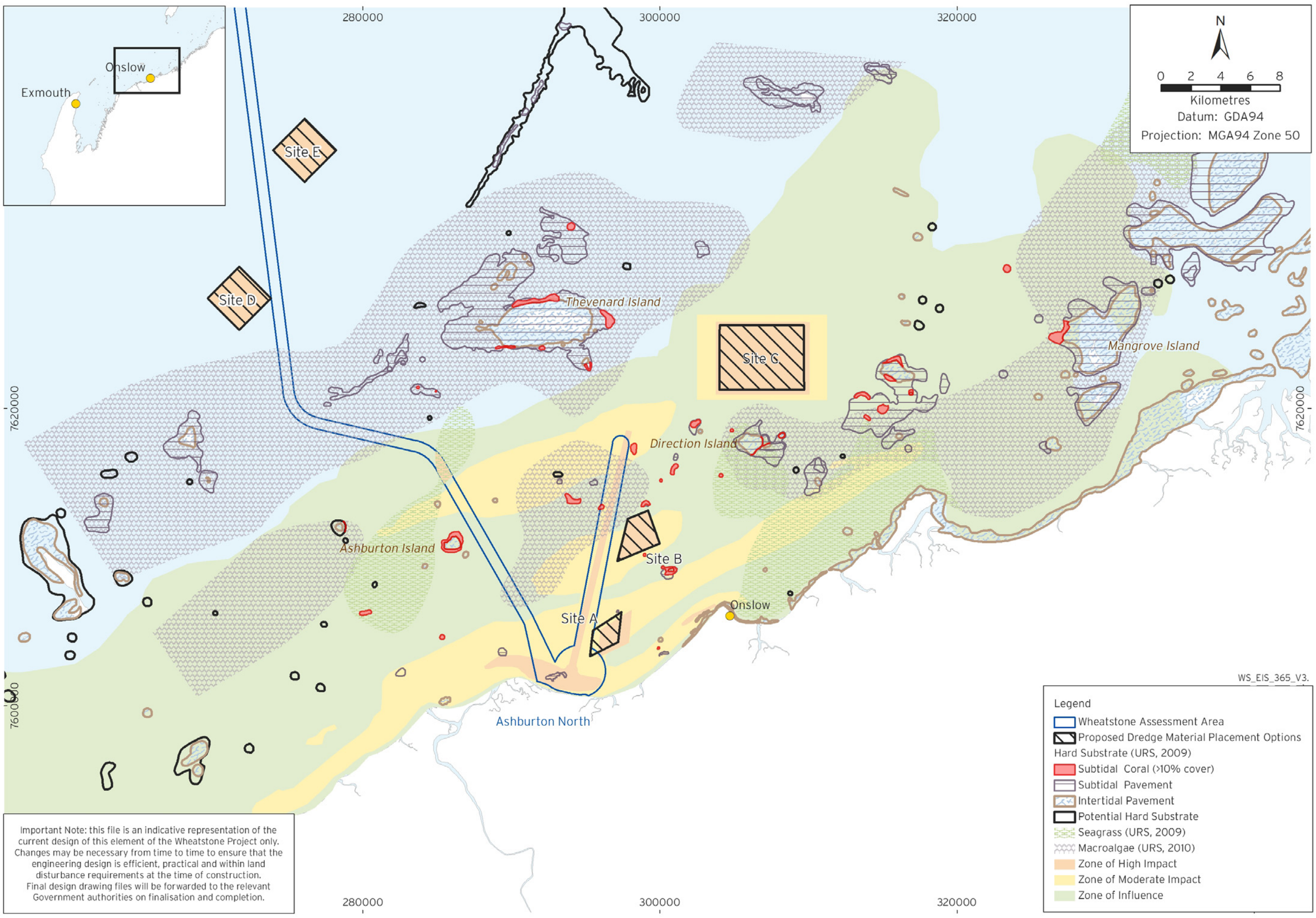

Figure 1: Zones of Impact and seagrass distribution of the Project area

Table 2: Summary of Predicted Seagrass Losses in the Project Area

Type of Impact	Area	Biological and Habitat Response
Permanent and direct	Potentially[1] 10 ha	Permanent seagrass and habitat loss if rock armour is used for this stretch of the trunkline
Temporary and indirect[2]	1481.5 ha	Up to 50% reduction in biomass (not total loss of above ground biomass) No impact to habitat

[1] This impact will only occur if rock armour is used to cover the pipeline. The base-case is still to use sand (Appendix FN).
[2] This impact type is defined as an indirect impact because the disturbance will be associated with the turbidity plume, not direct mechanical disturbance at the dredge footprint or associated with rock armour (Appendix FN).

2.1 Temporary Loss

Losses considered temporary are those where there will be a measurable decrease in above ground biomass of seagrasses and where recovery is predicted within one to three years (Appendix A). In addition, the habitat (i.e. unconsolidated seafloor sediment) will remain undisturbed by the dredge program.

In summary, seagrass loss is predicted to be temporary for the following:

- Up to 50% of the above ground biomass will remain intact,
- No impacts are predicted to rhizomes of seeds,
- No impacts are predicted to the habitat (e.g. sediment will not be removed and there will be no permanent change to the sediment particle size distribution), and
- Exposure to the turbidity plume is short-term.

2.2 The Potential for Seagrass Recovery in the Project Area

Within the Project area, seagrass meadows are predominantly ephemeral and comprised of structurally small species of low biomass (i.e. *Halophila*) (Appendix A and Appendix N15 *Benthic Primary Producer [Seagrass and Macroalgae] Habitats of the Wheatstone Project Area*). Tropical seagrass beds are known to be resilient habitats able to recover rapidly after disturbance (Preen et al. 1995; Rasheed 2004; Coles et al 2007; Unsworth 2008). The commonly found *Halophila* genus is known to be important colonisers of bare substrates and include the fastest growing seagrass species in tropical seagrass beds. Several studies have reported the rapid recovery potential of tropical seagrasses following impacts similar to those expected from dredge plume impacts within the Project area (reviewed in Appendix A).

Additionally, while the dredging program is expected to extend for four years, impacts to particular seagrass areas are not predicted for this entire four year period. Because the currents run perpendicular to the dredge channel (and parallel to the shore), and the 16km channel will be dredged in distinct sections (draft EIS/ERMP Section 8.2.5.1), impacts will be confined to areas in the direct plume flow path from those areas, which are also strongly seasonal (i.e. the entire area is not affected continually for the four year dredging program). Impacts to the seagrass area to the west of the channel are predominantly predicted during winter periods, while impacts to the seagrass area east of the channel, including at Coolgra Point, are predominantly predicted during summer (draft EIS/ERMP Section 8.3.5.2).

3.0 CONFIDENCE IN PREDICTIONS

The predicted permanent and temporary seagrass losses presented within this paper are based on: extensive mapping of the benthic primary producer habitats (BPPH) in the Project area; robust modelling conducted by DHI (Appendix N2 *Dredge Plume Impact Assessment*) and conservative tolerance limits (Appendix N3 *Tolerance Limits Report*).

3.1 Habitat Mapping

An extensive campaign of habitat surveys has been conducted to date, the surveys included:

- Three Remotely Operated Vehicle (ROV) video surveys of the subtidal habitats on the seafloor in the Project study area undertaken in December 2008, May 2009 and August 2009 (URS 2009e, draft EIS/ERMP Appendix N12). The summer survey, conducted in December 2008, inspected 150 sites and focussed on the navigation channel, trunkline and dredge material placement sites and contiguous potential impact areas. The May 2009 survey inspected 46 sites and was focussed on hard substrate areas in the vicinity of the channel (reef, bommies, shoals, islands) with the aim of identifying suitable areas to establish coral dive transects for future impact monitoring. The winter survey (August 2009) inspected 155 sites and was focussed on:
    - "ground-truthing" gaps in potential hard substratum areas (reef, bommies and shoals) derived from Admiralty charts and URS interpolated nearshore bathymetry surface map
    - revisiting soft sediment areas identified in the summer ROV survey as supporting algae and seagrass, to look for seasonal trends
    - surveying far field areas and proposed dredge material placement sites.
- Surveys of intertidal habitats in the vicinity of the Project area and along the adjacent coastline between the Ashburton River and Coolgra Point were undertaken between November 2008 and May 2009. Focus was primarily on beach, sand flat and rocky shore habitats, mangroves and adjoining high tidal mud flats in the Ashburton delta, Hooley Creek area and a selection of regional sites using a combination of land access, vessel and aerial survey techniques (URS 2009f, draft EIS/ERMP Appendix N13).
- Survey of representative inter-tidal habitats on eight islands within the Project area conducted in February 2009 with a focus on rocky shore communities (URS 2009g, draft EIS/ERMP Appendix N10).
- Tow and drop camera survey of the continental shelf break, defined in this region as the area between the 20 m and 70 m isobath, conducted in August 2009. Towed video footage covering five transects on the shelf break was analysed according to substrate and biotic composition of benthic assemblages (UWA 2009a, draft EIS/ERMP Appendix N8).

Information obtained by the above surveys was collated and the distribution of the various benthic habitats was mapped, an overview of the survey locations and seagrass distribution based on the above survey findings is illustrated in Figure 2. Notably, although the ROV surveys are presented as points in this illustration, the surveys were conducted in transects originating from these points.

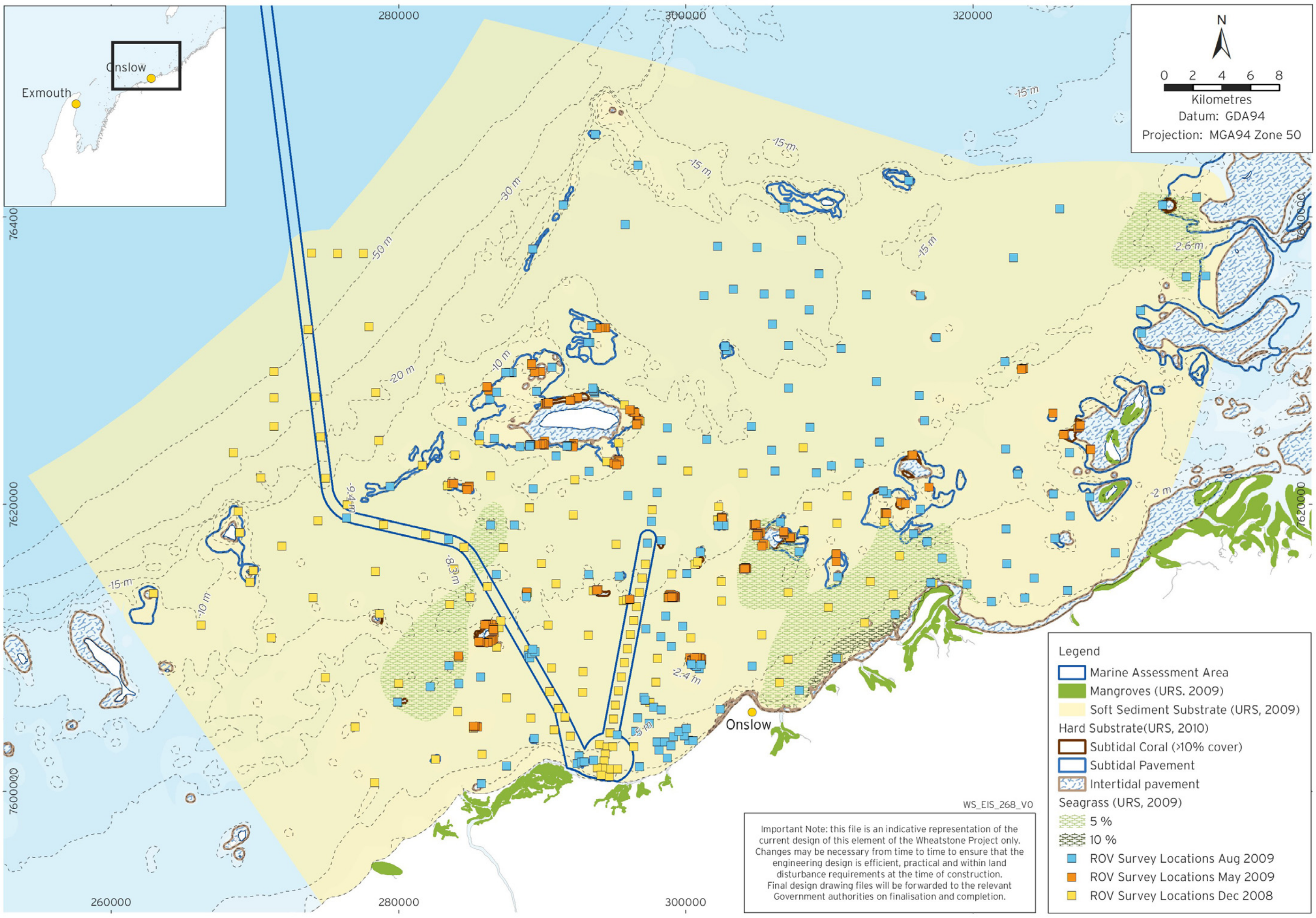

Figure 2: ROV transect areas and identified seagrass habitat in the vicinity of the Project (note that the ROV points on this figure represent short transect lines not spot-checks by a drop down camera)

3.2 Tolerance Limits

Tolerance limits, for sediment plume impact predictions, were developed for benthic primary producers (BPP) in the Project area. These are based on extensive monitoring experience and literature reviews by DHI (draft EIS/ERMP Appendix N3 *Tolerance Limits Report*). Seagrasses were identified as moderately tolerant with a short recovery time. These tolerance limits were applied to the sediment plume model results to derive impact zones. The impact zones were subsequently overlaid onto the BPPH distribution map in order to predict the spatial extent of impacts to seagrass.

In combination, the extensive mapping of BPPH, the conservative tolerance limits and the dredge plume modelling is considered to have produced a robust assessment of predicted impacts.

3.3 Modelling

Based on the proposed Dredging and Disposal Plan (unpublished report, LWI 2009), seven base case dredge scenarios were defined. The sediment plume modelling considered two climatic conditions (strong and representative drift), three seasons (summer, winter and transitional periods) and two spill estimates (realistic and worst case) for each of the combined dredge scenarios, covering the full range of dredging equipment and dredged material placement sites (draft EIS/ERMP Section 8.2.5.1 and Appendix N2 *Dredge Plume Impact Assessment*). This gives a total of 84 different scenarios (i.e., two release rates x six climate scenarios x seven dredging scenarios) that have been modelled, which are expected to cover the full spectrum of variability in terms of potential sediment plume impacts on sensitive receptors. Additionally an eight scenario was developed that incorporated reduced overflow for critical sections of the navigation channel dredging to reduce the plume impact.

4.0 ECOLOGICAL CONSEQUENCES

4.1 Background

To help Chevron predict the ecological consequences of seagrass impacts to marine megafauna in the Project area, two detailed desk-top studies were undertaken:

Appendix A: Literature Review of Seagrass Dynamics: Resilience and Recovery

Appendix B: Potential for Displacement of Resident Marine Megafauna Species.

Appendix A describes the natural dynamics of seagrasses, the food source of dugongs and turtles, in the Project area. It describes how seagrasses respond to natural and dredging impacts, and the mechanisms for recovery including seed and vegetative growth. These issues are described in context to the Wheatstone Project. Appendix B predicts the impact to marine megafauna resulting from human impacts to seagrasses and other benthic habitats in the Project Area. A synthesis of the two reports is provided below.

4.2 Seagrass Losses and Impacts to Marine Megafauna

Data presented in Appendix A, combined with extensive information on the distribution of resident megafauna (RPS 2009), allow a reasonable prediction of the likely effect of temporary seagrass absence on dugongs and other megafauna in the project area, both as a food source and a habitat. Several key aspects should be noted from the data presented in this report. Firstly, the seagrass partial mortality caused by dredging (approximately 12.5% of the total area) is relatively limited in extent. Secondly the seagrass disturbed, (predominantly *Halophila* sp.), will return within a period of one to three years. Thirdly there are three major seagrass patches within the study area (although low densities of seagrass occur extensively throughout the study area), one of which is outside the areas of predicted impacts and the other two of which will not have contiguous loss such that habitat will be unavailable for faunal usage.
RPS (2009; Appendix B) undertook an extensive review of the potential for displacement of resident megafaunal species, of which there are six; dolphins (Indo-Pacific humpback, common bottlenose and Indo-Pacific bottlenose), green sawfish, turtles (flatback and green) and dugongs. Only three of these utilise seagrass as a food resource to a large extent and the primary user of the seagrass species in the study area (i.e. *Halophila* sp.) are dugongs. Both turtles utilise seagrass, particularly green turtles, but they prefer to consume more robust species.

The potential displacement study (Appendix B), based upon foraging behaviour and habitat ranging, concluded that the species at least risk were dugongs, turtles and bottlenose dolphins. This is due the species' large home ranges and their lack of aggregation (including density) in potential impact areas. Additionally nearby habitat, may provide a temporary alternative during the predicted short term displacement. Once habitat recovery has occurred animals would be able to move back into the area (Table 7.1, Chevron 2011). Those species considered at a higher risk of displacement were green sawfish and Indo-pacific humpback dolphins, primarily due to their smaller home ranges and, for sawfish, a lack of information on fidelity regarding breeding grounds that lessens the strength of predictions. Regardless of this lack of information it can be stated with high certainty that the area of available displacement is insignificant when compared with the area of available habitat in the study area. That is, the short-term displacement area is 100 times less than the available habitat and the long term displacement is 1000 times smaller (Chevron, 2011).

5.0 MANAGEMENT TO REDUCE IMPACT

During the scoping phase of the Project an important aspect was to identify a site for the development that would cause the least impact to the surrounding environment. A short account of the site selection process is provided below. Furthermore, management and reduction of impacts have been considered throughout the impact assessment, in particular the dredge plume management options for optimisation have been explored at large, and the key management measures are provided in the following.

5.1 Site selection

At the conceptual stage, a multi-criteria site selection process was conducted for the Project's environmental impact considering marine benthic habitat, such as seagrass meadows, and other conservation values. An initial assessment was undertaken for the conceptual footprints at a number of proposed sites, and this process identified key constraints leading to the final selection. The identification of the least environmental and social constraints led to the selection of Ashburton North SIA.

5.2 Dredge optimisation

The scenario approach adopted for the dredge plume impact assessment assisted in optimising the dredge methodology to reduce impact to sensitive receptors. As a result the dredging for marine infrastructure will be conducted with restricted overflow, to reduce the extent of the plume, along parts of the proposed navigation channel. As mentioned in Section 2.0, seagrass mortality will not occur within the Zone of Influence (Figure 1) and, therefore, reducing the spatial extent of this Zone is unnecessary to protect seagrass resources in the Project area.

5.2.1 Management for minimization of impact

The following management measures will be employed during the dredging program to minimize impact to sensitive receptors:

- Restricted overflow in some dredge areas; these have been identified through the modeling and assessment of the of dredge plume impact
- Collection of dredge plume field data as soon as possible after dredging commences to revalidate the dredge modeling
- Monitoring of sensitive receptors as set out in the DSDMP
- Implementation of adaptive management measures in the event of identified impact to sensitive receptors beyond those that are accounted for in the loss assessment for the dredging program
- During the early stage stages of the dredging programmes the accuracy of the impact predictions presented in the Draft EIS/ERMP and the Final EIS/RTS will be validated. This will include the validation of the dredge plume model predictions with regard to sediment plumes. Should the actual impacts occurring in the field vary considerably from the impact predictions presented in the Draft EIS/ERMP and the Final EIS/RTS, the mitigation measures and monitoring programs will be amended accordingly. This approach is consistent with, and, meets the needs of an adaptive management approach to both monitoring and mitigation measures.

5.3 Seagrass Monitoring

Chevron is committed to undertake seagrass surveys to test the impact predictions given in Section 2 and in the draft EIS/ERMP. Surveys will be undertaken before and after the commencement of dredging, and will include seasonal sampling (wet and dry season). Surveys will be undertaken in areas predicted to be impacted and in areas far removed from the dredge program. Baseline surveys will be undertaken in March and July 2011. Response variables will include percentage cover, leaf density, seed density, rhizomes (presence/absence) and particle size distribution. Seeds and rhizomes will be assessed to determine the potential for recovery in areas where above ground biomass is not observed. Assessing the particle size distribution will be used to assess potential change to habitat.

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APPENDIX A – LITERATURE REVIEW OF SEAGRASS DYNAMICS: RESILIENCE AND RECOVERY

SINCLAIR KNIGHT MERZ

SKM

Wheatstone Project

SEAGRASS DYNAMICS: DISTURBANCE AND RECOVERY

- Rev 1
- 14 February 2011

Wheatstone Project

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Terminology, Definitions and Abbreviations

α	Maximal quantum yield
Benthic	Living upon or within the sea floor.
Benthic Light Climate	The light intensity available at seafloor for primary producers
I_k	Saturation Irradiance – light intensity at which maximum rates of photosynthesis are achieved
I_c	Compensation irradiance – the light intensity at which photosynthesis equals respiration
LNG	Liquefied Natural Gas
MLR	Minimum light requirements
PAR	Photosynthetically available radiation – range of light wavelengths utilised by the photosynthetic pathways of primary producers *also known* as Irradiance
PUR	Photosynthetically usable radiation – range of light wavelengths utilised for the photosynthetic pathways of seagrass
P_{max}	Maximal photosynthetic rate
TSS	Total Suspended Solids

LIMITATION STATEMENT

The sole purpose of this report and the associated services performed by Sinclair Knight Merz ("SKM") is to review the seagrass scientific literature in order to describe its variability, drivers, resilience and recovery, in accordance with the scope of services set out in the contract between SKM and the Client. That scope of services, as described in this report, was developed with the Client.

In preparing this report, SKM has relied upon, and presumed accurate, any information (or confirmation of the absence thereof) provided by the Client and/or from other sources. Except as otherwise stated in the report, SKM has not attempted to verify the accuracy or completeness of any such information. If the information is subsequently determined to be false, inaccurate or incomplete then it is possible that our observations and conclusions as expressed in this report may change.

SKM derived the data in this report from information sourced from the Client (if any) and/or available in the public domain at the time or times outlined in this report. The passage of time, manifestation of latent conditions or impacts of future events may require further examination of the project and subsequent data analysis, and re-evaluation of the data, findings, observations and conclusions expressed in this report. SKM has prepared this report in accordance with the usual care and thoroughness of the consulting profession, for the sole purpose described above and by reference to applicable standards, guidelines, procedures and practices at the date of issue of this report. For the reasons outlined above, however, no other warranty or guarantee, whether expressed or implied, is made as to the data, observations and findings expressed in this report, to the extent permitted by law.

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Executive Summary

Chevron Australasia Strategic Business Unit (Chevron) is progressing an Environmental Review and Management Programme (ERMP) for the Wheatstone Liquefied Natural Gas (LNG) Development. The LNG facilities will include an LNG export jetty that will require dredging and dredge material disposal activities. These activities will result in elevated turbidity and sedimentation levels and will create a turbidity plume during dredging. The elevated turbidity and TSS have the potential to impact seagrass and while the environmental impact assessment (EIA) process determined that seagrasses will suffer temporary, and possibly seasonal, losses, they are expected to recover soon after dredging ceases (Chevron 2010). This expectation is based on there being sparse seagrass coverage in the affected area, consisting of small ephemeral species (e.g. *Halophila ovalis*). This report reviews relevant literature to inform the Wheatstone EIA process in terms of the potential impacts of dredging on tropical seagrasses, and the likely resilience and recovery of these seagrasses.

The seagrass areas that are predicted to be impacted from the dredge plume are predominantly subtidal *Halophila* spp meadows. While other species (e.g. *Halodule*, *Thalassendron*, and *Syringodium*) are located within the Project Area they are located outside the predicted dredge plume. As there have been limited seagrass surveys within the Project Area, the variation in abundance and biomass of *Halophila* spp. is derived from published values. The likely temporal variations in seagrasses in the Project Area are:

- Seasonal variation in deeper water *Halophila* meadows – could be perennial or annual, however, there may be significant variation between seasons; and
- Potentially large interannual change in distribution and abundance of deep water *Halophila* meadows depending on prevailing environmental conditions (e.g. storms, freshwater runoff, available light, etc.).

The reduction in available light due to the increased light attenuation caused by suspended sediments within the predicted dredge plume is likely to be the primary impact on the subtidal *Halophila* meadows. There is support in the literature that *Halophila* communities can recover relatively rapidly once conditions return to “normal” (between 1 to 3 years after disturbance). Although there is strong evidence that *Halophila* meadows elsewhere in tropical and subtropical Australia have a good capacity for recovery from large disturbances, the lack of detailed information on local seed banks or nearby sources for dispersal creates a level of uncertainty in determining the capacity for recovery of the Project Area.

1. Background

Chevron Australasia Strategic Business Unit (Chevron) is progressing an Environmental Review and Management Programme (ERMP) for the Wheatstone Liquefied Natural Gas (LNG) Development. The LNG facilities will comprise a processing plant situated at Ashburton North producing 25 mega tonnes per annum (MTPA), a domestic gas plant, associated upstream infrastructure, pipelines, and an LNG export jetty. As part of the ERMP development, Chevron is required to develop a Draft Dredge Spoil Disposal and Management Plan (DSDMP) detailing the relevant monitoring programmes, to demonstrate to stakeholders that potential dredge impacts can be minimised and managed.

The dredging and dredge material disposal activities for the Wheatstone Project will result in elevated turbidity and sedimentation levels and will create a turbid plume during dredging. The dredge program is expected to occur over a 4-year period and while the plume is predicted to be extensive, extending up to 60 km south-west along the coast, its location will vary seasonally and with dredging locations. During summer periods the plume will extend north-east, during transitional periods the plume will be localised within 20 km of dredging, and during winter the plume will extend south-west. As the dredging moves along the access and navigation channels the plume will be limited to a 10 km swath. Therefore any one location is not likely to experience elevated turbidity or sedimentation levels for the duration of the dredging and dredge material disposal activities.

The elevated turbidity and Total Suspended Solids (TSS) have the potential to impact on benthic primary producers (BPP) and benthic primary producer habitat (BPPH), including hard corals, seagrass and macroalgae. However, the environmental impact assessment (EIA) process determined that while seagrasses will suffer temporary, and possibly seasonal, losses they are expected to recover soon after dredging ceases (Chevron 2010). This expectation is based on there being sparse seagrass coverage in the affected area, consisting of small ephemeral species (e.g. *Halophila ovalis*). *Halophila* spp. are considered moderately tolerant to sedimentation and suspended sediments. Furthermore, they can recover relatively quickly from disturbance due to their ability to rapidly colonise bare substrate (Chevron 2010).

1.1. Objectives

The objective of this report is to inform the Wheatstone EIA process of the potential impacts of dredging on tropical seagrasses, and the likely resilience and recovery of these seagrasses. In order to achieve this objective, literature on the ecology of tropical seagrasses, the potential impacts of the dredge program to seagrasses, and the resilience and recovery rates of seagrass to disturbance was reviewed.

1.2. Scope of Works

The report will be based on a desktop review of subtropical and tropical seagrass species literature. The review will detail:

- spatial and temporal dynamics of seagrass (changes in density, above and below biomass);
- resilience to disturbances (change in light climate and sedimentation);
- recovery mechanisms (seeds versus vegetative growth) and rates of recovery; and
- documented impacts associated with dredging.

2. Tropical Seagrass Species

The Indo-Pacific region has the largest number of seagrass species in the world, with approximately 24 species (Short et al. 2001). Intertidal areas are commonly dominated by larger species such as *Thalassodendron ciliatim*, *Thalassia hemprichii* and *Enhalus acoroides*, with the smaller *Halophila* spp. more common in deeper subtidal areas (Coles et al. 2007). The tropical *Thalassodendron ciliatum* is unusual in being restricted almost exclusively to rocky or reef substrates. Often found on reef edges exposed to wave action, *Thalassodendron ciliatum* is protected from damage by its flexible woody stem and strong root system. *Syringodium isoetifolium* and *Cymodocea serrulata* are usually found in subtidal waters associated with reefs, inter-reef lagoons and reef platforms. *Thalassia hemprichii* is mostly associated with coral reefs and is common on reef platforms where it can form dense meadows, but can also colonise muddy substrates particularly in water pools at low tide. Both *Thalassia hemprichii* and *Enhalus acoroides* can be found in intertidal regions where tolerance to temperatures of 40 ºC and low salinities allow these species to colonise (Coles et al. 2007).

2.1. Seagrass Species in the Region

Seagrass in the Pilbara nearshore bioregion is patchily distributed, occurring to depths of approximately 30 m. Tropical and subtropical seagrass species occuring in the bioregion and include *Syringodium isoetifolium*, *Halophila* spp., including *Halophila decipiens*, *Halophila minor*, *Halophila ovalis and Halophila spinulosa,* and a small number of persistent, meadow-forming (perennial) species such as *Thalssia hemprichii*, *Enhalus acoroides* and *Thalassodendron ciliatum (Chevron 2010)*. Other species known to occur in the Pilbara are *Cymodocea angustata*, *Cymodocea serrulata*, *Halodule pinifolia* and *Halodule uninervis* (Walker and Prince 1987).

The distribution, abundance and ecological role of seagrass communities in tropical north-western Australia, including the Pilbara region, are poorly documented. Walker and Prince (1987) looked at the distribution and biogeography of seagrass species along the Pilbara coast and found a large seagrass meadow of *Cymodocea angustata* at Mary Anne Reef, which had several hundred hectares of 30–50% cover in a depth of 2–3 m. *Cymodocea* meadows were also identified in the Exmouth Gulf (McCook et al. 1995) between low tide and 5 m depth, however distribution was generally patchy and had low biomass. Cover was usually less than 5%, biomass was generally less than 60–100 g wet weight m^2 and mean shoot density was often less than 100 shoots m^{-2} (McCook et al. 1995). *Halophila ovalis, Halophila spinulosa* and *Syringodium isoetifolium* and *Halodule* spp. were also present in *Cymodocea* meadows, typically in low abundances. Seagrass meadows in the Exmouth Gulf were not extensive and were rare or absent below 5 m (McCook et al. 1995).This could be because the shallow waters of the Exmouth Gulf were very turbid with large amounts of suspended material due to rough sea conditions and strong tidal currents, resulting in reduced light for photosynthesis. The relatively patchy distribution and low abundance was similar to that found within the Wheatstone Project Area (the Project Area).

2.2. Seagrass Species and Distribution within the Project Area

Surveys conducted in the Project Area (see **Figure 1** for Project Area) in summer and winter found that seagrasses were generally sparsely distributed. Areas of seagrass cover are illustrated in **Figure 1.** Species identified within the Project Area are:

- *Halophila spinulosa;*
- *Halophila decipiens;*
- *Halophila ovalis;*
- *Halodule* spp.;
- *Syringodium isoetifolium; and*
- *Thalassodendron* spp.

Seagrasses encountered occurred in small patches (<10% cover–species included *Halophila spinulosa*, *Halophila decipiens* and *Halophila ovalis*. Low cover (<10%) seagrass areas lie south-west of Thevenard Island and north-east of Onslow (**Figure 1**). Small areas of higher cover (<50%) occurred in shallow clear waters, but these were not common (URS 2010). Seagrass cover as described by URS (2010b) is consistent with a survey of subtidal areas off Onslow in November 1989, which found seagrass absent from most sites and only 'rare' patches of *Halophila decipiens* (Paling 1990). Seagrass was present in greatest cover (12%) along localised areas of shoreline extending north-east along Beadon Bay towards Coolgra Point, with lower cover (5–10%) extending from this shoreline towards Direction and Twin Islands. At Coolgra Point, seagrass abundance was lower in December 2008 as compared to August 2009 and *Syringodium isoetifolium* and *Halodule* spp. were only observed in the latter survey. Low percentage cover of seagrass (5%) was also present around Glennie Patches extending in a north-east direction towards Brewis Reef. *Halophila spinulosa* was identified on the spoil ground areas used by Onslow Salt.

Around the islands offshore from Onslow, several genera (e.g. *Halohpila, Halodule* and *Syringodium*) are known to occur in shallow intertidal platforms and in the lee of small reefs, while *Thalassodendron* is sparsely distributed among the shallow macroalgae meadows to the west of Thevenard Island (Chevron 2010). There are no known populations of larger-growing seagrass species, such as *Thalassodendron* or *Enhalus*, in the nearshore Project Area.

Distribution of seagrasses is patchy immediately west of Ashburton Island, north-west of Onslow and at West Reef (**Figure 1**). Within these areas, seagrass occupies space of a few square meters to tens of square meters, but the patches are not contiguous. **Figure 2** and **Figure 3** illustrate the seagrass that is predicted to be impacted from the dredge plume, based on the modelled plume distributions and longevity (DHI 2010). These areas are predominantly subtidal *Halophila* spp. The plume is predicted to affect 25% of seagrass habitats to the east and west of the navigation channel, resulting in mortality up to 50% in terms of abundance/biomass (DHI 2010; URS 2010).

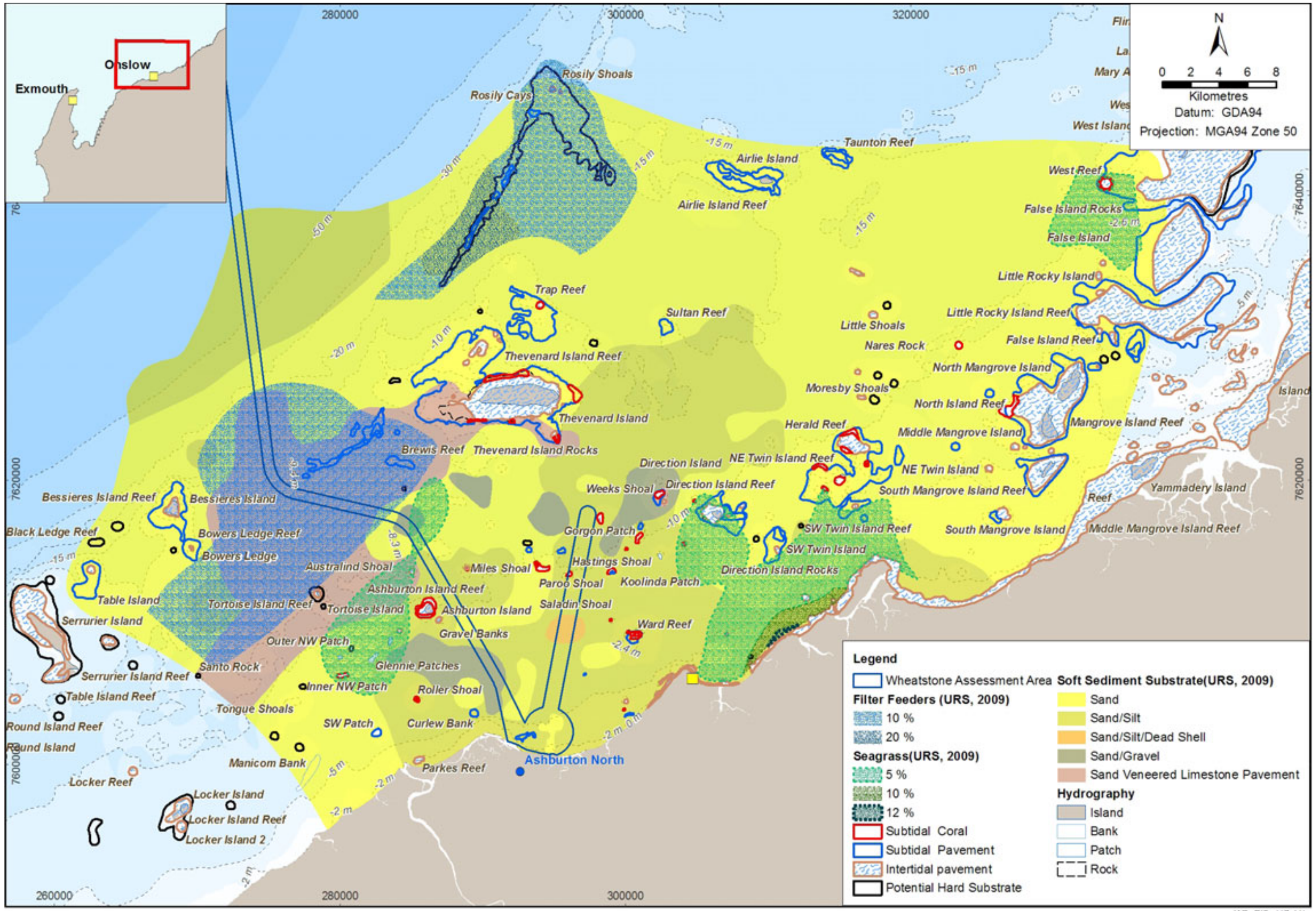
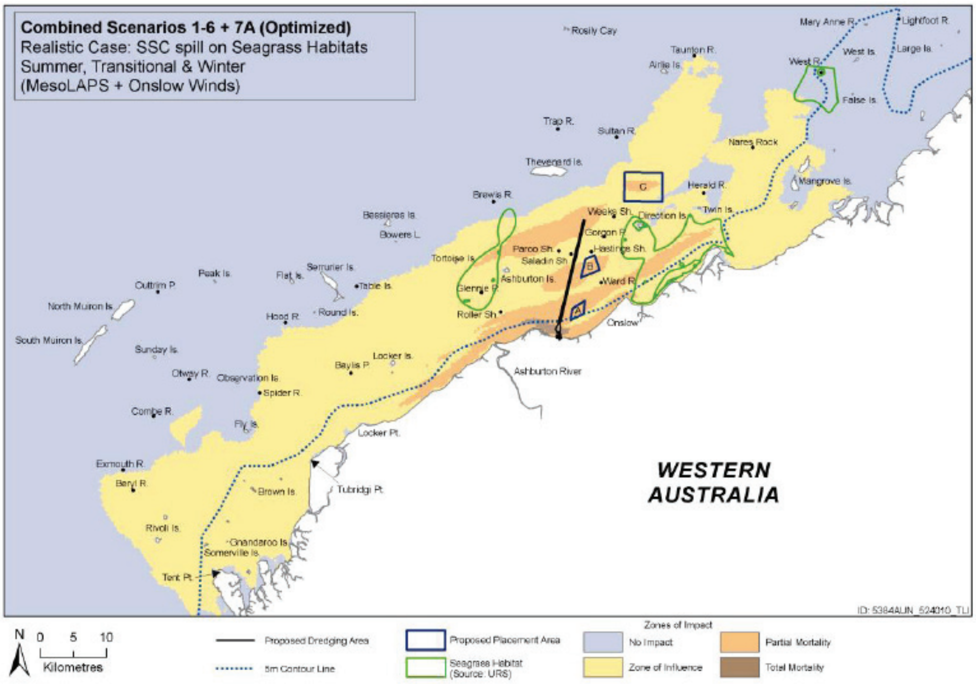
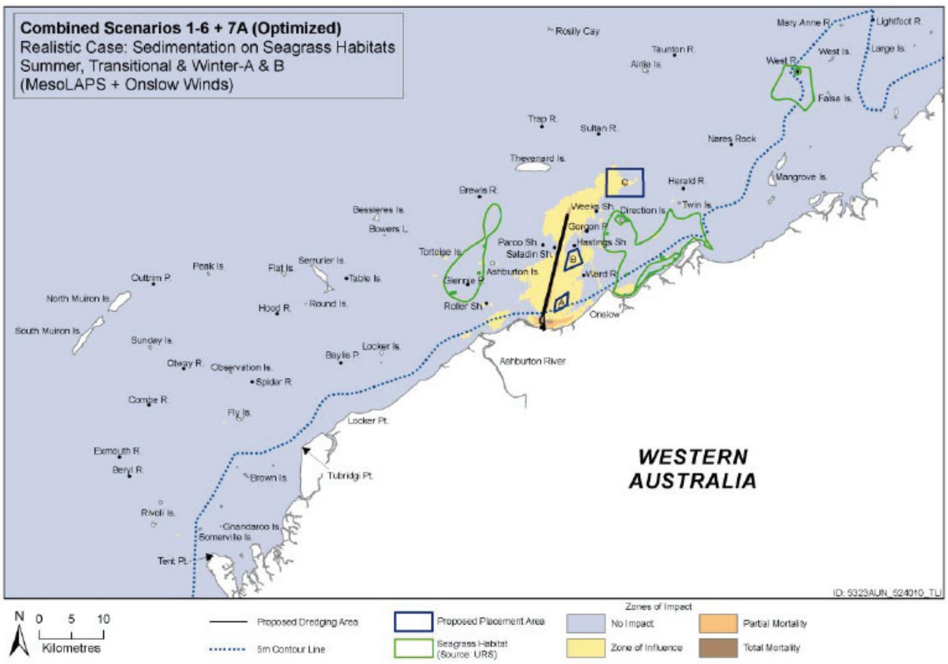


Figure 1: Distribution of seagrass within the nearshore Project Area



- **Figure 2: Optimised scenarios for all seasons for suspended sediment concentration tolerance limits on seagrass communities**



- **Figure 3: Optimised scenarios for all seasons for sedimentation tolerance limits on seagrass communities**

3. Dynamics of Tropical Seagrass

3.1. Spatial Distribution

The spatial distribution of seagrass can be highly variable and is dependent on a combination of physical and biological drivers. Physical drivers such as temperature, salinity, water and sediment movement, depth, light availability, nutrients and substrate type regulate the physiological and ecological status of seagrass and therefore their distribution. Biological controls include epiphytic growth, reproductive strategies, and predation and competition (Short et al. 2001).

3.1.1. Key Physical Drivers

Light

Light is a critical determinant of seagrass growth and survival. Under natural conditions, the depth to which a seagrass meadow extends will be limited by light availability and therefore minimum light requirements (MLR) can define seagrass distribution. In coastal waters, light attenuation with increasing depth is associated with absorption and scattering processes due to dissolved substances, phytoplankton, non-algal particulate matter, and the water itself (Kirk 1994). Consequently, there are differences in light penetration among habitat types as turbidity levels are generally higher in nearshore environments such as estuaries and coasts. Seagrass composition, distribution and characteristics can be influenced by light intensity gradients and the use of MLR allows prediction of how changes in water quality will affect species distributions (Fourqurean et al. 2003) or responses to low light events.

Seagrasses require light for photosynthesis. Studies of seagrass physiology have recently focused on Photosynthesis – Irradiance (P-I) curves, where photosynthetic O_2 assimilation of CO_2 is plotted as a function of incident light, in efforts to determine light levels needed to maintain healthy growth. Compensation irradiances (I_c) range from 20 to 98 µmol m^{-2} s^{-1} and saturation irradiances (I_k) range from 50 to 328 µmol m^{-2} s^{-1} (**Table 1**). Lower maximum photosynthesis and saturation irradiance values and higher α values (maximal quantum yield; moles of carbon fixed per mol of irradiance absorbed) indicate greater photosynthetic light-efficiency and adaptation to lower irradiances and inhibition by high irradiances (Kirk 1994). The variability of P-I parameters among species can be attributed to unique physiological and morphological adaptations of each species, and the variability within species can be attributed to photo-acclimation to local light regimes (Dennison et al. 1993; Lee et al. 2007).

Photosynthetic parameters often show seasonal variability (Dennison 1987; Herzka and Dunton 1997; Alcoverro et al. 1998). This is due to increased respiration rates at higher temperatures relative to photosynthesis; more light is necessary at higher temperatures to allow for positive carbon balance which is reflected in higher saturation (I_k) and compensation (I_c) irradiance values.

Seasonality in photosynthesis is therefore likely controlled by changes in water temperature and studies have found that P-I parameters usually increase with increasing water temperature (Herzka and Dunton 1997; Alcoverro et al. 1998).

Halophila spp. that dominate the study site are likely to be well adapted to low light conditions. *Halophila* spp. have the lowest minimum light requirements among seagrasses and hence the greatest depth limit (Coles et al. 2000). It is likely that the small elliptical or ovate leaves of *Halophila* spp. are more efficient at harvesting light than the linear or lanceolate leaves of other seagrass species (Durako et al. 2003). Additionally, *Halophila* spp. usually have low root:shoot ratios and the low underground biomass results in a reduced respiration requirement (Campbell et al. 2008). The morphological characteristics of *Halophila* spp. are likely to be reflected in their lower light requirements (Durako et al. 2003).

Campbell et al. (2008) measured the photosynthesis parameters of subtidal seagrass in the Torres Strait and found that smaller species with less biomass had greater distribution in low light environments. *Halophila spinulosa*, *Cymodocea serrulata*, *Halophila ovalis* and *Halophila decipiens* all had low minimum light requirements, based on their photosynthetic characteristics, and were found at depths greater than 10 m (Campbell et al. 2008). *Halophila ovalis* and *Halophila decipiens* were abundant in these deep water environments while *Halophila spinulosa* and *Cymodocea serrulata* were sparsely distributed. This distribution was attributed to the greater biomass of *Halophila spinulosa* and *Cymodocea serrulata* which would confer a higher respiratory demand that would impede the maintenance, productivity and biomass in very deep habitats(Campbell et al. 2008). In contrast *Halophila ovalis* and *Halophila decipiens* have a low biomass and therefore a low respiratory demand, thereby enabling maximal productivity at low light climates (Campbell et al. 2008).

Table 1: Photosynthetic parameters of tropical and subtropical seagrass species found in the Pilbara

Species	Location	Depth (m)	P_{max} (mg C h^{-1} $shoot^{-1}$)	R (mg C h^{-1} $shoot^{-1}$)	α (mg C h^{-1} $shoot^{-1}$ / μE m^{-2} s^{-1})	I_c (μE m^{-2} s^{-1})	I_k (μE m^{-2} s^{-1})	Reference
Halodule uninervis	Gulf of Eilat	0.5m				20	50	Beer and Waisel (1982)
Cymodocea serrulata	Cairns[1]	0.85	0.25 ± 0.02	-0.131		64.5 ± 17	104 ± 10	Greenway and Pollard (1993)
	Cairns[2]	0.85	0.23 ± 0.15	-0.036		52.0 ± 15	328 ± 10	Greenway and Pollard (1993)
	Cairns	0.10	0.133			21.0	148	Greenway and Pollard (1993)
	Cairns	0.85	0.31 ± 0.06		0.006	98 ± 7	144 ± 10	Greenway and Pollard (1993)
Thalassia hemprichii	Cairns	0.85	0.43 ± 0.04	-0.130		39.0 ± 32	126 ± 23	Greenway and Pollard (1993)
	Cairns	0.85	0.26 ± 0.03	-0.077		50.1 ± 21	163 ± 23	Greenway and Pollard (1993)
	Cairns	1.0	0.389			42.8	194	Greenway and Pollard (1993)
	Cairns	0.4	0.086			80.12	123	Greenway and Pollard (1993)
	Cairns	0.85	0.58 ± 0.07		0.005	80 ± 10	182 ± 23	Greenway and Pollard (1993)
Seagrass community	Indonesia	Intertidal				50 – 340		Erftemeijer et al. (1993)

[1] Insitu measurements taken during summer
[2] Insitu measurements taken during winter

Species	Location	Depth (m)	P_{max} (mg C h^{-1} $shoot^{-1}$)	R (mg C h^{-1} $shoot^{-1}$)	α (mg C h^{-1} $shoot^{-1}$ / μE m^{-2} s^{-1})	I_c (μE m^{-2} s^{-1})	I_k (μE m^{-2} s^{-1})	Reference
Halophila ovalis	Indonesia	15				33		Erftemeijer and Stapel (1999)
Halophila dicipiens	Florida	20				29		Dawes et al. (1989)

Nutrients

Seagrass productivity is often nutrient limited and changes in nutrient availability have been demonstrated to influence seagrass distribution (Fourqurean and Zieman 1992; Udy et al. 1999). Two key nutrients that are typically nutrient limiting are nitrogen (N) and phosphorus (P). The typical responses to the addition of nutrients are increases in biomass, productivities and shoot size.(Udy and Dennison 1997; Mellors 2003). At Green Island in north Queensland, increases in nutrient availability from human impacts have led to the expansion of seagrass meadows (Udy et al. 1999). Conversely, elevated nutrient levels can lead to seagrass decline or changes in species composition, through the reduction in light caused by phytoplankton blooms and high epiphyte growth (Coles et al. 2007).

The relationship between seagrass distribution and nutrient availability has been demonstrated in the Great Barrier Reef (GBR) where subtidal deep water seagrasses have the highest density in areas near high catchment runoff (Coles et al. 2000). Udy et al (1999) hypothesized that the low seagrass distribution on reefs in the southern GBR is due to relatively low nutrient input from catchment runoff in that region.

Temperature

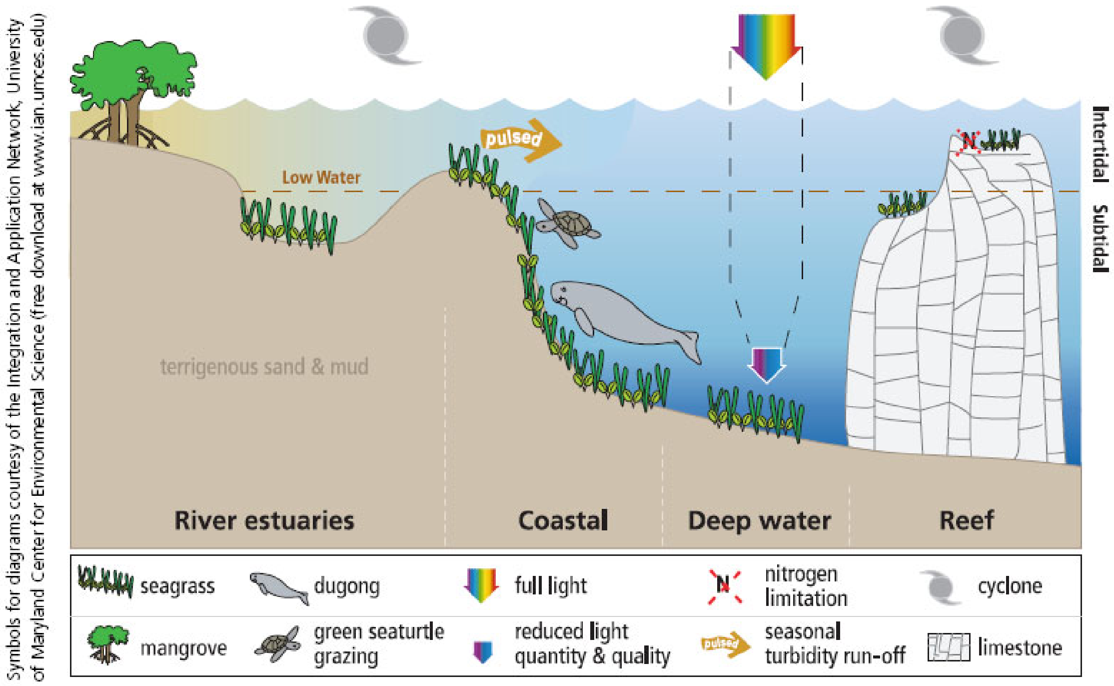
Temperature plays an important role in controlling seasonal seagrass growth, biomass and distribution (Lee et al. 2007). Experiments have shown a rapid decline in seagrass photosynthesis and productivity when temperature goes beyond the optimum temperature range (Hillman et al. 1995; Campbell et al. 2006) and seasonal seawater temperatures in tropical habitats can range from 19.8–41 °C (McKenzie 1994; McKenzie and Campbell 2004). Studies have found that the optimal growth temperature for tropical/subtropical species is between 23 °C and 32 °C (Lee et al. 2007), whereas the optimal temperature range in which *Halodule* spp., *Thalassia* spp., *Syringodium* spp. and *Halophila* spp. become reproductive is 20–26 ºC (McMillan 1982). Growth of seagrasses increases with temperature in high (saturating) light environments, whereas growth of seagrasses in low (near the light compensation point) light environments growth decreases as temperature increases. This is because of the increased respiration rate and limited light available for photosynthesis, suggesting a complex relationship among light, temperature and growth of seagrass (Bulthuis 1987).

3.1.2. Key Seagrass habitats

Seagrasses occur in a variety of habitats and may have different ecological processes and environmental/physical drivers. Carruthers et al. (2002) classified the diversity of seagrass habitats in north-east Australia into four habitat types and propose the main limiting factor for each habitat (**Figure 4**). The four broad categories of seagrass habitat and the environmental drivers are defined as:

- River estuaries – terrestrial runoff (episodic events result in pulses of increased turbidity, nutrients and a zone of reduced salinity in nearshore waters);
- Coastal – physical disturbance;
- Deep water – low light; and
- Reef – low nutrients.

These habitat types could be applicable to north-west Australia and the Project Area as the species and environments are relatively similar. Though the dominant drivers have been determined in each habitat type for north east Australia, all the environmental drivers will have an influence in all habitats to varying degrees (Coles et al. 2007).



Source Carruthers et al. (2002)

- **Figure 4: General conceptual model of seagrass habitats developed for north east Australia**

River estuaries

River estuaries can be subtidal or intertidal and are often highly productive. These seagrass meadows are characterised by fine sediments and are prone to high sedimentation and freshwater inputs. The dominant factor of river estuary habitats is terrestrial runoff from summer rains. Increased river flow results in high sedimentation loads leading to burial and increasing light attenuation, thereby reducing light available at the substrate.

Differences in life history strategies of seagrass species can result in varying species assemblages in different river estuary systems. *Enhalus acroides* is a persistent species and relatively slow growing and can survive periodic burial with shifting sediment. *Cymodocea serrulata* is also known to grow in deeper sediments and its presence within habitats has been linked to sediment accretion (Carruthers et al. 2002).

Ashburton River and the Ashburton delta are found within the Project Area. No surveys were done in the river due to logistic constraints, however a survey approximately 1 km seaward from the river mouth found no seagrass.

Coastal

Coastal habitats often have extensive and diverse intertidal and subtidal seagrass communities. Physical disturbance due to storm and cyclone related waves and swells, associated sediment movement and macro-grazers (dugongs and turtles) are believed to be the primary controls in coastal habitats. The sediment movement associated with storms and cyclones can create an unstable environment, which makes it difficult for seedlings to establish or persist. Storms can result in the physical removal of large of amounts of seagrass habitat that can take years to recolonise (Preen et al. 1995). Grazing by macro-grazers can also have a significant impact on the structure of coastal seagrass communities. Grazing by dugongs has been shown to favour rapidly growing opportunistic species of *Halophila* (Aragones and Marsh 2000).

The Project Area is characterised by coastal seagrass habitats as the majority of the seagrass meadows mapped occurred along the coast and within 20 km of the coastline. Both dugongs and turtles are known to forage within the Project Area (Chevron 2010). Dugongs were predominantly sighted in the south-western portion of the study area (i.e. towards Exmouth Gulf) and in water depths <10 m and near to known areas of seagrass and macroalgae.

Deep water

Light availability is the primary limiting factor of deep water seagrass beds (>15 m). In coastal waters, light attenuation with increasing depth is associated with absorption and scattering processes (Kirk 1994). In addition to reducing light levels, spectral quality is reduced with depth and only blue wavelengths reach water depths greater than 30 m. Distribution of seagrass within these deep water habitats is therefore particularly affected by turbidity events. The distribution of deep water seagrasses appears to be mainly influenced by water clarity and a combination of propagule dispersal, nutrient supply, bottom type and current stress (Carruthers et al. 2002).

In the Great Barrier Reef (GBR), deep water habitats are characterised by large seagrass meadows, comprised mainly of mixed *Halophila* spp., including *Halophila decipiens*, *Halophila ovalis*, *Halophila spinulosa* and *Halophila tricostata*. In contrast, coastal and estuarine meadows have a greater diversity of species. *Halophila* spp. display morphological, physiological and life history adaptations to survival in low light environments (Josselyn et al. 1986).

In the Project Area, seagrass meadows in waters greater than 10 m depth are likely to be considered deep water habitat and would include seagrass meadow immediately west of Ashburton Island. There are limited seagrass meadows found in waters greater than 15 m.

Reef

Reef platform seagrass communities support a high biodiversity and can be extensive and highly productive. Low nutrient availability is a feature of reef habitats as seagrasses can be nitrogen limited in carbonate sediments (Udy et al. 1999). These habitats are also characterised by shallow unstable sediments, fluctuating temperatures and salinity.

Seagrass distribution within the reef habitats in the Project Area only occurs around the islands offshore from Onslow, in shallow intertidal platforms and in the lee of small reefs.

3.2. Temporal Variations in Seagrass

Temporal variability in distribution, density and biomass can occur as a result of seasonal cycles and inter-annual change due to sporadic environmental events and natural variation. Seasonal trends in seagrass distribution, density and community composition have been documented in tropical waters in Australia and are largely driven by changes in growth and reproduction reflecting a response to seasonal changes in environmental conditions, particularly temperature and light (Lanyon and Marsh 1995; Short et al. 2001; Loneragan et al. 2003; Duarte et al. 2006)

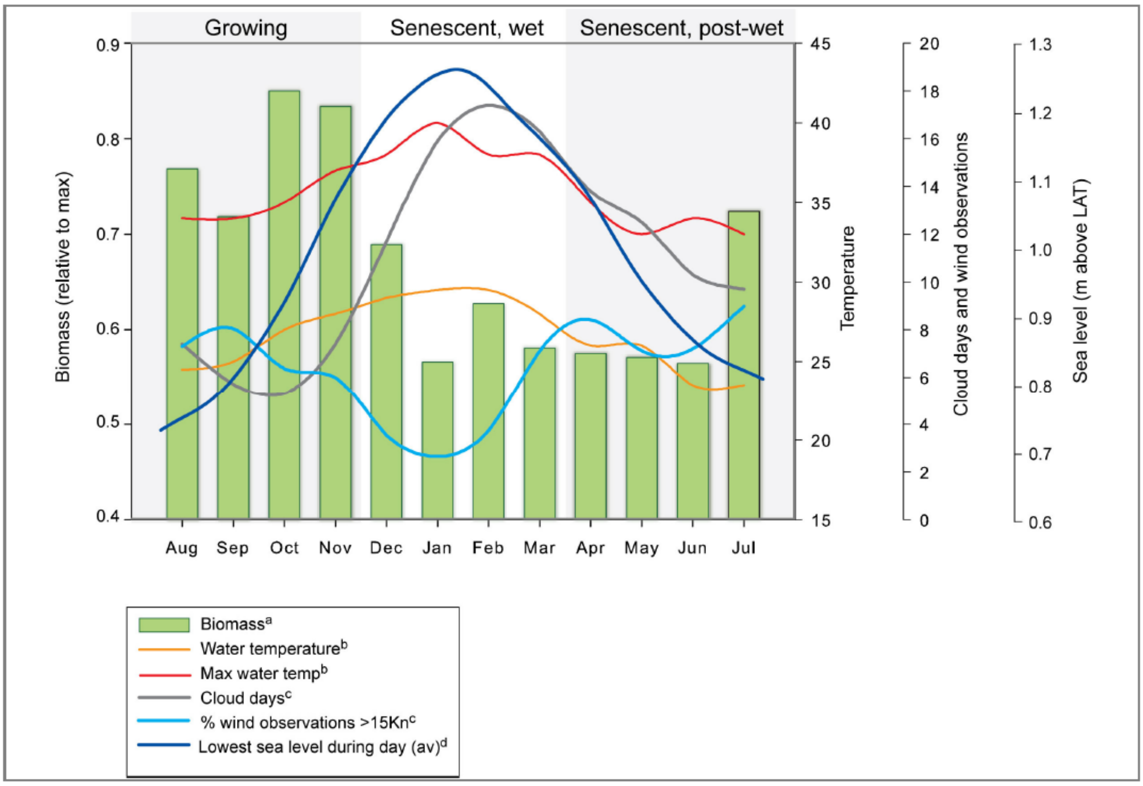
3.2.1. Seasonal Trends

Seasonal variation in water temperature and light are strong drivers of changes to seagrasses, although in tropical meadows a range of other factors can influence seagrass dynamics. For example, the seasonal cycle in biomass, production and nutrient contents in a mixed seagrass bed of *Thalassia hemprichii* and *Enhalus acroides* in Indonesia was found to be largely determined by tidal exposure and water motion (Erftemeijer and Herman 1994). Desiccation resulted in a significant loss of above-ground plant biomass through drying and burning of leaves. These observed seasonal dynamics of the seagrass meadow on reef sediment contrast with reports from the Caribbean, where the effect of tidal exposure on comparable shallow-water seagrass communities is relatively insignificant due to a small tidal amplitude. The change in depth associated with these tidal cycles can also affect diurnal changes in light availability in subtidal communities, with seagrasses experiencing days of very high light, followed by days of very low light, which have implications on seagrass growth and survival. Therefore the drivers of change in seagrass dynamics will vary between sites and species and be dependent on local environmental regimes.

Monitoring of seagrasses in the GBR and the Torres Strait has demonstrated significant natural variations in seagrass distribution, growth and biomass (Mellors et al. 1993; McKenzie 1994; Lanyon and Marsh 1995; Rasheed 1999; Mellors 2003; McKenzie and Campbell 2004; Rasheed 2004; Rasheed et al. 2008). Some of this variation can be explained by natural cycles in climate. Seasonal data commonly demonstrate a unimodal model with a single peak and trough, described as the growth and senescent period. For example *Halophila tricostata* (a structurally small deep water seagrass) is considered an annual in the GBR reef. *Halophila tricostata* can form extensive subtidal meadows but is absent in autumn and winter months and only re-establishes from its seed bank when sea temperatures rise to 26–28 °C (Kuo et al 1993). *Halophila decipiens* can also have an annual growth cycle, with seedlings known to germinate in early spring and grow throughout the summer, flowering prolifically and producing abundant fruits and seeds, and then disappearing in the winter when light levels are reduced (Kenworthy 2000). In tropical eastern Australia, *Halophila decipiens* can be annual at some locations (Chartrand et al. 2008) but persist throughout the year in others. Various *Halophila* spp. are considered annual species demonstrating a peak during summer months and then a senescent period when biomass decreases resulting in loss of seagrass meadows during winter months.

Seasonal studies in the Cairns region have shown that seagrass biomass peaks in late spring and early summer with minimum biomass recorded in winter. This pattern has also been demonstrated in Townsville (Mellors et al. 1993; Lanyon and Marsh 1995) and Moreton Bay (Conacher et al. 1994). Seagrass biomass in the Cairns region increased from June to November (**Figure 5**) as water temperature and light (longer days, less cloud cover, low turbidity) increased. Late summer is the onset of the wet season, where temperatures continue to increase. While higher temperatures can increase growth, very high water temperatures can be detrimental to growth (due to increases in I_c) and therefore peaks in water temperature can correspond to seagrass mortality in shallow or intertidal meadows, resulting in a narrowing of their depth range and a loss of biomass (Campbell et al. 2006). Increases in temperatures also coincide with the wet season when cloud cover and increased turbidity (from high rainfall and turbid runoff from catchments) can lead to reduced light levels. Thus photosynthetic production in seagrasses is more susceptible to high water temeperatures at reduced light conditions and therefore reductions in underwater light may be more harmful to seagrass during summer rather than winter (Hillman et al. 1995).

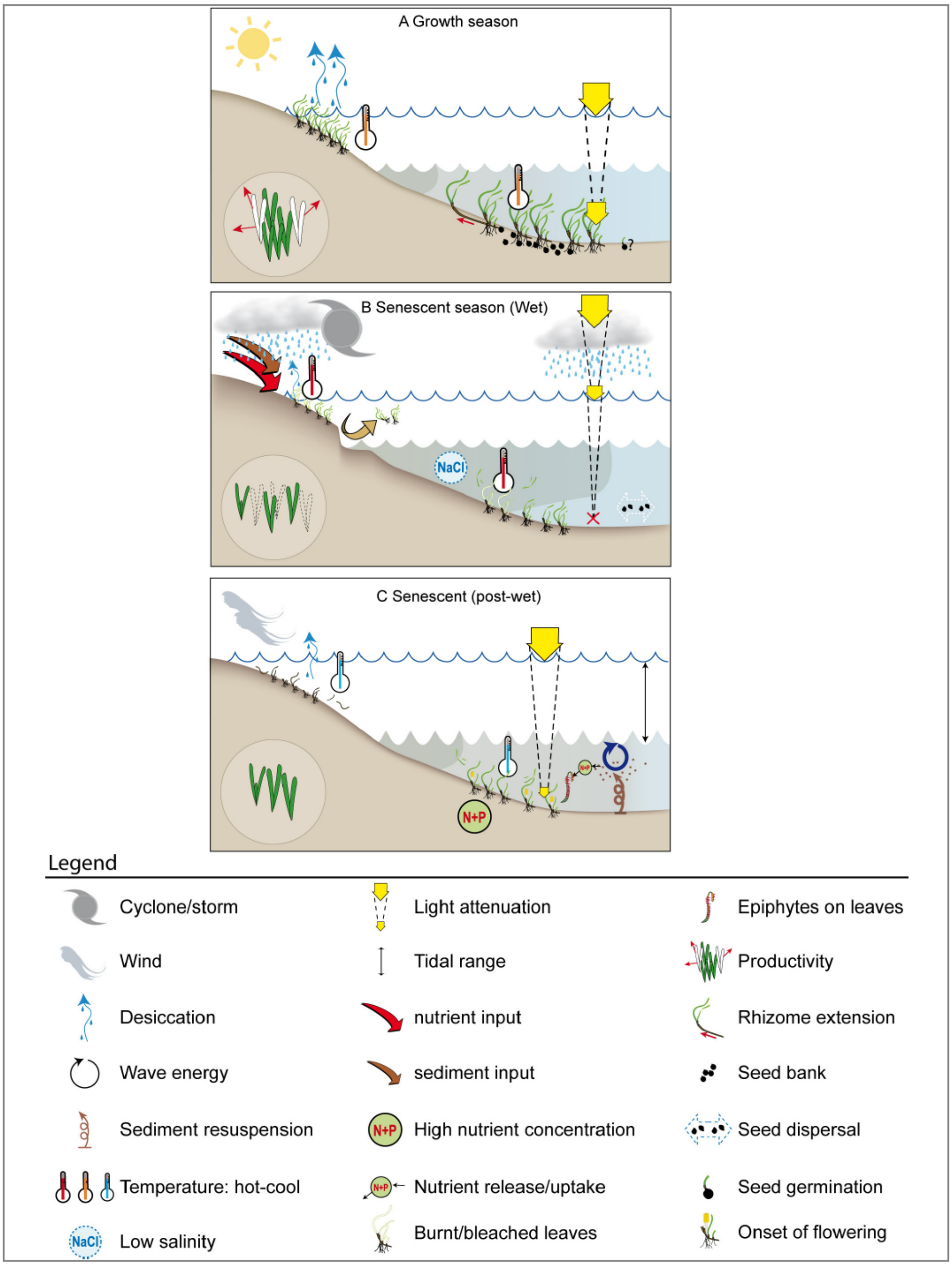
Seagrass biomass in the wet season can also be impacted through physical disturbance caused by storms and cyclones leading to sedimentation and scouring. Wind driven resuspension can lead to high turbidity (Anthony et al. 2004) and windiness can be correlated with declines in biomass (Mellors et al. 1993) contributing to the low biomass in the post-wet senescent period. These seasonal patterns and the environmental drivers are illustrated in **Figure 6**.



Source: Collier and Waycott (2009)

- **Figure 5: Generalised trends in seagrass biomass and long-term climatic variables for the Cairns region.**

[a]Biomass converted to relative value mean of Mellors et al 1993; Mckenzie 1994; Rasheed 2004); [b]Seagrass Watch 2003-2004; [c]Bureau of Meterology average of 66-year data; [d]Maritime Safety Queensland average of 66-year data.



Source: Collier and Waycott (2009)

- **Figure 6: Generic conceptual diagram of the key drivers of seasonality in the GBR**

3.2.2. Inter-annual Trends

The dynamics of tropical seagrasses are modified by long-term weather patterns as well as extreme flood and cyclone events, resulting in stochastic and cyclic patterns of abundance (Birch and Birth 1984, (Lanyon and Marsh 1995). Inter-annual differences in seagrass biomass, distribution and abundance can be attributed to regional-scale changes in climate (Collier and Waycott 2009). This has been hypothesised based on changes in seagrass biomass in the GBR. Five years ago there was considerable seagrass die-off, which was attributed to the Queensland-wide reductions in rainfall resulting in increases in exposure to sunlight and therefore desiccation. More recently there have been Queensland-wide increases in seagrass biomass, which has been attributed to increased rainfall and therefore reduced exposure to air and decreased solar irradiance (Collier and Waycott 2009).

3.3. Variation within the Project Area

Limited surveys have been undertaken over seasons or between years within the Project Area but the likely variation in seagrasses in the Project Area are:

- Seasonal variation in deeper water *Halophila* meadows – could be perennial or annual, however there may be significant variation between seasons (Kenworthy 2000; Chartrand et al. 2008).
- Potentially large interannual change in distribution and abundance of deep water *Halophila* meadows depending on prevailing environmental conditions (e.g. storms, freshwater runoff, available light, etc.).

As previously outlined, different drivers may be important for particular seagrass areas and one paradigm may not be appropriate for all locations including the Project Area.

4. Disturbance – Natural and Anthropogenic

Many tropical seagrass meadows are characterised by high disturbance regimes. This is mainly due to their prevalence in coastal habitats which are subjected to cyclones and flood events and the associated resuspension of sediment and the grazing by dugong and turtles. Such disturbances differentiate tropical seagrass meadows from many temperate meadows, which tend to be more stable (Collier and Waycott 2009). Disturbances can result in a change in plant density, biomass, plant tissue composition, and/or community species composition, occurring on a range of scales from centimetres (e.g. impacts from fauna) to kilometres (e.g. cyclones and flood events).

Disturbances can also be human-induced, those human activities most affecting seagrasses are those that increase light attenuation and therefore reduce light availability: nutrient and sediment loading from runoff and sewage disposal, dredging and filling, pollution, upland development, and certain fishing practices (**Figure 7**). Short et al. (1996) found that human population expansion is now the main cause of seagrass habitat loss and that increasing anthropogenic inputs to the coastal oceans are primarily responsible for declines in seagrass biomass, productivity and distribution. These human-induced disturbances have the potential to result in cumulative impacts if they coincide with natural disturbances such as storm or flood events.

4.1. Dredging-related Disturbances

There are many examples of dredging activities impacting on seagrasses (Erftemeijer and Robin Lewis 2006) **Table 2**. The scale and severity of impact from dredging on seagrasses is dependent on a range of factors including: 1) the magnitude of the disturbance; 2) the species of seagrass affected; 3) the physical and environmental conditions of the affected area; and 4) the existence of seed banks that may aid recovery (Carruthers et al. 2002; Chartrand et al. 2008).

The impacts of dredging-related disturbances are discussed in the following subsections:

- *Reduction in light* – includes discussion of minimum light requirements of seagrasses, spectral quality of light, duration of exposure to reduced light levels, and interspecific variation in resilience to reduced light.
- *Sedimentation* – includes discussion of gross and net sedimentation, burial of seagrasses, seagrasses responses to burial, and interspecific variation in resilience to burial.

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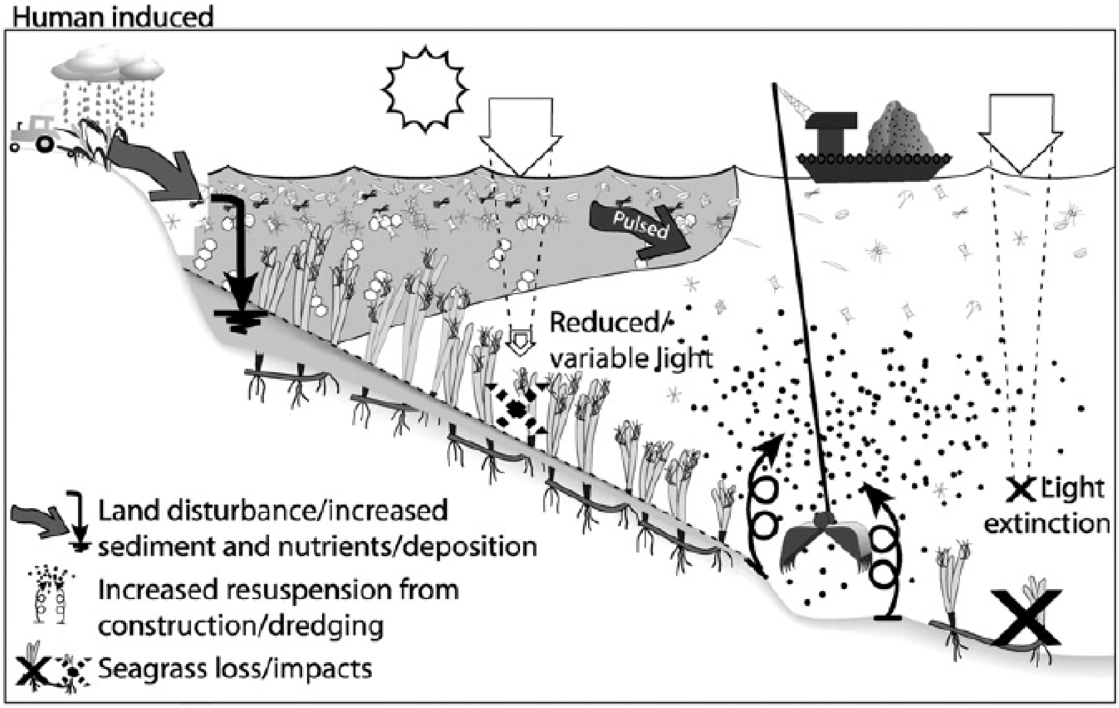
- **Table 2: Documented scale of impacts to seagrass meadows from dredging**

Region	Climate	Species	Scale of Impact (km^2)	Source
South Western Australia	Temperate	*Posidonia sinuosa*	1.0	Gordon et al. (1994)
Laguna Madre, USA	Tropical	*Thalassia testudinum, Halodule wrightii, Syringodium filiforme*	10	Onuf (1994)
Boca Ciega Bay, USA	Tropical	*Thalassia testudinum, Halodule wrightii, Syringodium filiforme*	10–100	Taylor and Saloman (1968)
North east Australia	Tropical		100	Pringle (1989)
Northern Australia	Tropical		0.1	Kenyon et al. (1999)
Bahrain	Tropical		10	Zainal et al. (Zainal et al. 1993)
Bermuda	Tropical		0.1	Smith (1999)
Indonesia	Tropical		0.1	Shaw (2000)

Adapted from Erftemeijer and Lewis (2006); Orth et al. (2006)



Source: Ralph et al. (2007)

- **Figure 7: A conceptual model of light reduction from human activities and seagrass**

Reduction in Light

Dredging and disposal of dredged material can lead to a temporary decrease in water transparency through increased suspended sediments within the water column. The resuspension of sediment, particularly fine sediment particles, results in increased turbidity of coastal waters and an increase in light attenuation, which limits the light availability for seagrass photosynthesis (Ruiz and Romero 2003). The resulting reductions in light can result in decreases in below-ground biomass and carbohydrate contents of rhizomes, tissue nutrient contents, chlorophyll *a* content of leaves, and various photosynthetic growth parameters (Lee et al. 2007).

Extended periods of reductions in light, below minimum light requirements, can lead to seagrass mortality (Longstaff and Dennison 1999; Longstaff et al. 1999), therefore an understanding of MLR allows for prediction of how changes in water quality will affect species response to low light levels. The MLR of the most common seagrass species, *Halophila*, within the Project Area are presented in **Table 3**. The MLR will be species- and site-specific, as species and individuals have unique physiological and morphological adaptations and are able to photo-acclimate to local light regimes (Dennison et al. 1993; Lee et al. 2007).

- **Table 3: Minimum light requirements based on the percentage of surface irradiance for seagrass species occurring within the Project Area.**

Species	MLR (% SI)*	Location	Reference
Halophila ovalis	16	Zanzibar, Tanzania	Schwartz et al. (2000)
Halophila decipiens	4.4	St. Croix (Caribbean US), tropical	Dennison et al (1993)
Halophila decipiens	8.8	Northwest Cuba, tropical	Duarte (1991)
Halodule uninervis (Halodule pinifolia)	14	Karumba, QLD, tropical	Longstaff and Dennison (1999)

**percentage of surface irradiance*

The changes in spectral quality of available light (colour) can also have impacts on seagrass survival and growth. Longstaff (2003) and Gallegos (1994) found that seagrass only used 60% of available light for photosynthesis. This was attributed to the differences in photosynthetically active radiation (PAR) and photosynthetically usable radiation (PUR). Seagrass lack accessory[3] pigments and therefore are limited to a specific spectral range for photosynthesis (Longstaff 2003). Seagrass have a greater capacity to use blue and red light for photosynthesis as opposed to green light. Turbidity results in the depletion of blue wavelengths which therefore reduces the amount of useable light for photosynthesis. While a dredge plume may not reduce the light to levels below established MLR, based on total photosynthetically available radiation (400-700µm), there could be negative impacts to seagrass if the light available for utilisation in photosynthesis (i.e. red and blue) is significantly reduced. Therefore under turbid conditions, reduced spectral quality, seagrass may require more light than the MLR generated under neutral light conditions.

In addition to light reduction and a reduction in the spectral quality from dredge plumes, the duration of exposure and resilience of seagrass species will also impact on survival. Temporary fluctuations in turbidity/reduced light may be accommodated by the seagrass plant depending on the species and the duration of reduced light. Under laboratory experiments and in-field shading studies it has been demonstrated that seagrass can survive at light intensities below their MLR for periods ranging from a few weeks to several months. Seagrass can use stored carbohydrates and reduce carbon demand to persist below their MLR (Lee and Dunton 1997; Longstaff et al. 1999), they also reduce shoot and/or leaf densities in order to reduce self shading and enhance light harvesting efficiency (Longstaff et al. 1999). The survival of seagrass is dependent on the intensity of light reduction (Bulthuis 1983; Lee and Dunton 1997) and the species (Czerny and Dunton

[3] Chlorophyll *a* is the main photosynthetic pigment however other pigments called *accessory pigments* absorb slightly different wavelengths of light. The combination of all of the pigments increases the range of colours that seagrass can use in photosynthesis.

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1995). Smaller species with low carbohydrate storage capacity have a shorter survival period as compared to larger species (Longstaff et al. 1999).

Longstaff (2003) investigated the minimum light requirements and resilience of two seagrass species (*Halophila ovalis* and *Halodule pinifolia*) in north-east Australia. *Halodule pinifolia* had the higher minimum light requirement and was more resilient, persisting for over 78 days when placed into darkness using shade screens. *Halodule ovalis* had lower minimum light requirements and displayed limited tolerance to light deprivation with die-off after 40 days during shading and 30 days during a flood event (**Table 4**).

- **Table 4: Minimum light requirements and time where mortality was observed in two known seagrass species in the Project Area**

	Halophila ovalis	*Halodule pinifolia*
Long term (>10 weeks) MLR (mol photon $m^{-2}\,d^{-1}$)	2.8	9
Seagrass survival from shading experiments (days)	40 (shading) 30 (flood)	<78

Source: Longstaff (2003)

Sedimentation

Sedimentation refers to the deposition of suspending sediments over benthic habitats. Sedimentation can be quantified by either the number of centimetres of sediment that has accumulated during a given time frame (e.g. cm/year) or the rate of deposition of sediment ($g/m^2/d$). However, it should be noted that a there is a distinction between the gross sedimentation rate and the net sedimentation rate. The gross sedimentation rate measures the total rate of accumulation of sediment on the seabed while net sedimentation rate only measures the sediment that remains on the seabed for an extended period and does not include the sediment that is removed due to resuspension. In high energy environments where currents and waves action cause significant resuspension, the net sedimentation rate can be significantly lower than the gross sedimentation rate. The Project Area is considered a high energy environment due to meso-tidal ranges, strong currents and wind currents, and therefore net sedimentation may be different from gross sedimentation.

Dredging results in increased sediment particles within the water column which, depending on their size, will settle onto the seabed potentially leading to burial of seagrass plants. Disturbance of seagrass meadows through sedimentation has both direct and indirect components. Direct effects include smothering, toxicity, reduced light intensity and physical abrasion. An indirect effect is the modification of the sediment attributes, which can result in unsuitable conditions for seagrass growth. The effect of increased sedimentation on seagrass as a result of dredging and material disposal depends on the duration of increased sedimentation, frequency of increased sedimentation events, load (intensity and depth of burial), type of material, and the degree to which plants can utilise morphological and/or physiological means to deal with deposited sediment (Wilber et al. 2005).

While seagrasses have evolved to cope with mobile sediments and resuspension (Vermaat et al. 1997), consistent or permanent burial of seagrass from sedimentation can lead to mortality. Burial impacts seagrass by reducing light availability to photosynthetic tissue, reducing diffusion of O_2 to roots and rhizomes, and mechanically counteracting the production of new leaves at the meristem.

Seagrass species demonstrate a varied response to burial from sedimentation (**Table 5**). The main response following burial appears to be shoot mortality (Cabaço et al. 2008) though the timing of the response varies between species. Shoot mortality can be an immediate reaction (e.g. *Cymodocea serrulata*, *Halodule uninervis*, *Syringodium isoetifolium*), while other species may show a reduction in shoot density after a prolonged exposure to burial (e.g. *Enhalus acoroides*) (Duarte et al. 1997). Seagrass species with vertical shoots (e.g. *Cymodocea*, *Thalassia*, *Thalassodendron*, *Syringodium*, *Halodule*) can also respond to increased sedimentation by making adjustments in vertical stem elongation (growth centres) closer to the new sediment level. This mechanism for enhanced vertical growth appears to be triggered by a light-sensitive mechanism located in the shoot meristem (Duarte et al. 1997). However many species are incapable of this, including the majority of *Halophila* species that dominate the Project Area. Changes in plant morphology, such as longer leaves and leaf sheath and longer internodes, have been reported as responses to burial.

▪ **Table 5: Response of seagrass species to experiment burial in the Philippines**

Species	Main Responses to Sediment Burial
Cymodocea serrulata	▪ Initial decline in shoot density under high burial (8 and 16 cm) followed by recovery ▪ No response of vertical internode length ▪ No changes in age distribution ▪ No response of shoot size, sheath length and leaf specific weight
Enhalus acoroides	▪ Shoot density decline only by the end of the experiment (300 days) ▪ No response of shoot size, sheath length and leaf specific weight
Halodule uninervis	▪ Initial decline in shoot density under high burial (8 and 16 cm) followed by recovery ▪ Increased vertical internode length (up to 2 cm of burial) ▪ Changes in age distribution ▪ No response of shoot size, sheath length and leaf specific weight ▪ Increased branching frequency (up to 8 cm of burial)
Halophila ovalis	▪ Early increase of shoot density at intermediate burial levels (4 and 8 cm of burial) ▪ No response of shoot size, sheath length and leaf specific weight

Species	Main Responses to Sediment Burial
Syringodium isoetifolium	▪ Initial decline in shoot density under high burial (8 and 16 cm) followed by recovery ▪ Increased vertical internode length (up to 4 and 8 cm of burial) ▪ Changes in age distribution (increase in recruitment of young shoots (<1 yr)) ▪ No response of shoot size, sheath length and leaf specific weight ▪ Increased branching frequency (up to 8 cm of burial)
Thalassia hemprichii	▪ Shoot density decline ▪ Increased vertical internode length (up to 8 cm of burial) ▪ Changes in age distribution (selective loss of young shoots (<1 yr) and reduced recruitment) ▪ No response of shoot size, sheath length and leaf specific weight

Adapted from Duarte et al. (1997)

The capacity and resilience of seagrass species to withstand sediment burial is largely size dependent (Duarte et al. 1997; Cabaço et al. 2008). In a mixed seagrass meadow, Duarte et al. (1997) described a pattern of species loss after burial in which mortality increased with decreasing seagrass size. This is largely related the amount of biomass available in roots and leaves (above and below ground biomass) for storage of carbohydrates. Sediment burial results in the reduction of the available photosynthetic area of seagrass leaves and plants are therefore forced to use stored carbohydrates. For example, small seagrass species, such as *Halophila ovalis*, which are characterised by low shoot mass, low above-ground biomass, thin rhizomes, high horizontal rhizome elongation and small leaves are more sensitive to burial (Cabaço et al. 2008) and are less resilient than large species.

4.2. Natural Disturbances

Natural disturbances are common in tropical seagrass meadows and include currents, flooding, sediment resuspension, cycle of tidal exposure, grazing and storms. In the Project Area, grazing, storms and floods are likely to be major natural influences on the local seagrass populations.

Grazing

Considerable research has been conducted on the impacts of grazing on seagrasses by dugongs and green turtles in the GBR (Lanyon et al. 1989). Dugongs will graze on the whole plant which involves digging up the entire plant, including roots and rhizomes and therefore dugongs have a large feeding intensity in herds and can remove a large portion of biomass in the seagrass meadow (Preen 1995). The grazing of small patches has demonstrated increased growth rates and increases in biomass for seagrass meadows (Aragones and Marsh 2000). In the GBR, dugongs are the dominant grazers however there is also substantial grazing by fish and invertebrates.

Dugongs rely on seagrass as their sole food source and prefer smaller colonising species of seagrass (Marsh et al. 1999) as they have a higher nutritional value. The high intensity grazing means seagrass meadows persist in a high disturbance state as smaller structured meadows. Grazing by dugongs has been shown to prevent expansion of *Zostera capricorni* in favour of rapidly growing, opportunistic species of *Halophila* (Preen 1995). Additionally, Argones and Marsh (2000) demonstrated that grazing changed the species composition in favour of *Halophila ovalis* at the expense of *Zostera/Cymodocea* in the GBR.

Green turtles do not graze exclusively on seagrass and crop the seagrass rather than tearing up the whole plant. Therefore turtles primarily influence seagrass meadows through loss of biomass rather than changing species composition of communities (Aragones and Marsh 2000).

Dugongs and turtles are known to forage within the Project Area (Chevron 2010) and dugong feeding trails were thought to be identified within the Project Area (URS 2010). Surveys between May and December 2009 recorded 148 dugongs however the maximum observed in one survey was 31 individuals. This is considerably smaller than the populations in Exmouth Gulf and Ningaloo Reef which are both estimated to be 1000 individuals (Chevron 2010).

Cyclones/Storms and Floods

Cyclones and storms may cause destruction of complete seagrass meadows (Rodriguez et al. 1994; Preen et al. 1995; USGS 2005), change seagrass community structure through species-specific elimination, or cause 'blow out' patches devoid of vegetation in continuous seagrass meadows. These changes are due to three main physical disturbance impacts: high energy wave action, sediment scouring and sediment deposition leading to increased sedimentation (burial) and turbidity (reduced light). Over a 3-week period in 1992, the seagrass meadows in Hervey Bay experienced two major flood events and a cyclone which resulted in a loss of approximately 1000 km^2 of seagrass meadows; almost a quarter of the known area of seagrass along the QLD east coast at that time. The seagrass in deep water (at least 10 m deep) died as a result of a persistent reduction in light due to the increased turbidity from the flood plume and then the resuspension of sediment during the cyclone event, while seagrass in the shallow waters (less than 10 m) were lost due to physical disturbance from wave action (Preen et al. 1995). Storm events can also cause changes in seagrass community structure. Within Puerto Morelos reef lagoon (Mexico) the effects of Hurricane Wilma resulted in a significant reduction of *Syringodium filiforme* density while there were no changes to *Thalassia testudinum* (van Tussenbroek et al. 2008). In addition the effect of the storm event on the fringe of the nearshore environment was a complete loss seagrass meadows (van Tussenbroek et al. 2008). Storm events cause multiple physical drivers, including high energy wave action, sedimentation and increased suspended sediments, resulting in a range of impacts to seagrass meadows.

The Wheatstone area is subject to storms and cyclone events and these are likely to play a significant role in driving interannual changes to seagrass communities in the region.

4.3. Cumulative Impacts

The response of seagrasses to disturbances will be a result of the cumulative level of impacts, including both dredging related activities and natural disturbances, and the species present within the impacted area. The cumulative effects of disturbances was studied by Eklof et al. (2009) which demonstrated that after combined shading and rhizome grazing disturbances, seagrass had lower recovery rates as opposed to disturbances of shading and grazing alone.

The loss of seagrass within the Project Area due to capital dredging activities is expected to be due to a reduction in light and there are no predicted losses from direct removal or increased sedimentation. Subtidal areas comprised of *Halophila* spp. are likely to experience partial mortality (50% decrease in abundance/biomass), which is predicted to affect 25% of seagrass habitats to the east and west of the navigation channel (URS 2010). However the modelling has been based on excess suspended sediment concentrations and rates of sedimentation generated by the dredging and offshore disposal activities does not include background levels. The cumulative impacts of dredging are less well understood and any impacts could be larger than originally predicted if the dredge plume coincided with a cyclone, flood or persistent wind event leading to a further reduction of available light and increased rates of sedimentation.

5. Recovery from Disturbance

Recovery from large events, such as physically disruptive cyclones, may take decades (Birch and Birch 1984) or may be rapid (Waycott et al. 2009) and will depend on several factors:

- the magnitude of the disturbance (see **Section 1**);
- the species of seagrass affected (see **Section 2**);
- the physical and environmental conditions of the affected area (see **Section 3**); and
- the existence of a source of propagules and their ability to establish in disturbed areas .

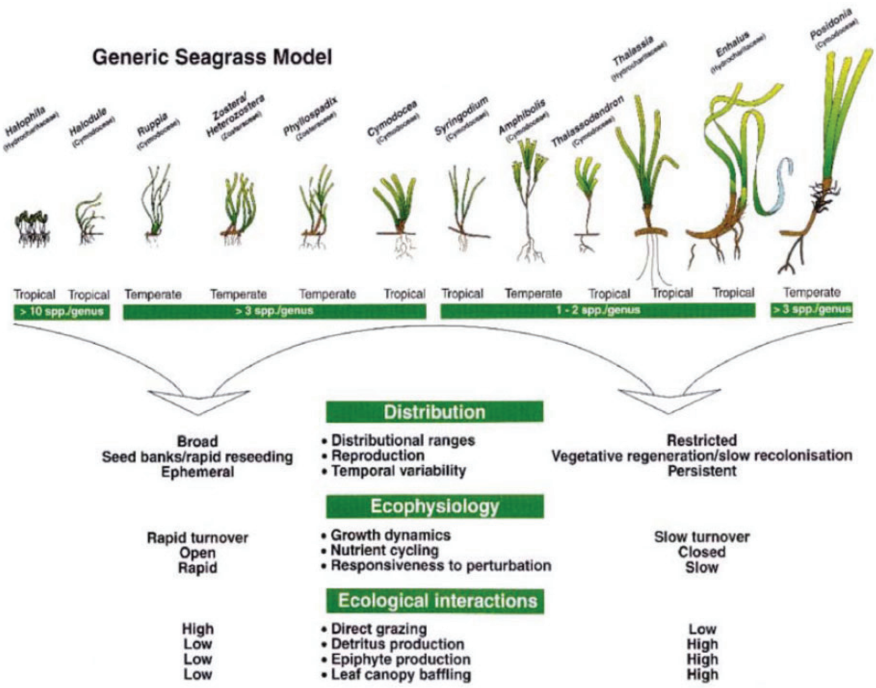
There are large differences between seagrass species and communities in their capacity for recovery from impacts. Seagrasses are flowering plants and capable of sexual reproduction through flowers fruits and seeds, but they are also clonal plants capable of recovery through asexual colonisation. The reproductive and life history strategy available to each seagrass species will control their ability to recover from disturbances.

5.1. Recolonisation Processes

Seagrasses species demonstrate a large range of life history strategies which strongly influence the recolonisation process. Walker et al. (1999) described seagrass genera according to their growth form, based predominantly on rhizome turnover rates. This functional form model describes the distribution, ecophysiology and ecological interactions of the spectrum of seagrass genera, as illustrated in **Figure 8**. Large species at one end of the spectrum have a high resilience and are slow growing (e.g. *Enhalus* sp.), whereas species at the other end of the spectrum (e.g. *Halophila* spp.) are fast growing, have a high reproductive output (sexual or asexual) but a low resilience. Based on this model it is expected that after a disturbance the first species to recolonise the area would be fast growing species, such as *Halophila ovalis* which has a horizontal extension of 574 cm/year (Duarte 1991). Therefore recently disturbed areas tend to be dominated by pioneer species, characterised by abundant seed production, high dispersal power and rapid growth. Often these species are eventually displaced by larger, slower growing species that are superior competitors.

Halophila ovalis is the fastest growing tropical seagrass species (Vermaat et al. 1995) making it a common pioneer species that can rapidly colonise areas and survive well in unstable depositional environments following a disturbance (Birch and Birch 1984). Rasheed (2004) found that while *Halophila ovalis* initially colonised gaps via sexual colonisation (where asexual colonisation was prevented) it was displaced by other species within ten months. Furthermore, a study by Nakaoka and Aioi (1999) found that it took two months for a patch within a seagrass bed that was removed of *Halophila* o*valis* to reach the same state of colonisation prior to disturbance. *Halophila ovalis* appears to display characteristics of high reproductive output and little investment in competition or maintenance (Rasheed 2004). Seagrass that grow in restricted and spatially distributed habitats which can be exposed to unpredictable mortality events could have an advantage using a strategy of rapid asexual colonisation and limited dispersal of sexual propagules (Rasheed 2004)

This is in contrast to the recolonization of a disturbed area (1200 m^2) in the Philippines where seedlings of the slow growing species *Thalassia hemprichii* and *Enhalus acoroides* dominated sexual colonization of the disturbed area (Olesen et al. 2004) while the small seagrass species *Cymodocea rotundata* and *Halodule uninervis*, characterized by fast rhizome elongation rates were the major contributors to vegetation cover through vegetation propagation.



Source: Walker et al. (1999)

- **Figure 8: Generic seagrass function form model describing seagrass plants according to growth form**

5.2. Seeds and Dispersal Strategies

The mechanisms of recovery in seagrass meadows are poorly understood (Rasheed 2004) and information on seed dispersal for seagrass and its role in recovery of vegetation is limited. Seagrasses are capable of sexual reproduction through the production of fruits, seeds or viviparous seedlings (Short et al. 2001) and is thought to contribute to regional population dynamics through the colonisation of unoccupied sites or to site population dynamics through the colonisation of disturbed sites (Inglis 2000).

Seagrasses produce a range of seed types that vary in size, longevity and dispersal ability and these characteristics have an influence on the distribution of the seed in time and space (Orth et al. 2000). Kuo and Kirkman (1996) categorized the seagrass genera into three groups based on seed anatomy and germination (**Table 6**).

- **Table 6: General characteristics of seeds and breeding systems of various seagrass genera**

Class	Genus	Breeding system	Seed size (mm)	Seed bank type
i. Species which produce viviparous seedlings	*Amphibolis* *Thalassodendron*	Dioecious Dioecious	80-100 35-50	None None
ii. Seeds with membranous coverings and indistinct dormancy	*Posidonia* *Enhalus* *Thalassia*	Bisexual Dioecious Dioecious	8-20 10-15 8-10	None None None
iii. Seeds with hard coverings and distinct dormancy	*Halodule* *Cymodocea* *Syringodium* *Zostera* *Heterozostera* *Phyllospadix* *Halophila*	Dioecious Dioecious Dioecious Monoecious Monoecious Dioecious Dioecious (10 spp.) Monoecious (2 spp.)	2-3 7-10 4-8 2-4 3-4 9-11 0.2-1	Persistent Persistent Persistent Transient Transient Transient Persistent

Source: Inglis and Waycott (2001)

Long-lived locally dispersed seeds offer seagrass a means to recolonise areas following infrequent meadow scale losses of adult plants (McMillan 1982; Rasheed 2004). Some seagrass genera produce buoyant fruits which disperse relatively long distances, or disperse seeds in rafting flowering shoots. However, seeds for most seagrass species are poorly adapted for dispersal and fall rapidly through the water column once they are released from the flower or fruit (Orth et al. 2006). Both *Cymodocea* and *Halodule* release seeds below the surface sediment and dispersal is limited to centimetres (Inglis 2000; Inglis 2000). These long-lived seeds may form a persistent seed bank. Thus for species with seeds that lack dispersal-enhancing characteristics spatial distribution generated from seed banks may be intimately linked to sediment dynamics and seagrass species that have highly persistent seed banks may have evolved to maximise seed dispersal in time rather than space.

Halophila decipiens is the only circumglobal tropical seagrass to grow in both hemispheres and therefore may be capable of long distance dispersal, implied by its global distribution with very little genetic divergence (Waycott et al. 2005) however seeds released by this seagrass are deposited into sediments near parent plants. Recently, Bell et al. (2008) studied the effects of Hurricane Irene on *Halophila decipiens* in the Gulf of Mexico and found sand and seagrass on what was hard bottom in previous surveys and hypothesized that it was a result of seeds and sand being transported into the location during the storm event as *Halophila decipiens* often behaves as an annual. Therefore the dispersal and generation of new seagrass patches for *Halophila decipiens* may be a result of the movement of seagrass seed banks, en masse, during large and intense disturbances.

In many instances local populations are incapable of recolonising via sexual reproduction due to limited sexual reproduction and small or non-existent seed banks, and are therefore reliant on asexual recolonisation (or recruitment from a nearby population) (Rasheed 2004).

5.3. Asexual/Clonal Recovery

Vegetative growth has been assumed to be the mechanism for the maintenance and expansion of seagrass meadows as all seagrass species are capable of asexual reproduction through horizontal rhizome growth. Recovery of gaps within meadows exclusively by asexual means has been reported in a multi-species Caribbean meadow and multi-species tropical Australian meadows (Rasheed 2004). Vegetative recovery is, however, likely to be negligible initially unless portions of the original seagrass meadow remain allowing small areas to be recolonised. Rasheed (2004) found that the gaps in the seagrass meadows were able to recover total shoot density and above-ground biomass to the level of undisturbed locations within 7–10 months through asexual recovery and only areas where asexual recruitment was prevented did sexual recolonisation occur. This was also demonstrated in the Philippines where clonal recovery of *Cymodocea rotundata* and *Halodule uninervis* were the major contributors to increases in vegetation cover (Olesen et al. 2004). Studies have suggested that local persistence and long distance dispersal of clonal seagrasses are often achieved by asexual spreading via rhizome elongation and vegetative fragments respectively (Inglis 2000).

5.4. Project Area Seagrasses

There needs to be an understanding of the species and local population in order to understand the capacity to recover. *Halodule uninervis*, for example, has been demonstrated to use both sexual output and seed banks (Inglis 2000) and in other places be totally reliant on asexual growth (Rasheed 2004) for recovery. The capacity and mechanisms for recovery of seagrasses within the Project Area is unknown and can only be extrapolated from studies in other locations. However *Halophila* spp. are well adapted to cope with mortality by their rapid ability to recolonise areas.

Halophila spp. have commonly been observed to recolonise spoil grounds in eastern Australia (Chartrand et al. 2008) and were identified on the Onslow Salt spoil grounds (URS 2010).

6. Conclusion

The species likely to be impacted from the dredge plume and the most common species found within the Project Area are small *Halophila* spp., which are likely to have a highly variable spatial and temporal abundance and distribution. While there were other species such as *Halodule, Thalassendron* and *Syringodium* located within the Project Area, these were located outside the predicted dredge plume and are unlikely to be impacted based on plume models.

There is support in the literature that *Halophila* seagrass communities can recover relatively rapidly once conditions return to "normal" (between 1 to 3 years after disturbance) (e.g Chartrand et al. 2008; Preen et al. 1995). Additionally, there are portions of the seagrass meadows which are not predicted to be influenced by the dredge plume and therefore any gaps in the seagrass meadows due to reduced light may be recolonised through vegetative propagation. If the impacted areas are relying on seed banks for recovery, multiple years of low light or repeated loss and recovery could deplete those reserves and limit recovery.

However, while there is strong evidence that *Halophila* meadows elsewhere in tropical and subtropical Australia have a good capacity for recovery from large disturbances, the lack of detailed information on local seed banks or nearby sources for dispersal creates a level of uncertainty in determining the capacity for seagrass recovery in the Project Area.

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APPENDIX B – POTENTIAL FOR DISPLACEMENT OF RESIDENT MARINE MEGAFAUNA SPECIES

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EXECUTIVE SUMMARY

Chevron Australia Pty Ltd (Chevron), the proponent of the Wheatstone Project, proposes to construct and operate a multi-train LNG plant and domestic gas (Domgas) plant at Ashburton North, 12 km south-west of Onslow on the Pilbara coast of Western Australia (WA).

As part of the environmental approvals process, Chevron has prepared and submitted a Draft Environmental Impact Statement/Environmental Review and Management Programme (EIS/ERMP) to the WA Environmental Protection Authority (EPA) and the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPC). The Draft EIS/ERMP was released for public comment in July 2010.

The purpose of this report is to assess the Project's potential to displace dugongs (*Dugong dugon*), coastal dolphins, marine turtles and green sawfish (*Pristis zijsron)* from their usual habitats, and to clarify the assessment process used.

A framework was designed for the steps to be taken in the assessment of short-term and long-term displacement scenarios. Data collected was used to assess potential impact on the three marine megafauna species in the following areas:

- proportion of the population that may be displaced
- criticality of the original habitat
- frequency of possible displacement
- ability of the animals to move into a suitable 'substitute' habitat nearby
- ability of the animals to move back into that original area at some time, and the duration of possible displacement.

The final assessment concluded that, if displacement did occur, there would be no lasting effects on populations of the marine megafauna species considered.

It is assumed that the megafauna species considered are not restricted to the potential displacement areas because:

- megafauna have been widely recorded throughout the wider survey areas at densities equal to or higher than those in the potential displacement areas
- megafauna have not been recorded as aggregating within the potential displacement areas during any of the fauna surveys
- megafauna are highly mobile and are likely to have home ranges of greater distances than the span of the potential displacement areas
- habitat types that occur within the potential displacement areas are not restricted and are well represented in the region
- it is assumed that the potential displacement areas do not provide critical habitat
- the area of the potential displacement areas is proportionately insignificant in the surrounding available habitat (the short-term displacement area being more than 100 times smaller and the long-term displacement area more than 1000 times smaller).

1.0 INTRODUCTION

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train Liquefied Natural Gas (LNG) plant and a domestic gas (Domgas) plant at Ashburton North, 12 km south-west of Onslow on the Pilbara coast of Western Australia (WA) (Figure 1.1).

The plant will initially process gas from the Wheatstone natural gas fields, approximately 200 km offshore from Onslow in the West Carnarvon Basin. The Wheatstone Project will require the installation of gas gathering, exporting and processing facilities in Commonwealth and state waters, and in the Shire of Ashburton. The LNG plant will be located in the Ashburton North Strategic Industrial Area and have a maximum capacity of 25 million tonnes per annum (MTPA) of LNG.

The Wheatstone Project is currently subject to an environmental approvals process and is being assessed by the WA Environmental Protection Authority (EPA) and the Commonwealth Department of Sustainability, Environment, Water, Population and Communities (DSEWPC, formerly DEWHA) via a joint Environmental Impact Statement/Environmental Review and Management Program (EIS/ERMP) document (Chevron 2010). Chevron submitted the draft EIS/ERMP to the EPA and DEWHA in June 2010 and it was released for public comment in July 2010.

The purpose of this report is to assess the potential for and consequences of, the displacement of dugongs (*Dugong dugon*), coastal dolphins, marine turtles and green sawfish (*Pristis zijsron)* from their usual habitats that could be caused by project activities, and to clarify the assessment process.

To achieve this, a clear framework was followed so that the assessment of short-term and long-term displacement scenarios could be demonstrated. Available data has been discussed in the context of this framework for each of these marine megafauna species.

This report concludes with an assessment of potential consequences of both short-term and long-term displacement for each fauna groups.

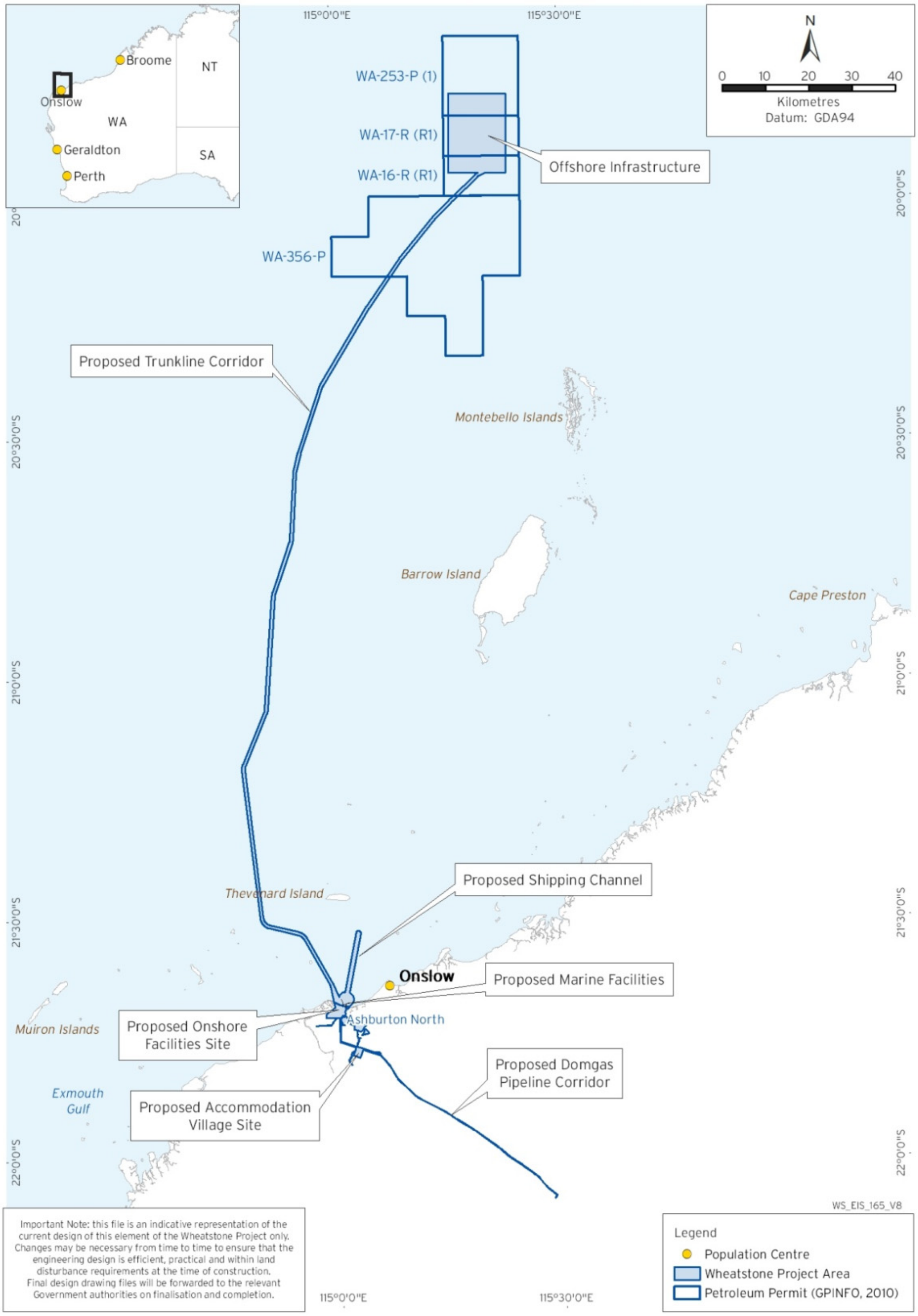

Figure 1.1: Location of the Wheatstone Project

2.0 DISPLACEMENT ASSESSMENT FRAMEWORK

2.1 Displacement Definition

A habitat is a certain area in the environment that is occupied by an organism, or group of organisms, and which provides the physical and biological conditions required by those organisms to sustain life. Displacement occurs when animals vacate a habitat that they have traditionally utilised, and this can be a direct response to a new anthropogenic activity.

The danger of habitat displacement is the potential for animals to select sub-optimal habitats or move into suitable habitat that is occupied already by individuals of the same species. Both actions could potentially compromise the survival of the displaced animals. A sub-optimal habitat would be one that does not possess characteristics that provide the best resources for important activities such as feeding, mating, calving or predator protection that enable the ecological maintenance of individuals, species or a population.

To avoid disturbance, animals may relocate away from foraging sites, conspecifics for mating, or protection from predators. The effects of displacement can be severe, resulting in impacts such as reduced reproductive success. However, magnitude of potential impact to a species or a local population of that species is dependent on factors such as the:

- proportion of the population that is displaced
- criticality of the original habitat
- frequency of displacement
- duration of displacement
- ability of the animals to move into a suitable ‘substitute’ habitat nearby
- ability of the animals to move back into that original area at some time.

These factors are the criteria on which the potential displacement and its impact has been assessed.

2.2 Species Considered

The factors affecting displacement (Section 2.1) have been considered for each marine megafauna species assessed, which are the ‘key receptors’ identified in Chapter 8.4 of the Wheatstone Project EIS/ERMP (Chevron 2010), and which have been found to reside within the Project Area at some time (Table 2.1). It was acknowledged in the EIS/ERMP that coastal species are at higher risk of potential impact from the Project as this is where most Project activity will occur.

Hawksbill turtles (*Eretmochelys imbricata)* and loggerhead turtles (*Caretta caretta)* have been omitted from this assessment because, although they nest within the Project Area, this occurs on islands further south and are expected to be present in the Project Area infrequently. Humpback whales (*Megaptera novaeangliae)* and whale sharks (*Rhincodon typus*) are not included in this report because, while they pass through the Project Area during migration, they are not resident in the area (Chevron 2010).

Table 2.1: Species considered within this report and their occurrence within the Project Area

Species	Occurrence
Indo-Pacific humpback dolphin *Sousa chinensis*	Likely to be present in coastal waters (<20 m deep) throughout year. (Coastal dolphins have been recorded, but not to species level.)
Common bottlenose dolphin *Tursiops truncatus*	Likely to be present in coastal waters (<20 m deep) throughout year. (Coastal dolphins have been recorded, but not to species level.)
Indo-Pacific bottlenose dolphin *Tursiops aduncus*	Likely to be present in coastal waters (<20 m deep) throughout year. (Coastal dolphins have been recorded, but not to species level.)
Dugong *Dugong dugon*	Present in coastal waters adjacent to the Project Area.
Flatback turtle *Natator depressus*	Nests on islands adjacent to the Project Area and on a mainland beach at the Ashburton Delta. Also present within coastal waters of the Project Area.
Green turtle *Chelonia mydas*	Nests on islands adjacent to the Project Area. Also present within coastal waters of the Project Area.
Green sawfish *Pristis zijsron*	Recorded in Hooley Creek and Ashburton Lagoon.

2.3 Species Information

An ecological understanding of the megafauna species considered is important in assessing the displacement factors listed in section 2.1 above.

Marine megafauna baseline survey data collected on behalf of Chevron for use in the EIS/ERMP has been used in this assessment. The suite of studies referenced here are:

- Detailed desktop literature review on marine mammals potentially occurring in the Project Area (RPS 2010a).
- Dugong aerial survey (RPS 2010b).
- Satellite study of nesting flatback turtles in the vicinity of the Ashburton North SIA (RPS 2010c).
- Vessel-based survey of foraging marine turtles in the vicinity of the Ashburton North SIA (RPS 2010c).
- Turtle nesting survey of mainland and island beaches in the vicinity of the Ashburton North SIA (Pendoley Environmental 2009 described in RPS 2010c).
- Aerial surveys of the abundance and distribution of humpback whales, dugongs, dolphins, whale sharks and turtles in the Project Area (12 month dataset) being undertaken by the Centre for Whale Research (CWR) (Jenner *et al*. 2010).
- Underwater acoustic surveys of whales and other marine organisms in the Project Area (12-month dataset) undertaken by Curtin University's Centre for Marine Science and Technology (CMST) (Jenner *et al*. 2010).

- Report on turtle nesting and hatchling orientation surveys of mainland and island beaches around Ashburton North for API in January–March 2009 (Pendoley Environmental 2009a; Appendix O).

Anecdotal reports of species observations recorded during surveys targeting other species are also presented.

The best available scientific information has been used to inform the assessments; where literature is not available from the southern Pilbara, information from other locations has been cited. Assessment certainty is presented in the results. Consistent with the risk assessments in the EIS/ERMP, these are confidence levels ranging through High, Reasonable and Low, which are relative to each other and based on the information available.

This information is discussed in sections 3.0, 4.0. 5.0 and 6.0 in the following context:

- distribution and assumed density within waters of the Project Area
- distribution and assumed density in waters surrounding the Project Area
- habitat needs at different life phases
- home range (the total area covered or traversed by an individual animal undertaking normal activities)
- dispersal (process by which individuals move from the immediate environment of their parents and neighbours and become less aggregated)
- residence within the Project Area and waters surrounding the Project Area (whether the population is sedentary within the these areas, or whether it moves around)
- site fidelity (the tendency to return to a certain site repeatedly over time to undertake a specific activity)
- triggers for displacement that have occurred at other locations.

2.4 Habitat and Populations

A population is an 'occurrence of the one species in a particular area', as defined under the *Environment Protection and Biodiversity Conservation Act 1999* (EPBC Act) (DEWHA 2009). It is particularly difficult to draw boundaries around specific populations in the marine environment because there are few physical boundaries to animal movement and dispersal.

There is also a knowledge gap of marine megafauna populations of north-west WA because very few surveys have been undertaken. Therefore, assumptions have been made regarding populations and available habitat.

In the absence of detailed information, habitat characterisation has been used to determine the potential presence of megafauna populations within the Project Area. A precautionary approach was taken by focussing on the immediate vicinity of the Project Area, rather than the whole of the North West Shelf or into Exmouth Gulf.

The 'Ecosystem characterisation of Australia's North West Shelf' report (CSIRO 2007), produced as part of the North West Shelf Joint Environmental Management Study, was used to determine levels of environmental characterisation to assist in the prediction of 'available habitat' surrounding the Project Area. Attempting to predict availability based on these biomes is not entirely satisfactory, but cannot be helped given habitats have not been adequately mapped at spatial scales relevant to the species described in this report.

With species distributions recorded by commissioned studies and knowledge of habitat characteristics, it was possible to combine the Onslow-Robe and Barrow-Monte Bello level 2A biome units. While dugongs, dolphins and turtles have been characterised as separate biomes, the three species have been found to be distributed throughout these areas, so it was deemed appropriate to group them together. This is highly conservative approach as the species discussed in this report range in WA from Shark Bay (500 km south of the Project area) to the Northern Territory border.

The Onslow-Robe and Barrow-Monte Bello biomes share unsheltered waters of the continental shelf (to 50m deep) and a complex array of habitats – sandy substrates, limestone pavements, submerged reefs, numerous coral reef-fringed islands, patchy ephemeral seagrasses and macroalgae. The cumulative area of this available habitat is 16,974 km^2 (1,697,455 Ha) (Figure 2.1).

Although Exmouth Gulf is also known to support dugongs, dolphins, turtles and sawfish, the habitat characterisation of this biome was too different to group with Onslow-Robe and Barrow-Monte Bello biomes. The resultant 'available habitat' is presented in Figure 2.1 and Figure 2.2 below. Figure 2.2, at a finer scale, presents the creeks and lagoons of the area that are important habitat for juvenile sawfish.

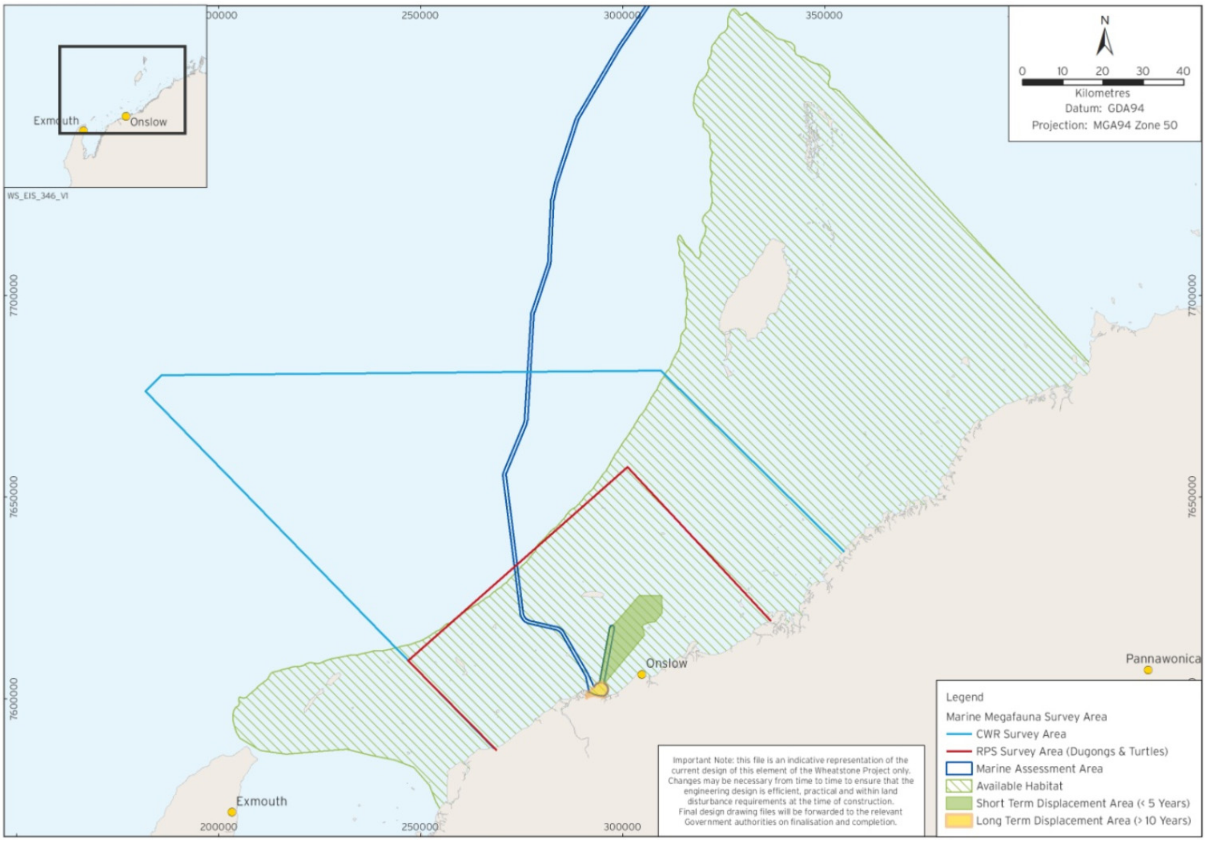

Figure 2.1: Available habitat in the vicinity of the Project Area and potential displacement areas.

(NB: These species are also known to occur outside of these boundaries.)

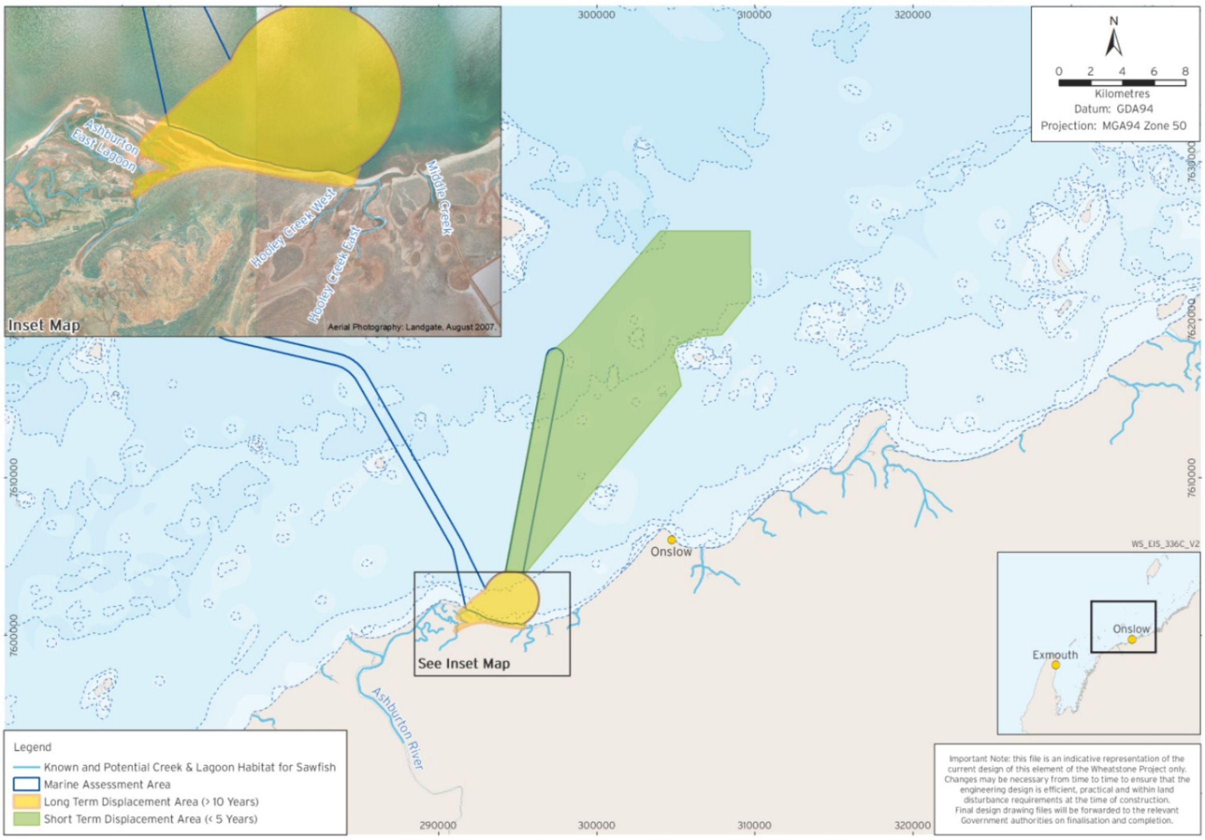

Figure 2.2: Available sawfish habitat in the vicinity of the Project Area and potential displacement areas.

The assessment of habitat criticality is based on the definition of a critical habitat provided by DEWHA (2009). It is an area that is necessary:

- for activities such as foraging, breeding or dispersal
- for the long-term maintenance of the species or ecological community
- to maintain genetic diversity and long-term evolutionary development
- for the reintroduction of populations, or recovery of the species or ecological community (DEWHA 2009).

2.5 Potential Areas of Displacement

Two potential areas of displacement have been identified (Figure 2.1; Figure 2.2; Table 2.2). The definitions of these areas are consistent with those from the EIS/ERMP (Chevron 2010), which are:

- short term – less than five years (construction period plus commissioning)
- long term – more than ten years (operational phase of the Project).

The short-term displacement area is based on dredging operations for the shipping channel, and areas of highest vessel movement associated with construction dredging and spoil placement.

The long-term displacement area is a conglomerate of all components of coastal infrastructure. This area includes the shared Common User Coastal Access (CUCA), which will service the entire 25 MTPA development.

The shipping channel has not been included in the long-term displacement area because, although shipping may cause some individuals to avoid the area, this is not classed as displacement because most of these animals will continue to cross through the area, rather than vacate it completely. It is not anticipated that the channel will present a barrier to movement of the species considered, which are all highly mobile. Further, the construction of the channel will not permanently impact habitat considered critical to any of the species discussed.

Potential displacement caused by increased recreational pressure associated with the project workforce and Onslow population growth has been excluded from this report due to information gaps. The risk assessment of recreational activities in the EIS/ERMP was at a low certainty level because future boat ownership and usage is unknown in the Project Area. However, undoubtedly recreational vessel use will increase with increasing population in the Onslow area due to the Wheatstone Project and others. A recreational code of conduct will be developed to help manage workforce activities that could pose a risk to these species.

Table 2.2: Features of Short-term and Long-term Displacement Areas

Displacement Area Features	Short-term Displacement Area	Long-term Displacement Area
Definition	Displacement for a duration of less than five years.	Displacement for a duration of more than ten years.
Approximate Habitat Coverage* (URS 2010; Figure 2.3) *Habitat coverage does not equal 100% in the 'short-term' displacement area because some habitat types overlap others	80% soft sand / silt sediment 15% low density (15%) macroalgae 15% sand / gravel 10% soft sand sediment 5% low density (5%) seagrass < 5% sand veneered limestone pavement < 5% subtidal coral < 5% subtidal pavement NB: Ashburton Lagoon East and West Hooley Creek have been included within the assessment	60% soft sand / silt sediment 25% soft sand sediment 15% subtidal pavement
Spatial Area	140.98 km^2 (14098 Ha)	12.68 km^2 (1268 Ha)
Minimum Distance Across	1.2 km	1.2 km
Maximum Distance Across	8.9 km	4.8 km
Additive Project Activities Potentially Causing Displacement	♦ Dredging and dredge material placement ♦ Marine construction activities (in the coastal area) ♦ Vessel movements ♦ Acoustic emissions (anthropogenic noise) ♦ Light emissions	♦ Physical presence of marine infrastructure ♦ Routine discharges ♦ Acoustic emissions (anthropogenic noise) ♦ Light emissions

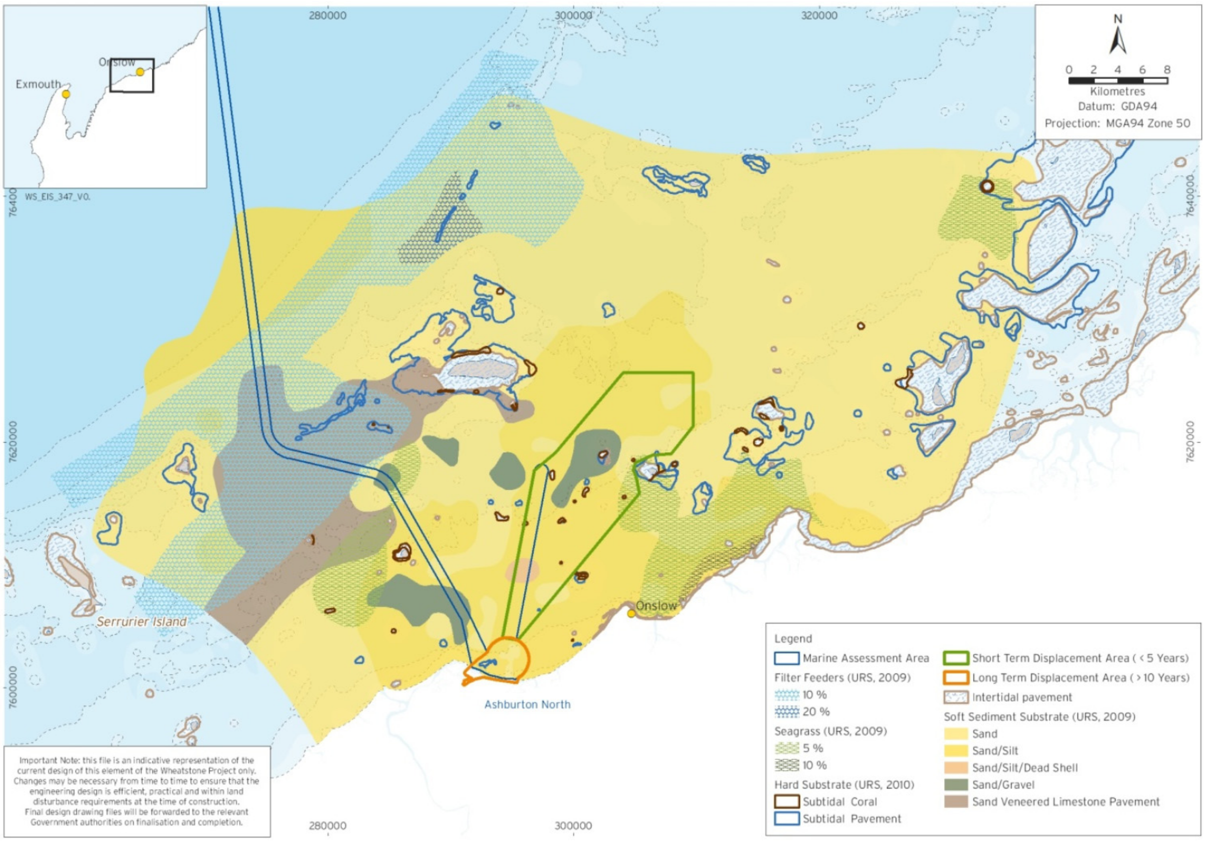

Figure 2.3: Habitats within the potential displacement areas.

2.6 Consequence Definitions

The definitions of potential displacement consequences follow those provided in Chapter 8.4 of the EIS/ERMP for protected marine fauna and are presented in Table 2.1. To uphold the Precautionary Principle during the assessment, in the lack of full certainty of the risks and associated consequences, definitions of consequences that were more severe were selected at times of indecision. Within the consequence definitions, 'local' is defined in this report as being within the potential displacement areas. 'Regional' is defined as being within the 'available habitat' presented in Figure 2.1 and Figure 2.2.

Table 2.3: Consequence Definitions

Consequence	Definition
Catastrophic	Species of protected marine fauna becomes regionally extinct
Massive	Species of protected marine fauna becomes locally extinct
Major	Loss of individuals/taxon leading to reduced viability of population in local area, or Loss of an ecologically significant proportion of the local population (NB: the second cannot happen within five-year period; only relevant to the long-term potential displacement area)
Moderate	Local short-term decrease in abundance, no lasting effects on population
Minor	No detectable decrease in abundance or lasting effects (definition) on population
Negligible	No detectable impacts to communities and populations

3.0 DUGONGS

3.1 Dugongs of the Project Area

Dugongs are present in nearshore waters (mainly in waters less than 10 m deep) of the Wheatstone Project Area at low densities throughout the year. Highest densities were recorded during winter and spring (RPS 2010b; Jenner *et al*. 2010). Over the 12-month survey period, Jenner *et al*. (2010) reported that the highest densities of dugong observations were in the north-east and to the south-west parts of the Project Area. During the dugong aerial survey (RPS 2010b), dugongs were primarily observed in the north-west portion of the Project Area and were often close to the coast or in the lee of reef-fringed islands.

The RPS survey confirmed that the Project Area does not have the same importance for dugongs as Exmouth Gulf or Shark Bay (RPS 2010b). The absolute abundance of dugongs within the Wheatstone Survey Area, which encompassed the Project Area, was less than one-sixth of that in Exmouth Gulf, and density was approximately one-fifth of that in Exmouth Gulf. While a number of calves were recorded in Exmouth Gulf, no calves were recorded within the Wheatstone Survey Area.

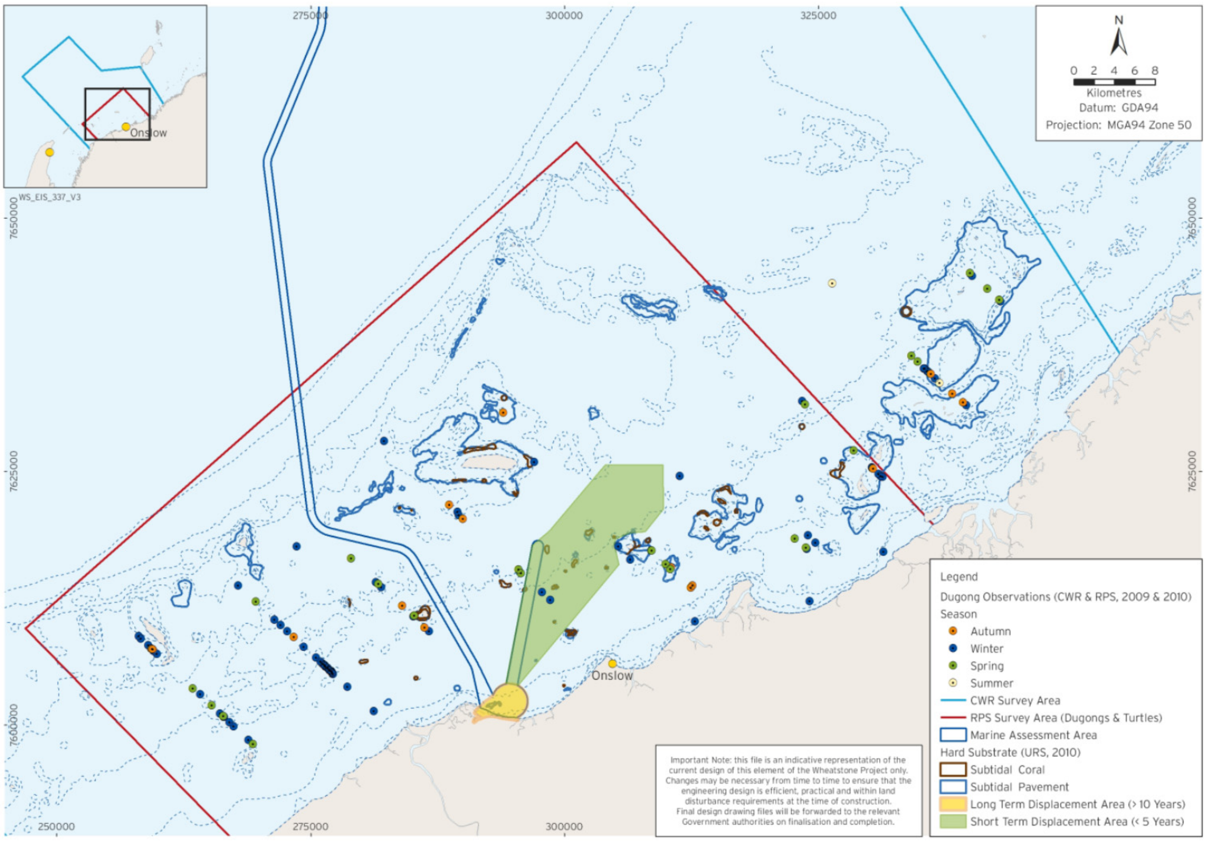

Figure 3.1: Overall seasonal distribution of dugong observations

3.2 Habitat Preference and Home Range

Local and regional dugong movement occurs in response to two main habitat requirements, seagrass availability and possibly by water temperature in the higher latitude areas of their distribution (Marsh *et al*. 2002; Holley 2006; Gales *et al*. 2004; Prince 2001).

In summary:

- Dugongs inhabit tropical coastal waters, favouring water temperatures in the range of 21–27 °C (Sleeman *et al*. 2007).
- Dugongs are strictly marine herbivorous mammals and spend most of their time foraging.
- As seagrass specialists, dugongs prefer tropical seagrass genera that are high in nitrogen content, such as *Halodule* and *Halophila* (Aragones *et al*. 2006; Sheppard *et al*. 2010). *Halophila* in tropical environments is ephemeral; its distribution influenced by seasonal tidal patterns, rainfall, nutrient availability and cyclonic activity (Lanyon 2007; Aragones *et al*. 2006; Sheppard *et al*. 2010; Sheppard *et al.* 2006a).
- Waters of the south-west Pilbara coast are exposed to mixing and do not experience a dramatic reduction in water temperature, remaining at about 21 °C during winter (Figure 9). Therefore, the driver for dugongs to migrate into deeper waters during winter does not occur in the Wheatstone Survey Area.
- Satellite tracking research of 70 dugongs over a periods of 15 to 551 days indicated a large range of individualistic movement behaviours; 37% of animals were relatively sedentary (<15 km) while 63% made large-scale movements (> 15km, up to 560 km) (Sheppard *et al*. 2006). Sheppard *et al*. 2006 suggested such movements represent ranging rather than dispersal.
- Breeding patterns follow an 'isolation by distance' model meaning breeding occurs locally, rather than on a regional level (Tikel 1998 *cited in* Marsh *et al*. 1999).
- Calving occurs in protected shallow waters, such as tidal sandbanks and estuaries (Marsh *et al*. 1999).

3.3 Triggers for Displacement

The key anthropogenic factors that cause dugong displacement are increased vessel movement and habitat damage. Dugongs have difficulty in detecting small recreational vessels as the sound frequency emitted is higher than the animals' hearing threshold. They also surface irregularly for short periods to breathe, rendering them difficult to observe from a fast-moving recreational vessel.

Therefore, dugongs are highly susceptible to vessel strike, which can lead to injury or death. In particular, dugong calves are vulnerable as they are often positioned over their mothers' backs in a predator-avoidance strategy (Anderson 1981). Over time, dugongs may learn to avoid areas of high recreational vessel use and have been reported to move away from areas of such activity entirely (Hodgson and Marsh 2007).

As seagrass is a known food source for dugongs, it is possible dugong abundance may vary due to the reduced availability of seagrass meadows, therefore loss of seagrasses due to dredging may have a significant impact on the foraging potential of seagrasses.

3.4 Assessment of Potential Displacement

It is highly unlikely that a significant proportion of the dugong population would be displaced from either of the potential displacement areas. Only 148 dugongs were recorded within the potential short-term displacement area throughout the 12-month period of CWR surveying, and no dugongs were recorded within the potential long-term displacement area.

While dugongs are found in the Project area, it is not considered critical habitat due to the lack of extensive seagrass habitat, the small number of individuals sighted during the survey and the lack of aggregations, especially in comparison with the dugong results recorded by RPS for Exmouth Gulf (RPS 2010b).

During surveys, dugongs were primarily recorded foraging close to the coast away from the Project Area, or in the lee of islands, areas which will not be affected by project activity. Further, the dominant distribution of dugongs in the north-west portion of the survey area recorded by RPS (2010b) contrasts with the findings of the CWR survey in which dugongs were more often recorded towards the south-west portion of the survey area over the full temporal extent of that survey (Jenner *et al*. 2010) (Appendix 2, Figure 1). This could suggest that there is no strong preference by dugongs for any particular area within the Wheatstone Survey Area over an extended period of time.

While the ‘area of displacement’ does encapsulate parts of Hooley Creek and the Ashburton River Delta, the vast majority of estuarine habitat along the coastline will be unaffected. The Short-term Displacement Area contains a low-density seagrass (5%), therefore dredging is anticipated to cause some damage to seagrasses, however, potential damage to seagrass has been predicted to be temporary, and on a seasonal basis only (URS 2010).

As migratory animals, dugongs are likely to move through the area. However, dugongs are mobile, they have been recorded migrating through waters over 500 m deep (Anderson 1981), and have been observed swimming in waters behind Thevenard Island (RPS 2010b). Due to this, barriers to migration dugongs resulting from the Wheatstone Project are not predicted as they are expected to circumnavigate any obstructions nearshore areas.

Although some animals may be temporarily displaced during the construction phase, this is not predicted to affect the local population.

4.0 COASTAL DOLPHINS

4.1 Coastal Dolphins of the Project Area

There is low level of scientific information regarding small cetacean populations of the Pilbara (Allen and Loneragan 2010). Coastal dolphins have been documented in the Wheatstone Project Area in varying abundance levels, with group sizes varying from seven to over 200 dolphins during the 12-month survey undertaken by CWR (Jenner *et al*. 2010). While dolphins could not be identified to species level, three species are predicted to occur in the Project Area: common bottlenose dolphins (*Tursiops truncates*), Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) and Indo-Pacific humpback dolphins (*Sousa chinensis*) (C. Jenner [Centre for Whale Research] 2009, pers. comm).

While the majority of dolphins were sighted close to shore (water depths less than 50 m), dolphins were also seen in deeper waters offshore, usually in large pods (> 100 animals) (Jenner *et al*. 2010). Interestingly, Figure 4.1 suggests that, in summer, proportionately more dolphin observations were recorded in offshore waters than near-shore. Other marine surveys in the Project Area documented anecdotal dolphin observations with similar distribution and abundance patterns. Smaller dolphin groups (1-20 animals) were seen less than 5 km from shore (RPS 2010).

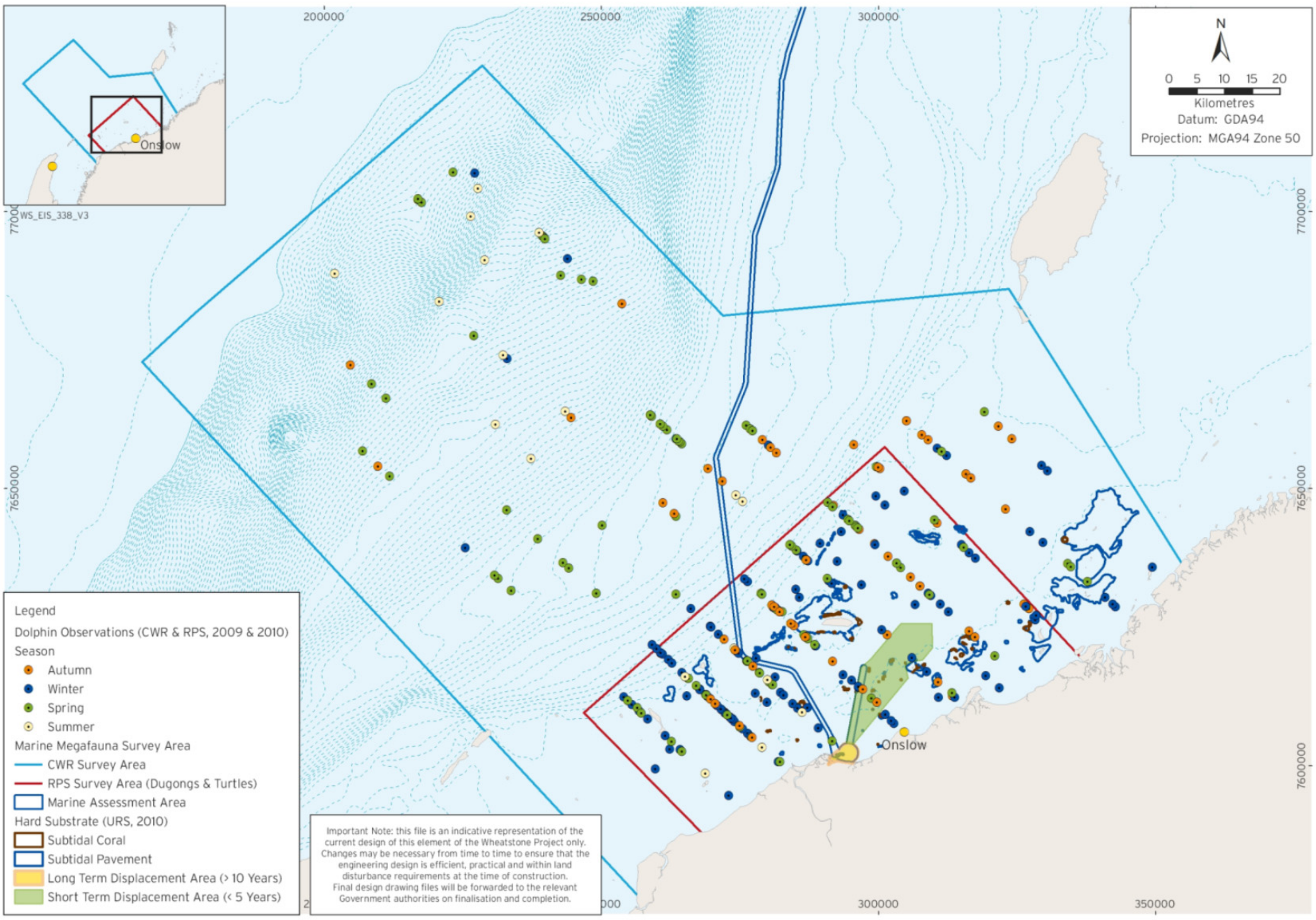

Figure 4.1: Overall seasonal distribution of dolphin observations

4.2 Habitat Preference and Home Ranges

There is no available information regarding habitat preference and home ranges for the three dolphin species in the Wheatstone Project Area. Dispersal patterns in dolphins are very difficult to document because these animals are long-lived (c. 45 years) and they may move widely (Möller and Beheregaray 2006). A general summary based of habitat preference and home ranges (from other locations) for each species is presented below.

Common bottlenose dolphins

- Habitats include several types of substrate, comprising of mud, sand, seagrasses, mangroves and reefs (Barros and Wells 1998; Hanson and Defran 1993).
- Known from coastal waters all over the world, but also inhabit offshore areas.
- Populations demonstrate home range diversity - coastal populations demonstrate year-round residency and permanent, local home ranges, forming small groups (Wells and Scott 1999). Offshore and pelagic with long-distance movements on a daily basis and form large groups (Wells *et al*. 1999).

Indo-Pacific bottlenose dolphins

- Primary habitat includes shallow coastal, estuarine, and occasionally riverine habitats.
- Documented to have limited home ranges within coastal, shallow waters, with high level of residency and no long-distance movements (Corkeron and Martin, 2004).
- Prey availability and predation risk are primary factors for this species' habitat selection (Reeves *et al*. 2002).

Indo-Pacific humpback dolphins

- Habitat includes coastal lagoons, enclosed bays with mangrove forests and seagrass beds through to open coastal waters with rock and/or coral reefs.
- Occur both close to the coast (less than 20 m from shore) and offshore in shallow water (55 m from shore) (Corkeron *et al*. 1997, Jefferson 2000). Individuals repeatedly returned to the same coastal areas.
- Adults appear to prefer shallow waters (2-5 m), and are often found in dredged channels (Parra *et al*. 2006a).
- Research in Queensland demonstrated a preference for coastal and estuarine areas that were commonly associated with freshwater input (Parra *et al.* 2006b).
- Parra *et al*'s (2006) study also suggested that these dolphins have small home ranges, within 10 km of their mean centre area (standard distance deviation) while they inhabit coastal areas on a seasonal basis.

4.3 Triggers for Displacement

Dolphins are known to respond to several forms of anthropogenic disturbance, including habitat degradation, bycatch in fisheries, and pollution (Reeves *et al*. 2002). The greatest recognised threat to Indo-Pacific humpback dolphins is habitat destruction and degradation, including noise pollution and harassment (Bannister *et al*. 1996). Boat and vessel avoidance has been documented by changes in behaviour, residency and communication (Janik and Thompson 1996; Nowacek *et al*. 2001; Hastie *et al*. 2003; Buckstaff 2004; Mattson *et al*. 2005; Lusseau 2006).

Changes in behaviour and distribution (including displacement) have been observed from eco-tourism industry activities (watching, swimming, and provisional feeding), the most well-documented evidence being from Shark Bay, WA (Bejder *et al*. 2006).

4.4 Assessment of Potential Displacement

It is highly unlikely that a significant proportion of any of the dolphin populations would be displaced from either of the potential displacement areas. While dolphins have been recorded within both potential short-term and long-term displacement areas, they have also been recorded regularly within the overall survey area.

While it is acknowledged that there is a lack of information on species composition, it is known that these animals range farther than the displacement areas. It is therefore not believed that coastal dolphins are restricted to the displacement areas, or the small areas of benthic primary producer habitats that are well represented within the area of available habitat. Nor are critical habitat features confined to the displacement areas.

Of the coastal dolphin species that are likely to be present in the area, it is the Indo-Pacific humpback dolphin that is considered to be most susceptible to displacement effects because of its smaller home range. However, it is unlikely that they are restricted to either of the potential displacement areas.

Coastal dolphin species are likely to avoid the potential short-term displacement area during levels of high noise or vessel activities, however some species such as the bottlenose dolphin are attracted to vessels. Due to the lack of critical habitat in that area and the presence of plentiful suitable habitat within the wider area, only short-term displacement to nearby habitats is anticipated. It is likely that dolphins will return to the short-term displacement area at completion of the Project’s construction phase.

Therefore, no predicted long-term effects on population size or distribution for the coastal dolphin species are anticipated. While shipping will occur in this area during the operational phase, it is considered that individuals will continue to cross the shipping channel due to their highly mobile and gregarious nature. Measures for managing potential vessel strike are described within the Marine Fauna Management Plan.

5.0 MARINE TURTLES

5.1 Marine Turtles of the Project Area

Green turtles and flatback turtles are known to occur in the Wheatstone Project Area during sensitive life-history phases (mating, nesting and inter-nesting), and may be present in the area year-round (RPS 2010c). Key conclusions of the marine turtle surveys presented in the Wheatstone Project EIS/ERMP Marine Turtle Technical Appendix (RPS 2010a) are as follows:

Nesting

- Ashburton North is unsuitable for nesting.
- The closest nesting beach to the Project Area is approximately 4 km to the west.
- Low-density flatback turtle nesting occurs at the Ashburton River Delta.
- Green and flatback turtles nest on islands adjacent to the Project Area.
- Flatbacks nest on islands closer to mainland; greens on islands further offshore.

Inter-nesting

- Satellite tracking showed that there were no specific areas of greater or lower turtle utilisation.
- Turtles moved through the marine footprint regularly, but spent little time there.

Hatching

- Preliminary surveys by Pendoley Environmental have shown that hatching success is low on the mainland but high on the islands.

Foraging

- Within the Project Area, densities of foraging turtles are greatest near reef habitats and islands.

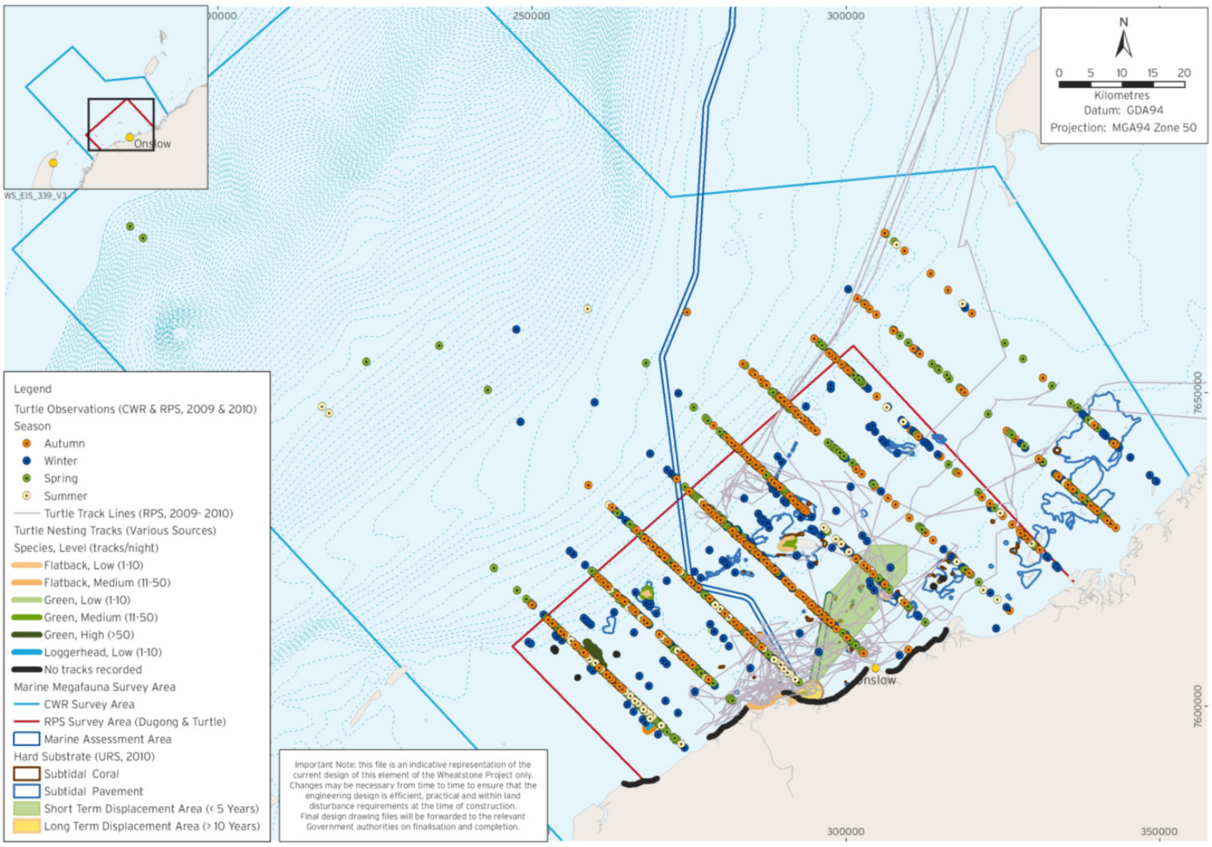

Figure 5.1: Distribution of turtle observations, movements of satellite tracked turtles, and location of nesting and non-nesting beaches

5.2 Habitat Preferences and Home Ranges

In general, the coastal areas (<100 km offshore) of the Pilbara and Kimberley regions comprise a northern migratory pathway for the majority of post-nesting turtles in WA. Different turtle species vary in their use of available resources, including habitat type. The preferred habitat for green and flatback turtles at life stages relevant to the Project are as follows.

5.2.1 Green turtles

- Adult green turtles can migrate thousands of kilometres between foraging areas and breeding areas (Miller 1997; RPS 2009). The average migration distance of green turtles nesting at the Great Barrier Reef is approximately 400 km.
- In their foraging habitats, green turtles are sedentary. Whiting and Miller (1998) recorded short-term movements of 4-25 km and foraging ranges 84-850 ha in Repulse Bay, central Queensland.
- In northern Australia, during the inter-nesting period, green turtles appear to remain within shallow, inshore waters (<20 m deep) (Hays *et al*. 2001; Pendoley 2005; Waayers *et al*. in press).

5.2.2 Flatback turtles

- Flatback turtles make long reproductive migrations (Pendoley Environmental 2006; RPS 2009).

- Satellite tracking of flatback turtles nesting at Barrow Island suggests that these turtles migrate along the northern WA coast from the Pilbara region into the Kimberley region at the conclusion of the nesting season (K. Pendoley [Pendoley Environmental Pty Ltd] 2007, pers. comm). Some individuals travelled north-east along the WA coastline to the Kimberley region (green and hawksbill turtles included); other individuals tracked from Ashburton Island remained within the Pilbara region at the conclusion of the nesting season, migrating between 73- 291 km from Ashburton Island.
- The inter-nesting habitat for flatback turtles nesting at Ashburton Island comprised approximately 1,500 km^2 covering the area between Baresand Point, Bessieres Island, Airlie Island and Coolgra Point. The straight line distances that the flatback turtles travelled from Ashburton Island during the inter-nesting period vary between 11-35 km.

5.3 Triggers for Displacement

Key anthropogenic factors that may potentially cause turtle displacement include noise, light, habitat removal and vessel movement.

Project-specific activities that may cause displacement in turtles include acoustic impacts from piling work in nearshore areas during construction, and vessel strikes when large numbers of fast-moving vessels are present in the area.

5.4 Assessment of Potential Displacement

Neither of the potential displacement areas represent critical habitat for flatback or green turtles. A very small portion of the overall turtles recorded during surveys were found to be utilising the potential area of displacement. However, nesting occurs mainly on the islands and densities of foraging turtles are greatest near reef habitats and islands. While these islands are considered critical habitat, it is not anticipate that turtles will be displaced from these areas.

Turtles are highly mobile animals and will avoid the area and, instead, target other areas for resource needs. In the unlikely event of displacement, a local short-term decrease in the abundance of the local turtle population may occur. However, no detectable decrease or lasting effects on the population of green and flatback turtles in the region are anticipated.

The application of appropriate management measures will ensure that areas of critical habitat are protected.

If turtles are displaced from the larger short-term displacement area during the Project's construction phase, it is likely that they will return at completion of construction-related activities. While shipping will occur in this area during the operational phase, it is considered that individuals will not only continue to cross the shipping channel but will also forage in the channel, which they have been found to do at other locations. Measures for managing potential turtle interaction or disturbance are described within the Marine Fauna Management Plan.

6.0 POTENTIAL SAWFISH DISPLACEMENT

6.1 Sawfish of the Project Area

The green sawfish has been observed near the Project Area in the north-eastern lagoon of the Ashburton Delta and in Hooley Creek in late 2009 (F Well [URS] 2009, pers comm). In November 2010, six to eight sawfish of varying sizes were observed during a fish netting survey. Three were identified as green sawfish, entering the sampling area on rising tide, and ranged from under 1.2-2 m in length (F Well [URS] 2009, pers comm).

Chevron plans to undertake a dedicated sawfish survey in 2011 to determine species occurrence, population demographics, home ranges and habitat utilisation.

6.2 Habitat Preference and Home Ranges

Green sawfish inhabit marine waters, estuaries, river mouths, embankments and waters along sandy and muddy beaches (Peverell *et al*. 2004; Stevens *et al*. 2005; Thorburn *et al*. 2004), and have been recorded in very shallow water (<1 m) to water depths of over 70 m (Stevens *et al*. 2005). Potential sawfish habitat of the southern Pilbara, and specifically within the vicinity of the Project Area, is presented in Figure 2.2.

Juvenile sawfish (up to nine years) prefer inshore marine coastal areas, as well as estuaries, river mouths, creeks and bays at slightly reduced salinities, but do not venture into freshwater (DSEWPC 2010a).

Sawfish typically return to inshore coastal waters to breed and pup on a seasonal basis. Evidence suggests green sawfish are most likely to breed and pup in January, during the wet season (DSEWPC 2010a and Department of Fisheries 2010).

The level of an animal's site fidelity, and its natural home range, contribute to its susceptibility to effects caused by displacement. While Stevens *et al*. (2008) reported that sawfish appear to occupy restricted areas, moving only small distances, a short-term habitat usage survey (Peverell and Pillans 2004) of a 3.5 m female green sawfish found the following:

- the animal moved 28.7 km at an average speed of 28.4 m/min
- movement was confined to within 200 m of the shoreline
- the animal remained in very shallow water (average depth 0.69 m)
- a diurnal shift in preferred depth from day (0.84 m) to night (0.48 m)
- movement parallel to coastline supported by studies on small tooth sawfish in North America (Simpfendorfer 2000)
- the animal moved continuously throughout the tracking exercise and did not rest on the bottom.

The survey, which will be undertaken by Murdoch University, will further define home range of sawfish in the Wheatstone Project Area.

6.3 Triggers for Displacement

The greatest threat to sawfish is habitat destruction and pollution, followed by overfishing (Stevens *et al*. 2004).

Project specific factors that may cause displacement include:

- degradation of river systems as a result of project construction
- habitat loss and eutrophication due to construction and discharges into estuarine and riverine environments
- noise and vibration due to construction activities, such as piling.

6.4 Assessment of Potential Displacement

There have been very few studies conducted on sawfish distributions, habitat requirements, home ranges and migration, rendering the assessment of potential sawfish displacement difficult. However, critical sawfish habitat is not restricted to the potential displacement areas, and the potential impacts identified are not anticipated to disrupt the sawfish breeding cycle, especially with the application of proposed management measures.

Further, green sawfish are a large species and capable of long distance movements along the coast (Stevens *et al*. 2005). Therefore, should impacts from construction activities such as piling noise induce avoidance behaviours, sawfish are likely to mobilise to other similar habitat nearby, such as creeks, which are abundant along the nearby coastline. Thus, any displacement may result in a short-term decrease in abundance; however, it is likely to be local and temporary, without long-term population level effects.

7.0 DISPLACEMENT ASSESSMENT RESULT

The best available scientific information has been used for this assessment. Where literature is not available from the southern Pilbara, information from other locations has been cited. Assessment certainty is presented in the results. Consistent with the risk assessments contained within the EIS/ERMP, these are confidence levels ranging through High, Reasonable and Low, which are relative to each other and based on the information available.

A Reasonable level of certainty has been recorded for the assessment of potential displacement associated with the shipping channel within the 'short-term' assessment area (Section 2.5).

The certainty in assessments was strengthened by the small areas of displacement in comparison to the available habitat in the wider area. For sawfish, it is anticipated that, as a worst case scenario, West Hooley Creek and Ashburton Delta East could be affected by project activities, which is a small proportion of the 97 creeks within the overall area of available habitat.

At 16,974 km^2 the available habitat is more than 100 times larger than the short-term displacement area and more than 1000 times larger than the long-term displacement area. Further, the longest distances across the displacement areas are 8.9 km (short-term displacement area) and 4.8 km (long-term displacement area), which are shorter than the home ranges recorded for any of these animals at other locations.

The assessments for dugongs and turtles were ultimately based on a High certainty level because dedicated surveys have been undertaken for these animals. It is possible that displacement from the larger short-term area of potential displacement could lead to a local short-term decrease in abundance, but without any lasting effects on dugong or turtle populations. Should these animals become displaced from the smaller long-term area of potential displacement, it is not anticipated that there would be any detectable decrease in abundance or any lasting population level effects.

Dolphin assessments were generally based on a Reasonable level of confidence. It is acknowledged that some data gaps exist, with species presence being inferred from anecdotal information provided by the Centre for Whale Research obtained during other vessel-based surveys in the area.

However, sufficient information to undertake the assessment was available by combining data collected from Wheatstone surveys designed for other fauna and information from other locations.

Of the coastal dolphin species that are likely to be present in the area, it is the Indo-Pacific humpback dolphin that is considered to be most susceptible to displacement effects due to its smaller home range. However, it is unlikely that they are restricted to either of the potential displacement areas. Due to the high mobility of these animals and large home ranges, it is anticipated that displacement is unlikely to lead to any detectable decrease in abundance or any lasting population level effects.

The assessment of potential sawfish displacement was of the Low certainty level because the level of site fidelity for sawfish pups is unknown. It is anticipated that displacement of sawfish from either potential displacement area would not lead to any consequence greater than a local short-term decrease in abundance because of the vast amount of available habitat in the area, and the very small proportion of habitat that could be affected. It is expected that the results of targeted sawfish surveys will verify these assumptions.

Table 7.1: Assessment of Potential Consequences of Displacement on Dugongs, Coastal Dolphins, Turtles and Sawfish, Incorporating Confidence Levels (High, Reasonable or Low, based on available information)

Assessment Criteria	Duration	Dugong	Coastal Dolphins	Turtles	Sawfish*	Reference
Is it likely that a significant proportion of the population could be displaced?	Short-term	No: High	No: Reasonable	No: High	No: Reasonable	Sections 3.1; 4.1; 5.1; 6.1 (Survey findings)
	Long-term	No: High	No: Reasonable	No: High	No: Reasonable	
Is it likely that the 'displacement area' represents critical habitat?	Short-term	No: High	No: Reasonable	No: High	No: Low	Sections 2.4; 3.4; 4.4; 5.4; 6.4
	Long-term	No: High	No: Reasonable	No: High	No: Low	
Is it likely that displacement will occur frequently?	Short-term	No: Reasonable	No: Reasonable	No: Reasonable	No: Reasonable	Section 2.5
	Long-term	No: High	No: High	No: High	No: High	
Is it likely that animals will be displaced for a significant duration?	Short-term	No: Reasonable	No: Reasonable	No: Reasonable	No: Reasonable	Section 2.5
	Long-term	Yes: High	Yes: High	Yes: High	Yes: High	
Is it likely that animals will be able to move into a suitable 'substitute' habitat nearby?	Short-term	Yes: High	Yes: High	Yes: High	Yes: Low	Sections 2.4; 3.4; 4.4; 5.4; 6.4
	Long-term	Yes: High	Yes: High	Yes: High	Yes: Low	
Is it likely that animals will be able to return to the 'displacement area' following	Short-term	Yes: Low	Yes: Reasonable;	Yes: High	Yes: Low	

Assessment Criteria	Duration	Dugong	Coastal Dolphins	Turtles	Sawfish*	Reference
cessation of project activities?	Long-term	Yes: Reasonable	Yes: Reasonable	Yes: Reasonable	Yes: Low	Sections 2.5; 3.4; 4.4; 5.4; 6.4
Likely Consequence	Short-term	Moderate**: High	Minor: Reasonable	Moderate**: High	Moderate: Low	Summary of each of this table's columns
	Long-term	Minor: High	Minor: Reasonable	Minor: High	Moderate: Low	

*Pups are the most vulnerable age class

**The overall consequence for dugongs and turtles is deemed to be potentially higher from short-term displacement because this would be from a larger area than the long-term displacement area, but it is anticipated there still would be no lasting population level effects.

8.0 CONCLUSION

Of the megafauna species considered, those at least risk of potential displacement are dugongs, marine turtles and bottlenose dolphins. Those at highest risk are Indo-Pacific humpback dolphins and green sawfish, because of smaller home ranges and some lack of scientific information from the Project Area.

Should displacement occur, it is not anticipated there would be any lasting effects on populations of any of these animals. It is assumed that the megafauna species considered are not restricted to the potential displacement areas because:

- megafauna have been widely recorded throughout the wider survey areas at densities equal to or higher than those in the potential displacement areas
- megafauna have not been recorded as aggregating within the potential displacement areas during any of the surveys
- megafauna are highly mobile and likely to have home ranges of greater distances than the span of the potential displacement areas
- habitat types within the potential displacement areas are well represented in region
- it is assumed that the potential displacement areas do not provide critical habitat
- the area of the potential displacement areas is proportionately insignificant when compared to the surrounding available habitat (the short-term displacement area being more than 100 times smaller and the long-term displacement area more than 1000 times smaller).

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Appendix FN

Revised BPPH Loss Assessment Report

The total area of living coral cover mapped for the Project area has increased slightly with the addition of coral areas including Direction Island, Tortoise Island and Brewis Reef. The revised additions increase live coral cover (>10%) in the nearshore area (ECU1) east of the proposed navigation channel from 205 ha to 263.2 ha, and west of channel from 132 ha to 153.2 ha.

A revised coral BPPH loss assessment arising from dredging works has been produced by overlaying the new LAU boundaries on the dredge plume modelling presented in the Draft EIS/ERMP and consideration of Draft EAG 7 for a Zone of High Impact (ZoHI). The predicted loss in the ZoHI is 23.4 ha representing 9.6% of corals in LAU 1A; and 8.6 ha representing 5.9% of corals in LAU 1B.

In accordance with EAG 7, a Zone of Moderate Impact (ZoMI) is proposed that includes Paroo, Hastings and Gorgon Shoals average net mortality of hard corals predicted to be less than 30% in the ZoMI. Coral losses on these shoals is expected to be temporary given both their distance from the channel and the fast growing and colonising nature of the coral species which dominate the shoals.

A Trunkline alignment in waters to the west of Thevenard Island is being investigated as an alternative to the base case alignment presented in the EIS/ERMP. The predicted loss of filter feeder habitat as a result of this revision is reduced from the base case. No coral loss is predicted.

Report

Wheatstone Project Update

Revised BPPH Loss Assessment

13 JANUARY 2011

Prepared for

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Introduction

This document updates the BPPH Loss Assessment for dredging and trunkline installation presented in the Wheatstone Project (the Project) Draft Environmental Impact Statement/Environmental Review and Management Programme (Draft EIS/ERMP; Chevron Australia Pty Ltd (Chevron), 2010) and in detailed in URS (2010a). Revisions to that assessment have arisen as a result of:

- Additional diving field surveys undertaken since the Draft EIS/ERMP (Chevron, 2010) was released for public review.
- Re-analysis of existing Project survey data.
- Selection of monitoring sites for the Draft Dredging and Spoil Disposal Management Plan (Draft DSDMP)
- Response to submissions received during the public review of the Draft EIS/ERMP (Chevron, 2010)
- Potential realignment of the trunkline in the area to the west of Thevenard Island
- Consideration of the recent (October 2010) Draft Environmental Assessment Guidance (EAG 7) on Dredging Proposals in Western Australia, and
- Responses to comments received from the Office of the Environmental Protection Agency (OEPA) on the 24th of December, 2010.

The outcome of the above is that:

a) The total area of living coral cover mapped for the Project area has increased slightly with the addition of coral areas from Direction Island, Tortoise Island and Brewis Reef. In addition, a review of existing habitat data resulted in the inclusion of additional live coral areas in the vicinity of Herald Reef to the east of the navigation channel and on Inner NW Patch to the west of the channel (and west of Ashburton Island).
b) Loss estimates for coral shoals and macroalgae beds close to the channel have been revised upward.
c) A revised map of Loss Assessment Unit (LAU) boundaries and applicable Cumulative Loss Guidelines (CLGs) has been produced in response to comments regarding the intent of Environmental Assessment Guidance Statement (EAG) 3 received from the OEPA in November 2010, and subsequently refined in response to comments received in December 2010.
d) A revised coral and macroalgae BPPH loss assessment arising from dredging works has been produced by overlaying the new LAU boundaries on the dredge plume modelling presented in the Draft EIS/ERMP (Chevron, 2010) and consideration of Draft EAG 7.
e) A revised Trunkline alignment in waters to the west of Thevenard Island is being investigated as an alternative to the base case alignment presented in the Draft EIS/ERMP (Chevron, 2010).
f) The BPPH loss assessment arising from Trunkline installation has also been revised to incorporate the new impact assessment and the revised applicable CLG.

1.1 Outline of Document

This document is divided into the following sections:

- Coral Area and Impact Predictions – updating the areas of live coral cover in the Project area as a result of additional survey work and data review; and revision of the zones and area of potential coral impact in alignment with EAG 7.
- Revision of Loss Assessment Units and Applicable Cumulative Loss Guidelines – Coral loss revisions in relation to applicable CLGs; presentation of alternative LAUs proposed by the Environmental Protection Agency (EPA) and corresponding loss assessment with applicable CLGs;

1 Introduction

justification of predicted potential coral loss including assessment of connectivity of reef assemblages and community structure in Project area.

- Potential Trunkline realignment – Presenting an alternative trunkline alignment with predicted BPPH loss.
- Loss Assessment from Synchronous Dredging and Pipeline installation – Assessment of controlling factors and sensitive receptors in synchronous dredging and pipeline installation; and presentation of associated sediment transport modelling arising from a worst case assessment of dredging impacts.

Coral Area and Predicted Potential Impacts

2.1 Additional Coral Area

Figure 2-1 presents an update of sites currently considered to support >10% live coral cover (in red outline) in the Project area including additional sites at Direction Island, Brewis Reef, Tortoise Island and in the vicinity of Herald Reef and Inner NW Patch. This coral habitat map update has resulted from an additional recent field survey and a review of existing survey data.

Table 2-1 and Table 2-2 presents the live coral area calculated by ARCVIEW GIS for each reef and shoal in the original LAU 1A and LAU 1B presented in the Draft EIS/ERMP (Figure 2-1; Chevron, 2010). The recent additions are indicated in bold italics. The revised additions increase LAU 1A from 205 ha to 263.2 ha, and LAU 1B from 132 ha to 153.2 ha. This table now forms the basis for live coral area loss calculations in ECU 1.

2.2 Revised Coral Impact Prediction

2.2.1 Zone of High Impact (ZoHI)

The ZoHI is described in the EAG 7 as 'the area immediately about the proposed dredging and dumping areas where indirect impacts are predicted to be severe and irreversible. This zone defines the area where mortality of, and long term (i.e. months to years) serious damage to, biota and their habitats would be predicted' (EPA, 2010). The ZoHI is considered equivalent to the Zone of Total Mortality used in the Draft EIS/ERMP (Chevron, 2010).

Further consideration of the predicted losses in this near-field region has resulted in the development of a more conservative prediction which includes consideration of:

- the predicted loss from dredge modelling
- the proximity of these reef areas to the large scale proposed dredging operations (Figure 2-2)
- inherent uncertainty of mishaps occurring in dredging operations in such close proximity to these sites that cannot be accommodated in modelling
- inherent uncertainty arising from ongoing chronic turbidity associated with regular ship passage along the navigation channel including that of a number of additional Proponents for the Ashburton Strategic Industrial Area
- occasional maintenance dredging requirements
- the need to comply with non-exceedance of predicted loss in accordance with guidance provided in Draft EAG 7 (EPA, 2010).

Given these considerations the Proponent is now seeking approval to include the shoals listed in Table 2-3 within a Zone of High Impact (ZoHI) as defined in Draft EAG 7 and presented in revised Figure 2-2.

2.2.2 Zone of Moderate Impact (ZoMI)

In accordance with guidance in Draft EAG 7, the Proponent proposes a Zone of Moderate Impact (ZoMI) immediately adjacent to the ZoHI for the purpose of managing the dredging works via monitoring of coral condition on shoals located within this zone.

The ZoMI is described in the EAG 7 as the zone where 'sub-lethal effects on key benthic biota would be predicted, but there should be no long term damage to, or modification of, the benthic organisms, the communities they form or the substrates on which they grow'. Such impact or loss is defined in

EAG 3 (EPA, 2009) as irreversible within a five year period. Following this definition, no permanent loss of BPPH as a result of dredging or dredge material placement during the proposed Project has been predicted within the ZoMI. Consequently, the Outcome-Based Condition developed for the ZoMI is 'No permanent impacts to BPPH that are attributable to dredging of the MOF and channel and placement of dredged material'. For the purposes of monitoring and management, this Outcome-Based Condition has been represented as 'no greater than 30% average net mortality of hard corals'.

The coral shoals proposed for the ZoMI include Paroo (to the west of Saladin), and Hastings and Gorgon to the East of the Channel. Therefore the Proponent is now also seeking approval for up to 30% reversible loss of corals from the shoals within the ZoMI. It is predicted that any coral losses to these shoals will be temporary given both their distance from the channel and the fast growing and colonising nature of the coral species which dominate the shoals.

Figure 2-2 presents the proposed ZoHI and ZoMI monitoring sites for coral shoals discussed above, plus other indicative monitoring sites proposed for the updated DSDMP.

Extensive evidence of coral recovery following mass mortality at levels up to and exceeding 50% loss has been documented over a variety of areas (notably in the Persian Gulf: Burt *et al*. 2008 and the Great Barrier Reef: Diaz-Pulido *et al*. 2009). These studies found that the taxa most likely to be affected by bleaching events were also those fastest to recover. For example, recovery in *Acropora* species in the Persian Gulf was relatively rapid following the widespread bleaching events of the late 1990's (Burt *et al*. 2008), despite the fact that *Acropora* cover was virtually eliminated within one $38km^2$ study area (Riegl 1999). On the Great Barrier Reef, *Acropora* recovered extremely rapidly following mass mortality, reaching pre-bleaching levels within 12 to 14 months. Within 6 months a 100 to 200% increase in cover of *Acropora* was recorded (Burt *et al* 2008) at the affected sites. Recovery was not a result of new recruitment, but a rapid regrowth/regeneration of surviving coral tissue. There is also evidence that massive habitat building coral genera such as *Porites* are capable of rapid recovery following mortality due to sedimentation resulting from dredging operations. Clarke *et al*. (1993) studied an intertidal reef flat in Phuket, Thailand where they reported as much as a 30 per cent reduction in the cover of coral communities (dominated by *Porites lutea*) one year after the start of dredging with subsequent recovery of coral cover values and diversity indices to former levels around 22 months after dredging began. The dominant hard coral genera within the ZoMI include *Acropora* and *Montipora* (MScience, 2009), which are relatively fast growing, highly fecund groups.

The Outcome Based Condition for the ZoMI proposes that:

- < 30% partial mortality of hard corals in the ZoMI
- Inclusion of threshold management triggers (10% and 20%) partial mortality of hard corals
- Exceedance of threshold management triggers leads to increased levels of monitoring and management actions.

2.2.3 Zone of Influence (ZoI)

EAG 7 describes the Zone of Influence as the area where at some time during the proposed dredging and material placement activities small changes in sediment-related environmental quality which are outside natural ranges might be expected however the intensity and duration is such that no detectible effects on benthic biota or their habitats should be experienced. This is an equivalent definition to that used in the Draft EIS/ERMP (Chevron, 2010).

2 Coral Area and Predicted Potential Impacts

Table 2-1 Total Area of >10% live coral cover to East of Channel in ECU1.

Reef/Shoal name	Acronym	Area in ha
End of Channel	EOCS	23.4
Hastings	H	14.1
NW Ward	NWW	2.5
West of Beadon Point	WOBP	2.5
Ward Reef	WR	30.0
SW of Gorgon Patch	SWGP	2.5
Gorgon Patch	GP	20.0
Weeks Shoal	WS	22.3
NE Koolinda Patch (SW of Direction Island)	NEKP	4.7
NW of Direction Island	NWDS	3.2
Subtotal 1		**125.2**
SW Twin Island (north side)	SWTI	9.2
NE Twin Island (NW side –boomerang shape)	NETI	23.5
NE Twin Island (South side)	NETIS	31.8
Nares Rock	NR	19.4
Subtotal 2		**83.9 (1+2=209)**
*Herald Reef (south side)**	*HRS*	*16.9*
*Herald Reef (North side)**	*HRN*	*27.2*
*Small shoal south of Herald Reef and NE of NE Twin island**	*NENETI*	*6.5*
*Direction Island NE reef**	*NEDI*	*3.5ha*
Subtotal 3		**54.1**
NEW TOTAL		**263.2**

** = revised (Oct 2010) addition*

Table 2-2 Total Area of >10% live coral cover to West of Channel in ECU 1.

Reef/Shoal name	Acronym	Area in ha
Saladin	SS	8.6
Paroo	PS	38.3
Ashburton	AR	76.3
Roller	RS	8.4
Subtotal		**131.6 (132)**
*Tortoise Island**	*TI*	*1.3 ha*
*Inner NW Patch**	*INWP*	*20.3 ha*
NEW TOTAL		**153.2**

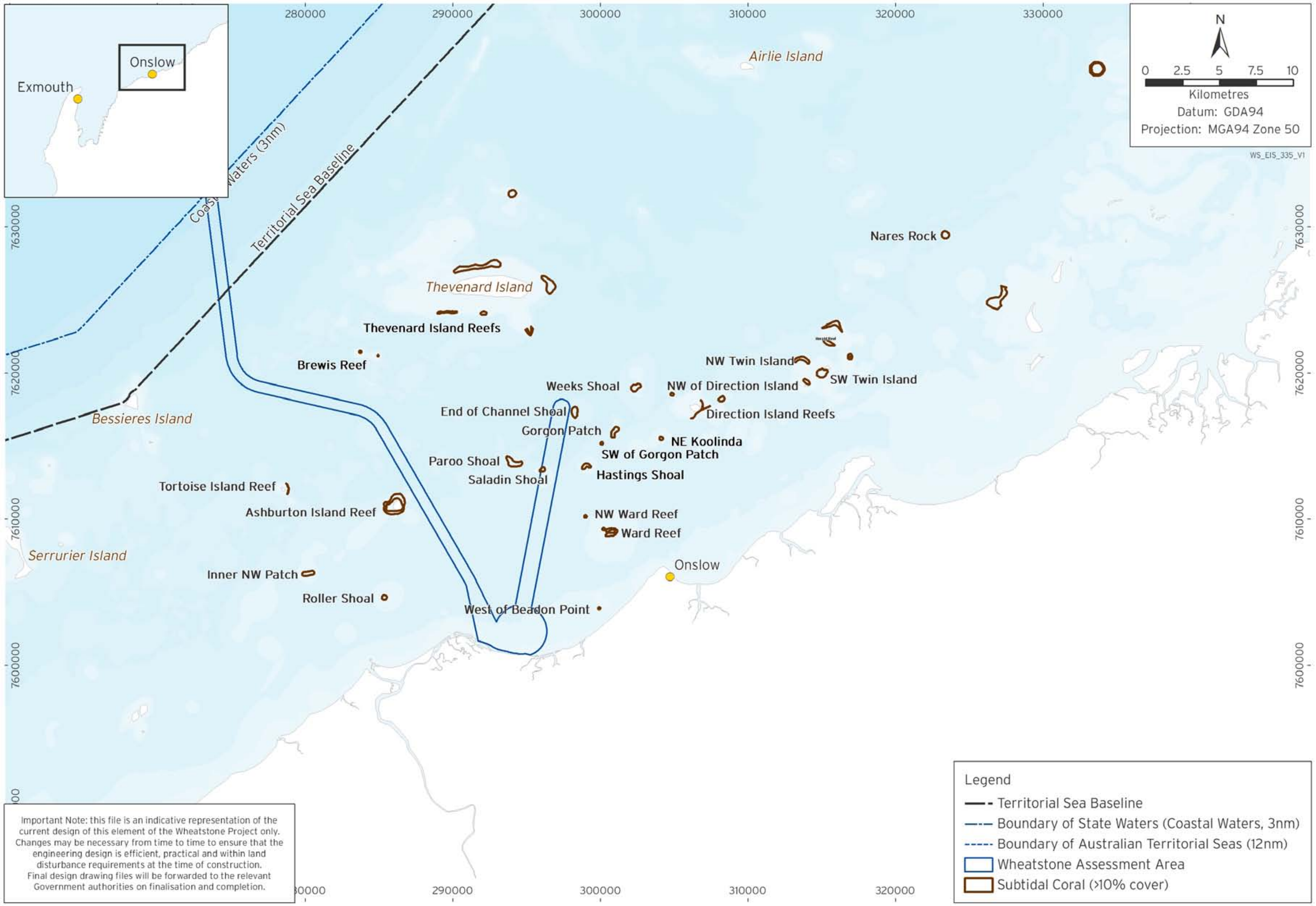
** = revised (Oct 2010) addition*

2 Coral Area and Predicted Potential Impacts

Table 2-3 Proposed Coral Areas of Potential Total Loss.

Coral Area	Acronym	Area (ha)
End-of-channel Shoal	EOCS	23.4
Saladin Shoal	SS	8.6
NW Ward	NWW	2.5
West of Beadon Point	WOBP	2.5

Figure 2-1 Names and location of coral habitat (>10% cover).



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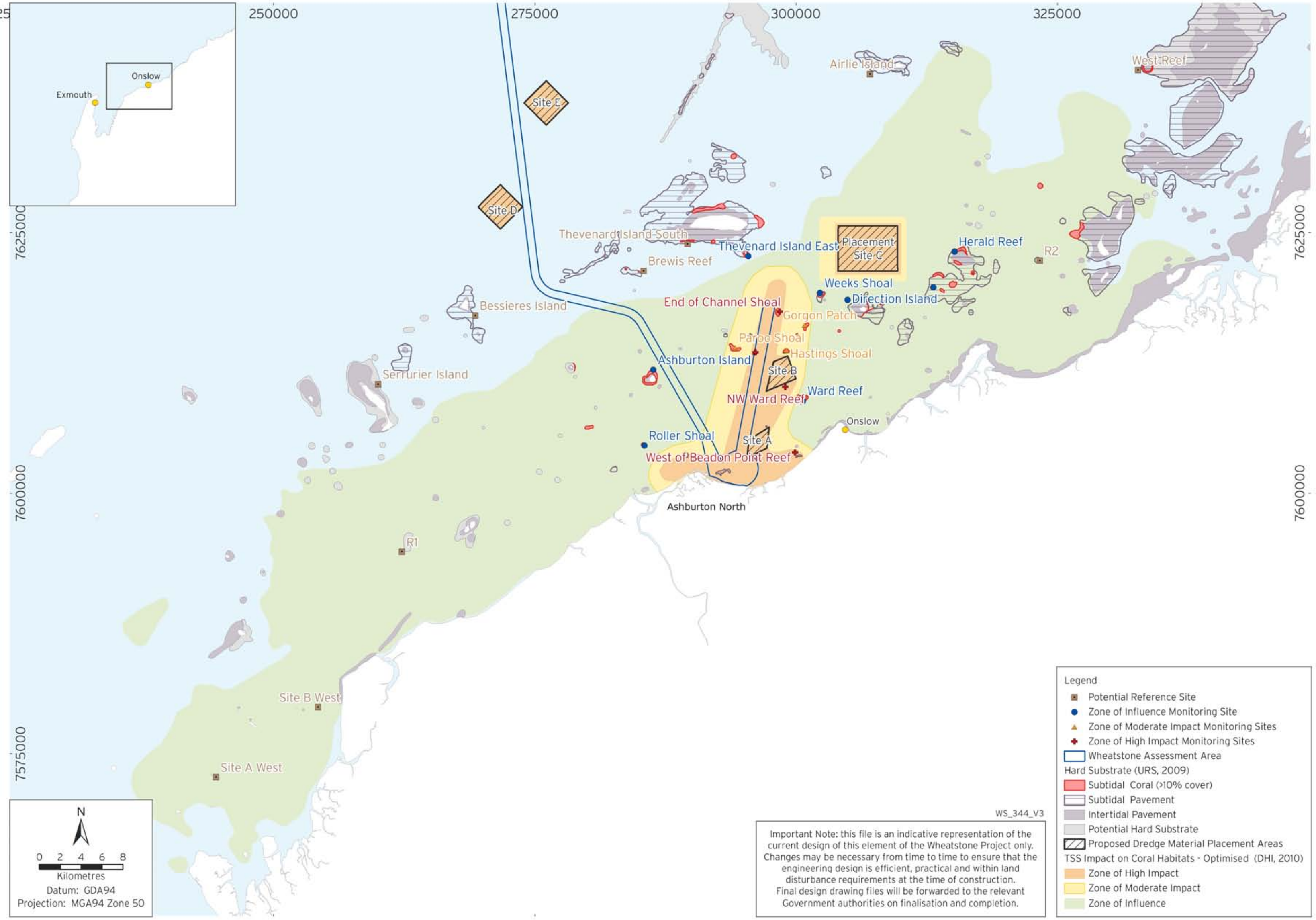
2 Coral Area and Predicted Potential Impacts

Figure 2-2 Impact Zone Boundaries and proposed monitoring sites in the updated DSDMP.



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Revised LAU Boundaries and Applicable CLG

3.1 Background

Figure 3-1 presents the LAU boundaries adopted in the Draft EIS/ERMP (Chevron, 2010). The CSIRO hierarchical classification system used by IMCRA as the basis for LAU definition was adopted. This classification system recognizes the line of coral reefs and shoals which occur roughly along the 10m isobath as one biotope. It also recognizes the conformity of nearshore sediment as one biotope. This approach enables simple and clear percentage loss calculations from each major BPPH type that occurs within the Project area. This justification for LAU boundaries presented in URS (2010b) has been supported by both peer reviewers (Dr Barry Wilson and Professor Charles Sheppard).

The OEPA submission to the Draft EIS/ERMP (Chevron, 2010) Public Review suggested that the assignment of some of the LAU boundaries and CLGs proposed in the Draft EIS/ERMP (Chevron, 2010) was inconsistent with the intent of Environmental Assessment Guidance (EAG) 3 – Protection of Benthic Primary Producer Habitat in Western Australia's Marine Environment. Further consultation with OEPA assessment officers has resulted in the revision of some of the proposed LAU boundaries and applicable CLGs. A revised LAU layout was submitted in the original draft of this document and has since been slightly modified in response to comment received from the OEPA in December 2010.

3.2 Revised Proposed LAU Boundaries

In recognition of the need to apply different nearshore and offshore CLG's, and the need to recognize administrative boundaries, the nearshore (ECU1) LAUs, as shown in Figure 3-3, have been redefined.

There are two administrative boundaries which apply in the Project area:

1. Those of EPA Guidance Statement 1 which provide Guideline Zones for Mangrove Protection (Figure 3-2). Guideline 4 area has a CLG E (10%) category extends from just east of Ashburton Delta to Coolgra Point; and a Guideline 1 zone extends around Ashburton River Delta.
2. Those of the Onslow Port Limits which occur close to the western edge of the Project as a line from the eastern mouth of Ashburton River to Ashburton Island and to the east of the Project as a line from Coolgra Point to Herald Reef (Figure 3-4).

In addition there are also different categories for nearshore and offshore CLGs within ECU1, and consequently ECU 1 has now been divided into seven LAUs as described in Table 3-1 and depicted in Figure 3-3.

Table 3-1 Revised ECU 1 LAU descriptions and corresponding CLG category and approximate area.

LAU	Descriptor	CLG Category	~Area (km^2)
1A	Offshore Corals (and other BPPH) to east of channel and within port limits	D	96
1B	Offshore Corals (and other BPPH) to west of channel and within port limits	D	73
1C	Nearshore corals within inner port area between navigation channel and Beadon Point	E	95
1D	Nearshore BPPH (primarily macroalgae) within inner port area between channel and western port limit	E	62
1E	Nearshore seagrasses to west of channel and port limits	D - in recognition of Ashburton River mouth	56
1F	Offshore corals and seagrasses west of port limits	D	50
1G	Sediments and Seagrasses to east of Onslow	D – in recognition of seagrass beds	113

3.3 Revised Coral BPPH Loss Assessment

As a consequence of the revised LAU boundaries the Coral BPPH loss assessment for LAU 1A, LAU 1B and LAU 1C has been revised. The overlay of the proposed LAU boundaries for ECU1 on the BPPH distribution map is shown in Figure 3-4.

3.3.1 LAU 1A Offshore Corals east of channel (CLG 5%)

- Coral loss = 23.4 ha (EOCS)
- Total coral in LAU = 244 ha (All corals east of channel except Nares Rock, Ward Reef, NWW and WOBP)
- Percentage loss = 23.4/244 x % = 9.6%

3.3.2 LAU 1B Offshore Corals west of channel (CLG 5%)

- Coral Loss = 8.6 ha (SS)
- Total coral in LAU = 123.2 ha (All corals west of channel except Roller shoal, Inner NW Shoal and Tortoise Island)
- Percentage loss = 8.6/123.2 x % = 6.9%

3.3.3 LAU 1C Nearshore Corals east of channel (CLG 10%)

- Coral loss = 5 ha (WOBP+NWW)
- Total coral in LAU = 35 ha (Ward Reef, NWW and WOBP)
- Percentage loss = 5/35 x % = 14%

The above losses all exceed the applicable CLG.

3.4 Justification of coral losses

In cases where the CLG is exceeded, EAG 3 requires proponents to present a “substantiated technically rigorous case that additional losses will not cause ecological integrity to be significantly compromised “. EAG 3 also recommends that such losses may be acceptable if the Proponent can demonstrate that there are no feasible alternatives to avoid the predicted damage and where proposals are consistent with relevant management plans or State Government decision. The Proponent considers that both these latter criteria apply to the Project, namely:

- The Project is of regional, state and national significance and has Government support
- A strategic industrial area (SIA; Ashburton North SIA) has been designated through the State planning process for the onshore component that encompasses the Project and third parties
- The port facilities are expected to be operated by a third-party for the benefit of the whole Ashburton North SIA
- An SIA also exists adjacent to this area between Four Mile Creek and Onslow
- There is no economically feasible alternative to the potential loss of these reefs; the proponent has committed to a series of management and mitigation measures, outlined in the Draft DSDMP (SKM, 2010) including a restriction of overflow from the TSHD in the Restricted Overflow Areas when sensitive receptors are at risk.

Furthermore, the Proponent's environmental advisers consider that the potential loss of the named reefs and shoals will not adversely affect the integrity of the remaining coral reefs and shoals in the Project area because larval connectivity within the Project area is believed to be high. Substantiation of this assertion is provided in the following subsections

3.4.1 Connectivity in Coral Reef Assemblages

Understanding the population connectivity of tropical corals through the dispersion of their larval propagules, and therefore the ecological and management implications, has been the focus of research for more than 30 years (Benzies, 1999). The factors that primarily determine the dispersion or coral propagules include metocean conditions (tidal, oceanographic and wind) influencing water movements, topology of reef systems, and specific competency and behavioural characteristics of the larvae. For brooding corals, larvae are competently motile from the moment of release. However for broadcast spawners (which accounts for the largest proportion of coral genera), propagules are generally not motile for the first three days after release, are positively buoyant and are therefore subject to the fate of local wind conditions during this period.

Rigorous modelling of coral propagule dispersal and retention for brooding and broadcast coral spawners on the Great Barrier Reef shows that the level of connectivity is a function of the constant directional current flow among reefs as well as specific larval competency periods and topology of reef systems (Blanco-Martin, 2006). Field based evidence suggests that generally, during periods of light to moderate localised wind conditions, retention of propagules to natal reefs is greatest, while under strong wind conditions (and usually unseasonal) inter-reef dispersal of propagules is increased (Willis and Oliver, 1988; Radford *et al*, in prep). Evidence from modelling coral propagule dispersal on the Great Barrier Reef demonstrates that inter-reef dispersal among reefs separated by several kilometres is common (Blanco-Martin, 2006). Moreover, on the Great Barrier Reef, where adjacent reefs form a highly interconnected system, allozyme surveys of approximately 3000 coral colonies demonstrated that populations are genetically diverse, and rates of gene flow for a suite of five species range from modest to high among reefs up to 1200 km apart (Ayre and Hughes 2004).

Preliminary modelling of broadcast coral propagule dispersal from reefs in the Project area using appropriate seasonal metocean conditions from 2007 (considered normal metocean conditions) demonstrates that propagules are dispersed up to 10 km within the first three days after release (DHI unpublished data). In a separate modelling study using metocean data from 2002 in North West Shelf of Australia, broadcast spawning coral propagules were projected to disperse approximately 20 km within the first four days after release (Radford *et al*, in prep). Collectively this evidence suggests the scale of connectivity in coral reef assemblages is relevant to the size and geographical alignment of the proposed LAUs. This scale of propagule dispersal suggests the LAUs that suffer greater levels of coral loss have the potential to be repopulated by fecund adult corals in the order of 10 to 20 km from the LAU boundary.

Connectivity operating at ecological (demographic) scales where breeding populations are patchy, forming mosaic spatial patterns of varying size and distances apart and with unsuitable habitat between them, is the norm in benthic shelf habitats and in coral reef complexes made up of patch reefs. The effective exchange rate of coral larvae may decrease with increasing distance between the elements. The distances at which connectivity becomes ineffective depends on a range of factors including those affecting local hydrodynamics including storms, the duration of larval competence of a species and the season/s of spawning of the species.

EAG 3 refers to a paper by Underwood (2009) who reported on genetic studies on selected coral species in a range of reef systems in NW Western Australia. The author suggested that short-term recovery of coral communities after severe disturbance requires areas large enough to encompass routine coral larval dispersal distances and that in some cases on complex NW reefs this may be less than 10 km. To facilitate recovery from severe disturbances, protected areas need to be replicated over spatial scales that accommodate routine larval dispersal distances in an area (Underwood 2009). Local hydrodynamics were recognised as a controlling feature and the author suggests specific designs need to account for size, complexity, and isolation of reefs, which will either restrict or enhance larval dispersal within this range. The paper concluded that functional scales of connectivity may be in the order of 20 km or less.

A more recent paper by Radford *et al* (in press) suggests a more complex pattern of connectivity may exist in coral reef systems. The distance of coral spawn dispersal is more likely a function of prevailing climate at spawning time in any one year. Cyclones, which frequently occur at the time of year that spawning occurs in NW WA, may be responsible for dispersal of larvae well beyond (100 km's) the parental reefs. The corollary is that during non-cyclone years, coral spawn dispersal remains localized (10-20 km) and many reefs may self-seed under these conditions. Radford *et al* conclude that consideration of the range of inter-annual climatic conditions affecting hydrodynamics in an area, around the time of coral spawning, may be highly influential to the pattern and scale of coral larval distribution.

The dredge plume modelling, presented in DHI (2010a) indicates that particles carried in tidal and wind driven currents may travel large distances in a relatively short space of time in the Project area under normal, non-cyclonic climate conditions. Preliminary coral spawn dispersal modelling undertaken by DHI (unpublished data) shows that dispersal to 10 km under normal representative wind conditions is readily achievable within 3 days. The results of this modelling indicate that the oceanographic hydrodynamics prevalent in the Project area are likely to accommodate routine coral larval dispersal between shoals and reefs at the 10m isobath across the entire Project domain. Hence given the alignment of the patch reefs alongshore and in the orientation of prevailing tidal and seasonal wind driven currents, a strong argument exists for there being a high level of connectivity between coral shoals and reefs within ECU1.

3.4.2 Coral Community Structure

A baseline coral community description presented in MScience (2009) provides a quantitative snapshot of a range of coral communities within the Project area. It concludes that there is a general cline in coral community structure from inshore which is dominated by species of *Montipora*, to offshore which is dominated by species of *Acropora* and *Pocillopora*. A zone of mixed coral community types is present in between these two areas. Cluster analysis (MScience, 2009) suggests that the coral community which occurs at Saladin Shoal is similar to that which occurs at Ashburton Reef and Thevenard Island, two regionally important reefs that are not predicted to suffer any “irreversible damage” as a result of the proposed dredging operations. End-of Channel Shoals was not included in the survey and therefore its coral community has not been quantified. However, field observations indicate that it is similar to Weeks Shoal which occurs about the same distance offshore and has been surveyed. Cluster analysis (MScience, 2009) suggests that the coral community which occurs at Weeks Shoal is similar to that which occurs at Hastings and Paroo Shoals and Ward Reef. Hence the potential for loss of coral biodiversity from the region is very low.

It is therefore considered reasonable to regard the cluster of small patch reefs along the 10m contour off Onslow between Ashburton Reef and the Herald Reefs (i.e. within LAU 1A and 1B) as a coral metapopulation. The notion of a "metapopulation" has developed from studies of the connectivity of fish populations on coral reefs (Sale 2002). It refers to a group of spatially separated patch reefs, where the units are spaced at various distances apart and individuals are exchanging genes in such a manner that the whole group may be regarded as a mutually supportive, single breeding population in the demographic ecological sense.

The limits of such a metapopulation are determined, on a species by species basis, by the distances apart, the effectiveness of circulation, and the dispersal capacity of the organisms in question. The period of larval competence of reef corals varies considerably. Some broadcast spawners may be competent for up to 105 days (Wilson and Harrison 1998). Most mass spawners have been shown to settle after 4 to 6 days (Babcock and Heyward 1986).

3.4.3 Summary of Justification of Coral Loss

In the Project area the Ashburton-Herald Island complex of shallow, nearshore patch reefs off Onslow, a figure of 4-6 days would be a reasonable estimate of normal competency and may be considered in a context of strong tidal and wave driven circulation as predicted in the coral spawn dispersal modelling (DHI unpublished data). The distances apart of these small reefs are rarely more than around 8 km and on this basis this complex of patch reefs is very likely to operate, under normal conditions, as a metapopulation.

None of these patch reefs are more than about 8 km apart and they form a network of populations that are highly likely to exchange larvae and to be demographically interdependent. The modelling demonstrates that in spite of the potential total loss of corals at the two larger near-field shoals, Saladin and End of Channel shoals, adjacent reefs (e.g. Paroo, Hastings and Gorgon Patch) could readily provide a larval source to recolonise these shoals with coral species and other reef organisms, potentially enabling them to recover to some extent over the longer term.

Therefore it is considered that larval connectivity within the metapopulation, and thereby the demography of other patch reefs in the system, would be unlikely to be affected by the loss of the two shoals in question. Given this, the EPA requirement regarding maintenance of “key functional ecological processes such as trophic connectivity" would still be met. It is also considered that the potential for loss of coral biodiversity from the region is very low.

3.5 Revised Macroalgae BPPH Loss Assessment

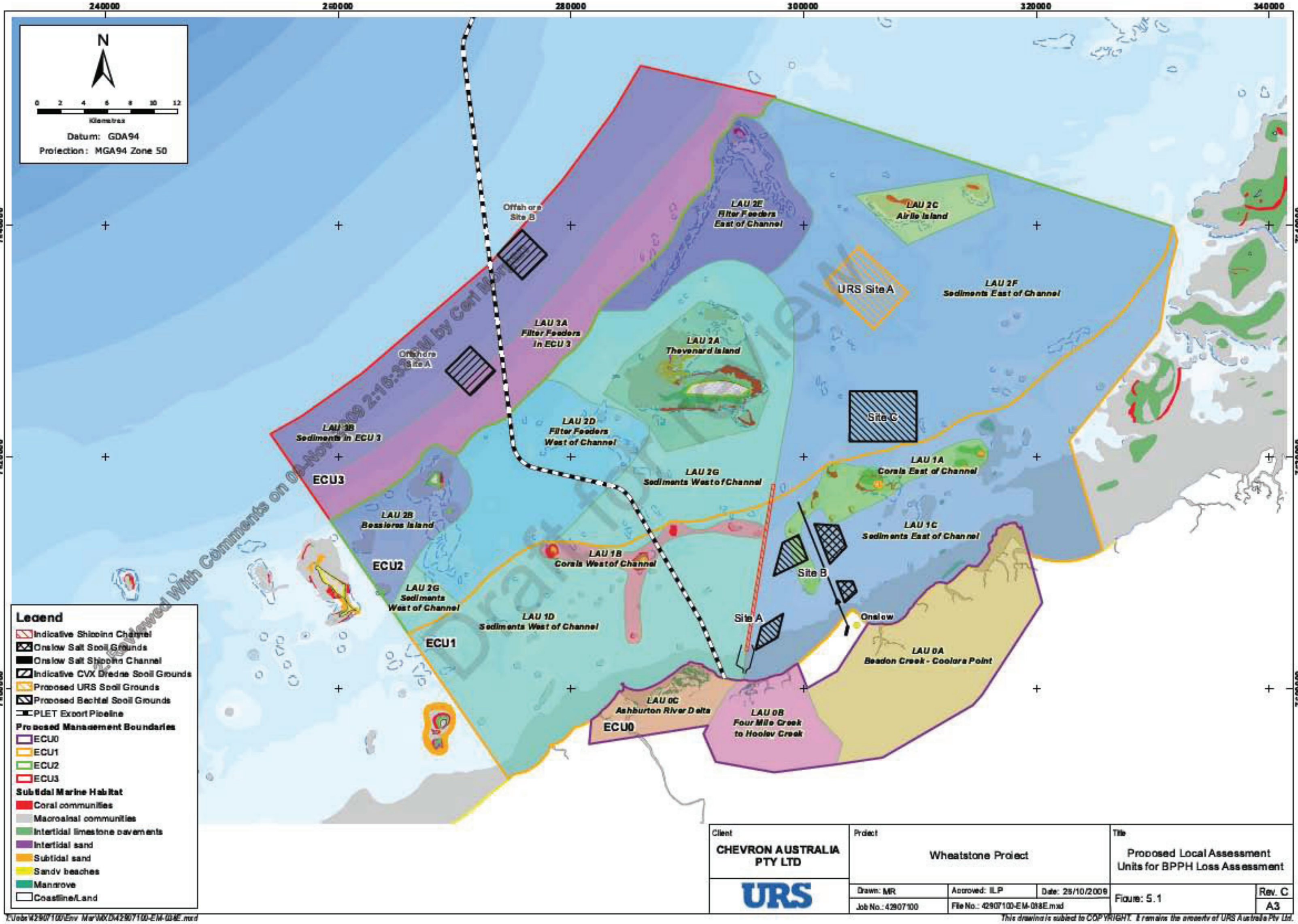
The Draft EIS/ERMP (Chevron, 2010) indicated that the only irreversible loss of macroalgae anticipated from the project was some 250 ha which occurred within the footprint of the navigation channel. This is still the Proponent's expectation. This loss was calculated to equate to 2% of (then) LAU 1D (Draft EIS/ERMP, Table 8.20; Chevron, 2010). Given that the LAU boundaries have since been revised, there is now a need to revise the loss assessment.

- Area of macroalgae loss = 250 ha
- Total area of macroalgae in LAU 1B = 4022.5
- Total area of macroalgae in western portion LAU 1A = 638 ha
- Total area of macroalgae in LAU 1D = 1525 ha
- Total area of macroalgae "meadow" in vicinity of channel = 6185.5
- Various calculations are possible depending on which LAU boundary is preferred. For example:
- The percentage loss in LAU 1B alone is 250/4022 x 100% = 6.2%; or
- The percentage loss in LAU 1B and the western portion of LAU 1A is 250/4660 x 100% = 5.4%; or
- The percentage loss in the total macroalgae meadow is 250/6185 x 100% = 4%.

The above macoalgae loss estimates are all close to the applicable CLG of 5%.

3 Revised LAU Boundaries and Applicable CLG

Figure 3-1 Draft EIS/ERMP (Chevron, 2010) Loss Assessment Units.



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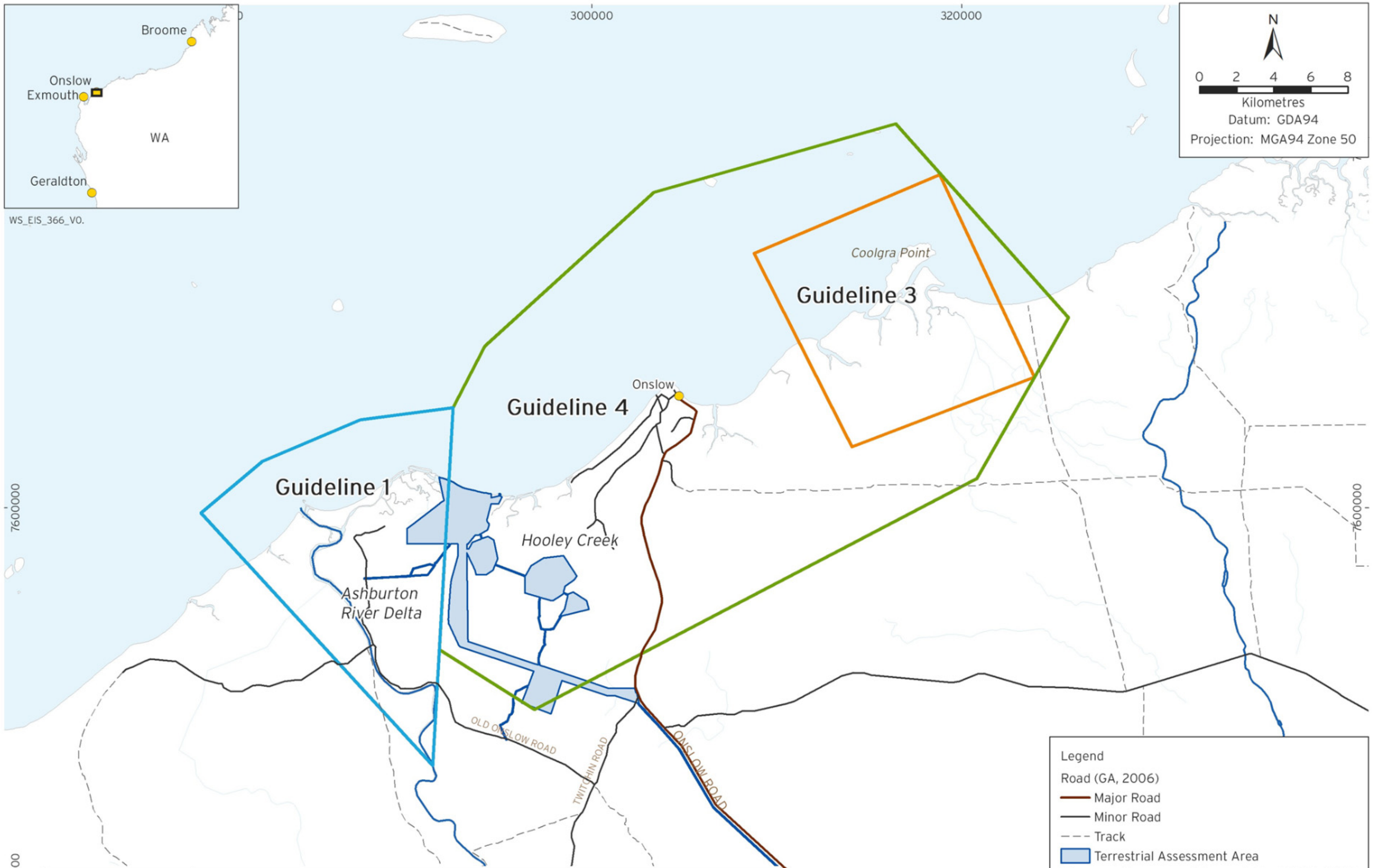
3 Revised LAU Boundaries and Applicable CLG

Figure 3-2 Guideline Zones for mangrove protection from EPA Guidance Statement No. 1.



Area	Description
Ashburton River Delta	Regionally significant mangroves - Outside designated industrial areas and associated port areas.
Coolgra Point	Regionally significant mangroves - Inside designated industrial areas and associated port areas.
Onslow Area	Other mangrove areas - Inside designated industrial areas and associated port areas.

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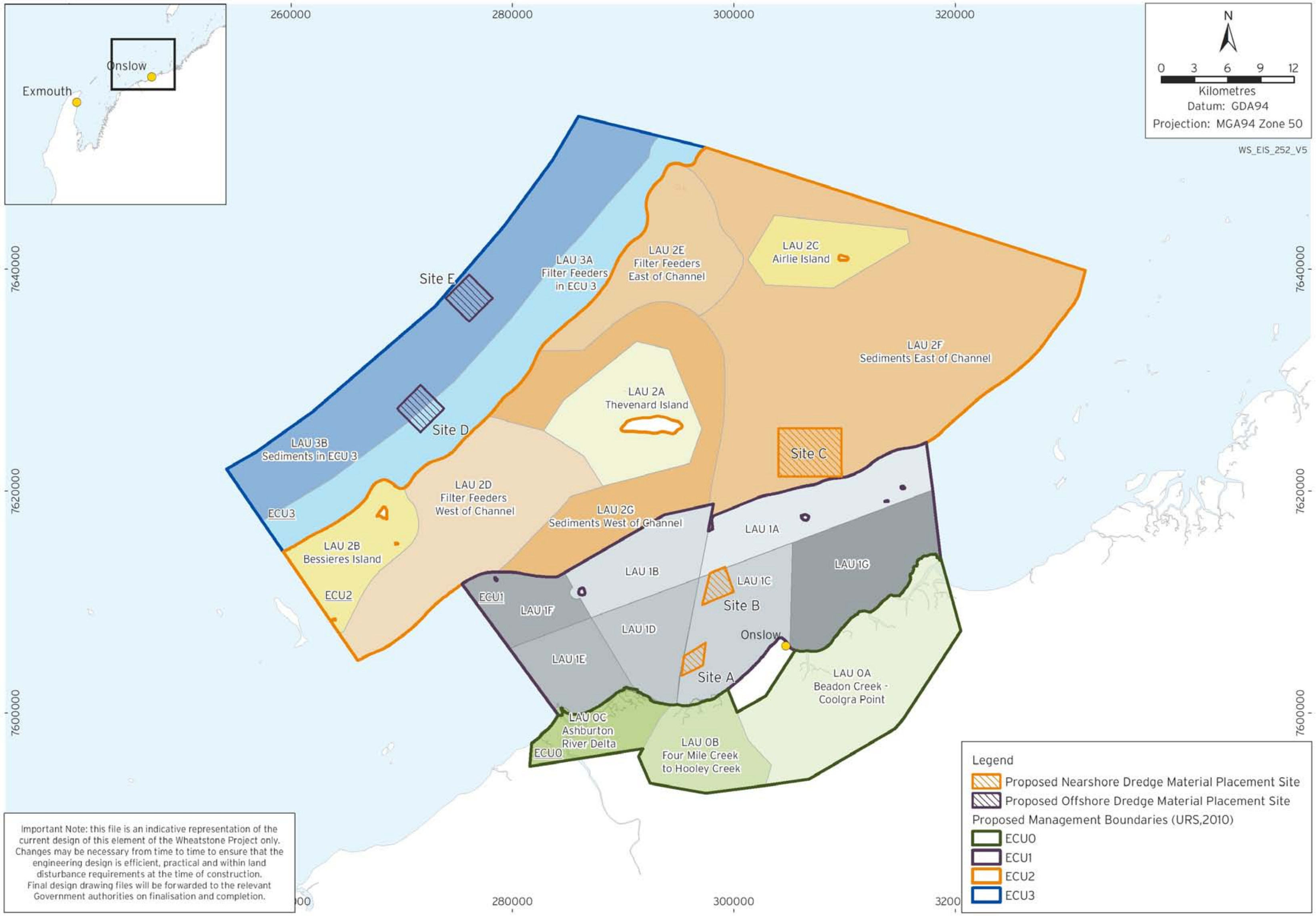
3 Revised LAU Boundaries and Applicable CLG

Figure 3-3 Revised LAU layout for the Project.



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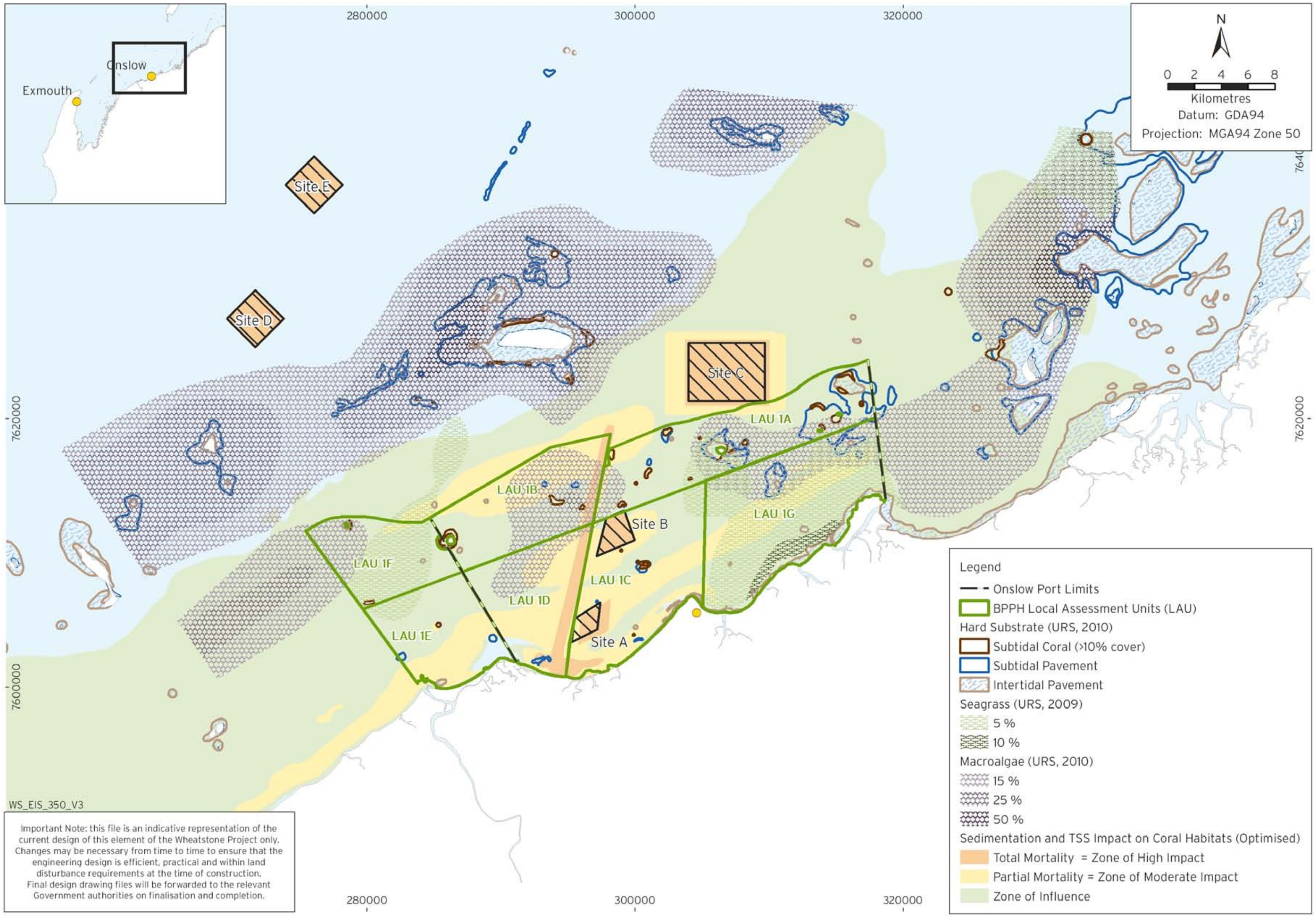
3 Revised LAU Boundaries and Applicable CLG

Figure 3-4 Onslow Port Limits and Revised LAU boundaries for ECU 1 on BPPH distribution Map.



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Potential Trunkline Realignment

Potential realignment of the trunkline, from that presented in the Draft EIS/ERMP (Chevron, 2010), in the area to the west of Thevenard Island is also being considered. This alignment is shown on Figure 4-1. The alignment passes closer to Brewis Reef and Thevenard Island, but further from Bessieres Island than the base case alignment presented in the Draft EIS/ERMP (Chevron, 2010).

Confirmation of the proposed alignment is ongoing. Consequently the Proponent is seeking approval to install the trunkline along an alignment to be confirmed within the green hatched area shown on Figure 4-2 labelled as “Refined investigative area”.

Construction methods for Trunkline installation and stabilization have not yet been confirmed. A range of methods are under consideration for different sections of the trunkline route through nearshore waters (5-40m depth). Methods will vary depending on substrate type (sediment or rock) and hardness of rock. Figure 4-3 indicates current knowledge on substrate type and hardness along the base case trunkline route. It shows that soft sediments extend offshore to KP 18 which is located approximately 2 km south of Brewis Reef. From there to KP 33 (Zone 5) rock substrate predominates and becomes very hard.

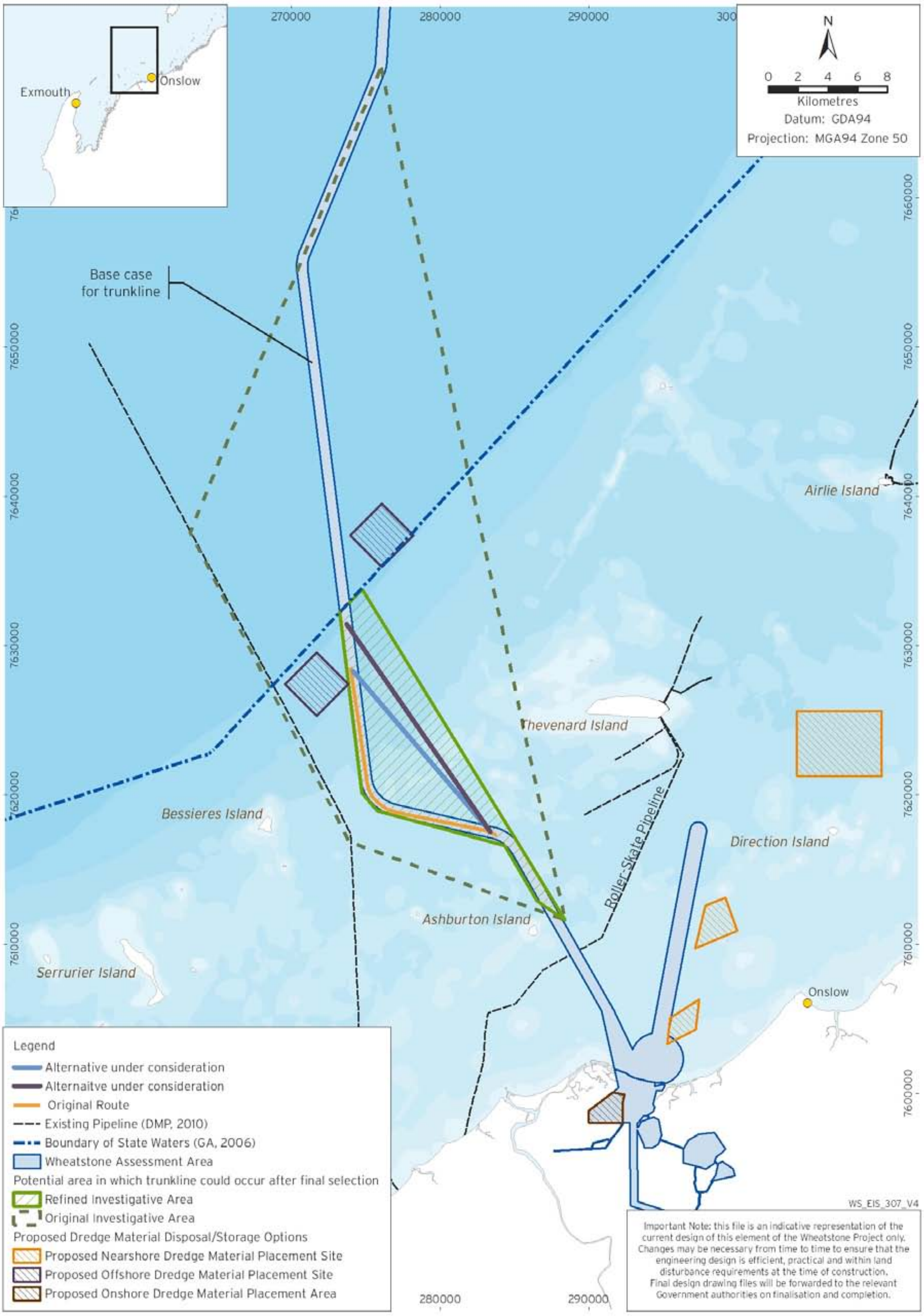
The commonly preferred method of trunkline installation in nearshore waters on the NW Shelf is to lay the pipe on the seafloor and stabilize it through placement of suitable backfill including rock on top of the trunkline. However because trawling occurs in nearshore areas and navigation route for small coastal vessels passes to the south of Brewis Reef, the Proponent is investigating the feasibility of burying the nearshore trunkline flush with the adjacent seafloor and covering it with a layer of sand at the surface. In softer sediments this could involve the use of backhoe excavators, or trailer suction hopper dredges (TSHD) to create a trench into which the pipe will be placed. However on the rock substrates which occur from KP 18 to KP 33, a large cutter suction dredge (CSD) may be required, or it may even be necessary to drill and blast with removal of rock by clamshell dredge or backhoe excavator. At present it is anticipated that all material removed when trenching will be disposed at dredged material placement site C.

Pipelay into the trench will occur via a pipelay barge which winches itself along the route using a spread of anchors. Trunkline stabilisation is then undertaken using engineered rock and other suitable material including coarse sand to cover the pipe and fill the trench. The median size of rock required to stabilize the Trunkline is considered to be 300 mm for most of the nearshore trunkline route. Coarse sand and gravel is also considered adequate for some sections of the trunkline.

Figure 4-3 presents a conceptual trunkline installation schedule which suggests that trenching operations may require approximately 128 days; the pipelay operation may require approximately 83 days; and subsequent backfill operations may require 175 days to complete.

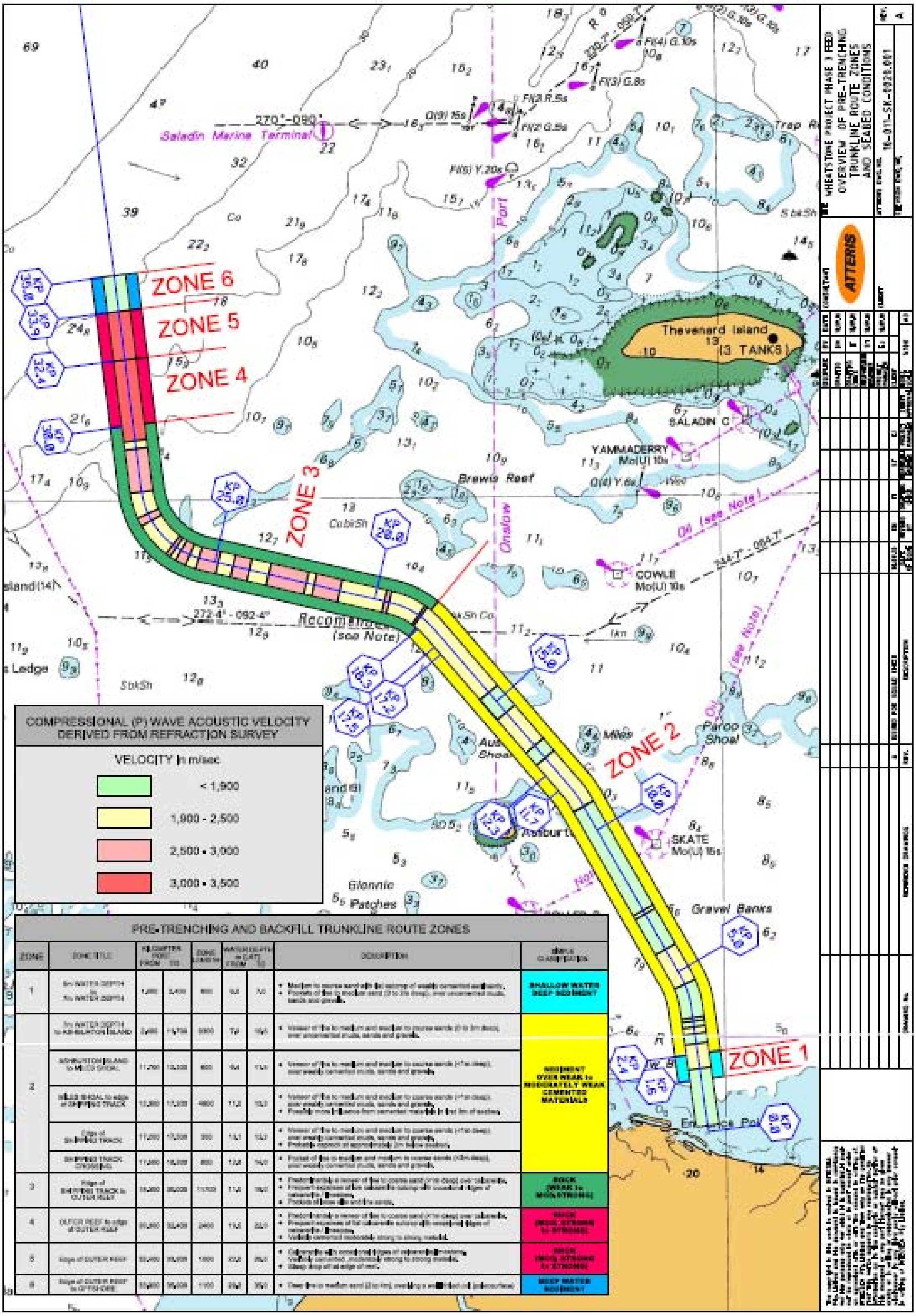
4 Potential Trunkline Realignment

Figure 4-1 Trunkline route alternatives currently under investigation.



4 Potential Trunkline Realignment

Figure 4-2 Overview of pre-trenching trunkline route zones and seabed conditions.



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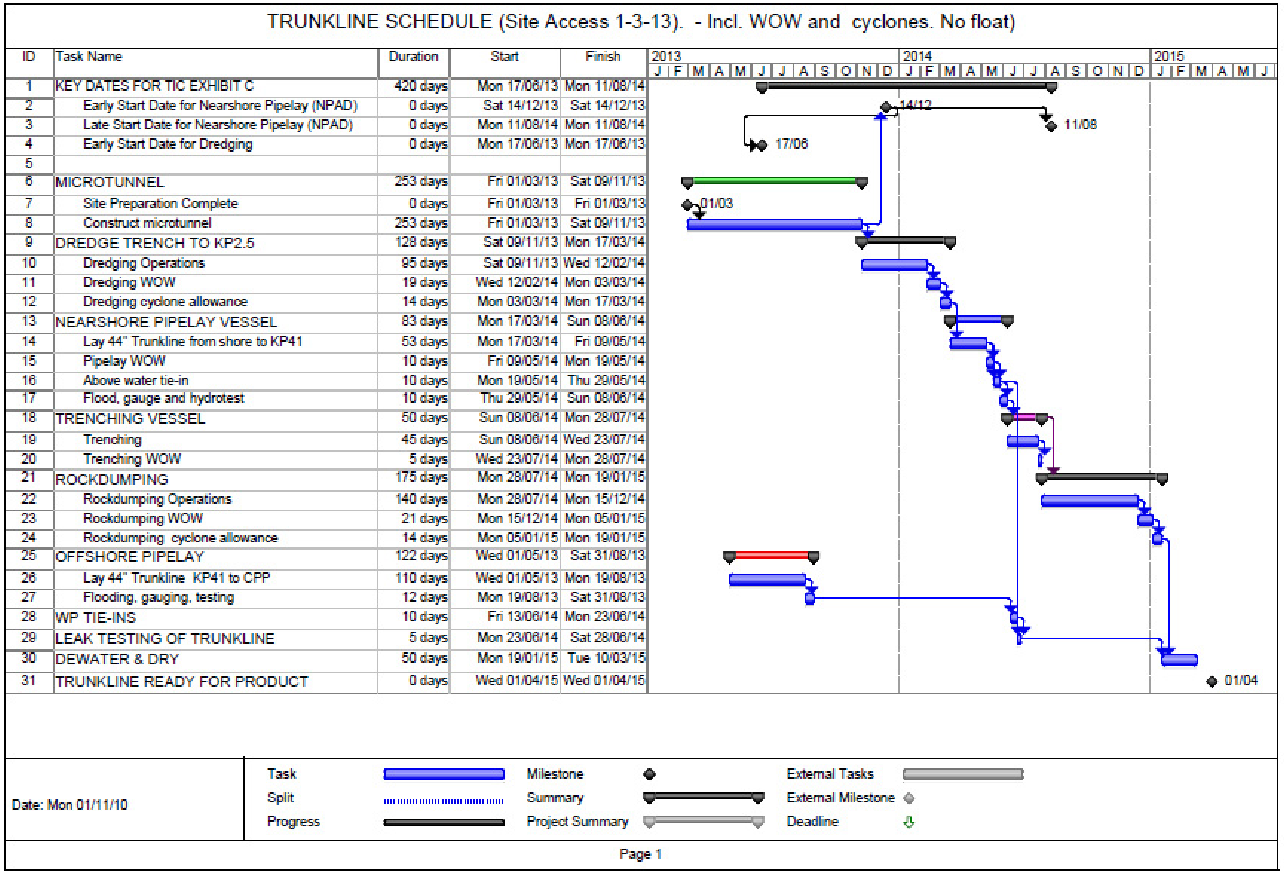
4 Potential Trunkline Realignment

Figure 4-3 Conceptual trunkline installation schedule.



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4 Potential Trunkline Realignment

4.1 Revised BPPH Loss Assessment for Trunkline

4.1.1 Base case loss assessment

Given the uncertainty in trunkline alignment and hence construction methods, a conservative "worst case" construction method was assessed in the Draft EIS/ERMP (Chevron, 2010) for the base case trunkline installation. This involved the use of a CSD pumping directly into a hopper barge for disposal of material at Dredged Material Placement Sites C and D. The assessment predicted that the maximum direct losses of BPPH from within the Trunkline footprint (assuming a 50m wide corridor of permanent disturbance) would be:

- 100 ha of filter feeder and macroalgae habitat.
- 10 ha of seagrass habitat.

Macroalgae is predicted to rapidly recover, and so will seagrasses if the preferred (and likely) method of burial is adhered to where the route crosses soft substrates (from shore to KP 18). Hence for BPPH Loss assessment purposes only 100 ha of filter feeder habitat will potentially be lost for longer than five years. However should a different method be implemented that results in irreversible loss of seagrass, then 10 ha of seagrass loss will arise from the "meadow" which occurs to the west of Ashburton Island. The total area of that "meadow" is (Draft EIS/ERMP, Table 8.30; Chevron, 2010) 4881 ha, resulting in a loss of BPPH which equates to 0.2 % of that meadow, or 0.7% of the amount of seagrass habitat in LAU 2G shown on Figure 3-3. Such a loss is well below the applicable CLG of 5%.

Maximum indirect losses of BPPH arising from turbidity and sedimentation resulting from dredging and disposal operations for the trunkline were assessed to be:

- Approximately 2000 ha of filter feeder habitat (10.6 %) in LAU 2D.
- Approximately 1000 ha of filter feeder habitat (5.3 %) in LAU 3A.

The applicable CLG for both LAUs is 5% (Category D).

Ashburton Reef was identified as being at potential risk of impact under certain conditions and appropriate management and mitigation measures were considered necessary to be adopted to mitigate this risk during trunkline construction.

4.1.2 Potential revised alignment BPPH loss assessment

The potential revised trunkline alignment will pass closer to Brewis Reef and Thevenard Island than the base case alignment, but will remain within the same LAUs. As a result of the reduced length of trunkline in the new alignment, the maximum direct losses of BPPH from within the Trunkline footprint (assuming a 50m wide corridor of permanent disturbance) would reduce to:

- 85 ha of filter feeder habitat.

Predicted potential indirect BPPH losses in this revised alignment have been calculated based on results of dredge modelling for the trunkline presented in the Draft EIS/ERMP (Chevron, 2010) for the base case (i.e., original modelling results have been overlayed on the new alignment). Maximum indirect losses of BPPH arising from turbidity and sedimentation resulting from dredging and disposal operations for the trunkline were estimated to be:

- Approximately 1650 ha of filter feeder habitat (8.9 %) in LAU 2D.

- Approximately 1000 ha of filter feeder habitat (5.3 %) in LAU 3A.

These are large areas and in LAU 2D the loss is almost double the applicable CLG of 5%.

Brewis Reef was identified at potential risk of impact under certain conditions and appropriate management and mitigation measures were considered necessary to be adopted to mitigate this risk during trunkline construction if this alignment is adopted. The Zone of Influence may also extend to Thevenard Island at various times during the trenching operation.

However please note that trunkline excavation impacts modelling undertaken to date and presented in both the Draft EIS/ERMP (Chevron, 2010) and this document is based on a worst case scenario which assumes that a large CSD releasing sediment at the same rate as for the channel dredging works will be used to cut the pipeline trench. As indicated in the Draft EIS/ERMP (Chevron, 2010), this scenario is a contingency in the event that the preferred method of trunkline installation cannot be implemented. The preferred method of trunkline installation is still being investigated and if implemented will release much less sediment to nearshore waters than the contingency approach and as a result the scale of potential damage to filter feeder assemblages and coral reefs adjacent the trunkline route will reduce substantially.

It is noted that the predicted losses of filter feeder habitat are based on coral tolerance thresholds. DHI (2010b)) reviewed literature on tolerance of a range of tropical marine organisms to sedimentation and light attenuation and found that filter feeders as a group were relatively understudied in comparison to corals and that very little information was available for filter feeders. A conservative approach was therefore adopted and coral tolerance thresholds were used to estimate impacts to filter feeder communities. Hence it is considered likely that the predicted loss estimate for filter feeders is a substantial overestimate.

4.1.3 Justification of losses of filter feeder habitat

As indicated earlier in Section 3.4 for loss assessments where the CLG is exceeded, EAG 3 requires proponents to present a “substantiated technically rigorous case that additional losses will not cause ecological integrity to be significantly compromised “. EAG 3 also recommends that such losses may be acceptable if the Proponent can demonstrate that there are no feasible alternatives to avoid the predicted damage and where proposals are consistent with relevant management plans or State Government decision.

In this instance, there are no relevant management plans or State Government decisions applicable to the offshore waters which would act to mitigate the estimated losses. In addition, feasible construction alternatives do exist that would be much less damaging than the contingency worst case method that has been modelled using a CSD. Alternative methods include burial of the trunkline by rock armouring, or trenching by blasting and clamshell excavation followed by rock burial. However the feasibility and usefulness of these methods is yet to be confirmed for the Project.

It is difficult to assess the effect of losses of filter feeder community at this scale on ecosystem integrity given the relatively low level of ecological information available about such communities. A summary of available information is provided below.

4 Potential Trunkline Realignment

Ecosystem function

Marine benthic filter feeder communities are important secondary producers within the marine ecosystem. Benthic filter feeding communities form a benthic-pelagic coupling through the consumption of phytoplankton and zooplankton from the water column. They may also provide habitat and prey for higher order sessile and motile organisms. In the Project area benthic filter feeder colonies or individuals inherently form patchy distributions predominantly characterised by substratum preference/availability and inter or intra-specific competition. Filter feeder communities are rarely contiguous. The structure and complexity of benthic filter feeder communities are determined by pelagic food availability (Gili and Coma, 1998) and, like all ecological communities, are affected by the level of disturbance (Thrush and Dayton, 2002).

Benthic filter feeders are reported to play important roles in structuring phytoplankton communities (Buss and Jackson, 1981). In areas where high densities of filter feeders occur, filtration rates can be sufficient to regulate phytoplankton levels. However, studies documenting this ‘top-down’ grazer control function have been conducted in shallow coastal waters and embayments which have higher water residence times (Newell and Koch, 2004; Kirby and Miller, 2004). It may be predicted that benthic filter feeders have much less influence on phytoplankton levels in deeper marine/oceanic water that have greater levels of mixing due to metocean conditions, particularly where filter feeder communities are sparse, such as within the Project area.

Benthic filter feeder communities also provide structural habitat for epifaunal communities including crustaceans, polychaetes and molluscs (Saier, 2002), settlement habitats for a range of fauna undergoing settlement from the pelagic environment (Young, 1989) and in some cases are food sources for higher order consumers (Menge, 2000). Therefore, the loss of benthic filter feeders is likely to impact on the organisms that rely on them directly and indirectly.

Recovery potential

Ecological communities respond to disturbance based on the spatial extent and duration/frequency of that disturbance. Since the Project area is a cyclone prone area with relatively shallow waters, benthic filter feeders are likely to be impacted due to large scale mobilisation of sediments under cyclonic conditions. Under these conditions the landscape is expected to be stable but exhibit large variance (Turner *et al*., 1993) as found in the habitat mapping for the Project area. This dynamic is explained by the ratio-based model that predicts that a disturbance is dependent upon the ratio between the frequency of a disturbance versus recovery time and the size of the disturbed area in relation to the overall habitat (Turner *et al*, 1993). Since the proposed trunkline installation dredging program is a once-off event, the frequency will be inconsequential. Although the scale of impact predicted exceeds the applicable EPA CLG, the spatial scale at which the disturbance will occur is not large compared to natural events such as cyclones. Therefore in the event of complete removal of similar species, re-colonisation is likely to occur. Issues surrounding connectivity regarding benthic filter feeder communities in the Project area would be expected to be similar to those for coral reef assemblages discussed in Section 3.4.1. If partial or sub-lethal mortality occurs, evidence suggests that common species of tropical sponges are capable of regenerating over 200% of their reduced size within nine months (Duckworth *et al*, 2007). Since reproduction in many marine tropical benthic filter feeders occurs annually or semi-annually and can be sexual or asexual (S.Whalan, personal communication, 7/1/2011, James Cook University), community level recovery is likely to occur relatively quickly.

4 Potential Trunkline Realignment

Effect on ecosystem

If the community recovers as discussed above, the ecosystem function in the impacted area is likely to recover also, albeit through a lagged response. The period over which recovery is likely to occur will vary among genera and will be dependent upon rates of reproduction and growth. It is not possible to accurately predict recovery times for this habitat, so it has been conservatively estimated that full recovery is unlikely to occur within five years, but is likely to occur within ten years. The predicted loss of a large area of this habitat type will mean that there will be a local reduction in abundance of both filter feeder organisms and other organisms that live on and amongst them for a period of time until full recovery occur. However, given the very large extent of this habitat type in the region, it is considered most unlikely that marine biodiversity will be adversely affected as a result of the loss and that there is ample breeding stock available in surrounding non-affected filter feeder habitat to ensure that a full recovery will eventually occur.

Synchronous Dredging and Trunkline Installation

5.1 Potential BPPH Losses from synchronous works

Given the uncertainty in schedules, trunkline alignment and construction methods it is difficult to determine the synergistic effects of synchronous dredging of the navigation channel and trunkline installation. The scale of impact will depend on the trenching method employed, the time of year that work is undertaken and the stage of progress for the channel dredging operations.

The key habitat at risk is the coral reef around Ashburton Island. This risk is increased if both Trunkline dredging and channel dredging occur synchronously upstream of the reef. A scenario assessment of trunkline dredge modelling (Appendix A; DHI, 2010c) demonstrates that simultaneous dredging for the navigation channel and the Trunkline under worst case climatic and dredge conditions can lead to a significant extension of the impact zones along the Trunkline route if the two predicted plumes overlap. This has demonstrated the need for careful management of the Trunkline dredging.

A number of management options are available to reduce the potential cumulative impacts, including:

- Avoiding overlapping plumes from other dredging activities, either by avoiding simultaneous dredging and/or dredging in areas along the same plume extension direction.
- Targeting seasons with the least risk of impacts, e.g. summer conditions when dredging east of Ashburton Island.
- Reducing total sediment release and release rates, e.g. through the choice of construction methodology or adapting methods of release reduction during the pipe laying.

Modelling has been carried out to investigate the efficiency of sample management options and has demonstrated that there is good scope for minimising the impacts through management of sediment release e.g. reduced release dredging and directing the release away from sensitive habitats.

This range of management and mitigation options available enables the Proponent to avoid additional losses of BPPH arising as a result of undertaking both dredging programs synchronously. Consequently additive impacts on coral BPPH resulting from synchronous dredging operations are not anticipated.

5.2 Management of trunkline installation

It is clear that management will be required to protect the nominated reefs from potentially adverse impacts of trunkline installation. Until the trunkline route west of Thevenard Island and the construction method is finally confirmed, it is not possible to commit to any particular construction method or mitigation action. A commitment has been made to protect Ashburton, Brewis and Thevenard Island reefs from damage (as defined in EAG 3) resulting from sediment released during both the trunkline installation works and the capital dredging works for the navigation channel. The impacts of the dredging works for the navigation channel will be managed via the Draft DSDMP referred to in the previous comment. The impacts of the trunkline excavation and burial works will be managed via a separate Trunkline Installation DSDMP which will be finalised once trunkline design and construction method are determined. However it will incorporate the same coral monitoring approach and the same management triggers as proposed in the DSDMP to protect coral reefs but may differ in range of management actions implemented in response to a management trigger being exceeded. Approval for the Trunkline DSDMP will be negotiated with the OEPA as a separate exercise.

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Summary of Anticipated Loss

In summary, the Proponent is seeking approval to cause the following irreversible losses of marine benthic habitat as a consequence of developing the Project:

- 4 ha of mangroves within footprint of onshore infrastructure
- 108 ha of samphires and bioturbated tidal flats within footprint of onshore infrastructure
- 52 ha of upper tidal algal mats within footprint of onshore infrastructure
- 250 ha of macroalgae habitat within channel footprint
- 37 ha of coral habitat adjacent the navigation channel (Saladin and End-of-Channel Shoals)
- 85-100 ha of filter feeder habitat within trunkline footprint
- 0-10 ha of seagrass habitat within trunkline footprint
- 1077 ha filter feeder habitat within and adjacent footprint of dredge material placement site D
- 1650 – 2000 ha of filter feeder habitat adjacent trunkline route
- 4641 ha of soft sediment substrate beneath the port related infrastructure listed in the Draft EIS/ERMP (Table 8.23; Chevron, 2010) (Note 250 ha of macroalgae has been subtracted from the channel area estimate and 900 ha of filter feeder habitat has been subtracted from dredge material placement site D).

In addition, the Proponent is seeking approval for the following temporary (reversible) losses of marine benthic habitat:

- 1481.5 ha of seagrass habitat (2963 ha divided by 2 (Draft EIS/ERMP, Table 8.30; Chevron, 2010)
- 1627.5 ha of macroalgae habitat (3255 ha divided by 2 (Draft EIS/ERMP, Table 8.30; Chevron, 2010)
- 2000 ha of macroalgae habitat adjacent trunkline route (occurring within filter feeder habitat)
- 1 ha of upper tidal algal mat beneath temporary haul road footprint, and
- 24 ha of coral reef habitat in Zone of Moderate Impact (up to 30% mortality of monitoring sites at Gorgon Patch, Hastings Shoal and Paroo Shoal).

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Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron Australia Pty Ltd and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Proposal dated August 2010.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between October 2010 and January 2011 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

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Appendix A Trunkline Dredge Modelling

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Water & Environment (M) Sdn Bhd (535484 - V)

Wheatstone Project

Trunkline Dredge Plume Modelling

Chevron Australia P/L

Chevron Australia P/L **Report**

DHI
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Wheatstone Project

Trunkline Dredge Plume Modelling

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Authors Amy Ling Chu Chu Claus Pedersen	Date October 31st, 2010 Approved by Claus Pedersen

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Revision	Description	By	Checked	Approved	Date

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Chevron Australia P/L DHI Water & Environment (M) Sdn Bhd	

CONTENTS

FIGURES AND TABLES

1.0 TRUNKLINE DREDGING

The final route and installation methodology for the Wheatstone subsea pipeline is still being developed. The draft Wheatstone EIS/ERMP therefore adopted a conservative assessment based on a contingency dredging methodology using a CSD for the entire route. The modelling results for this were reported in Appendix P1 of the EIS.

An assessment of potential cumulative impacts demonstrated that simultaneous dredging for the navigation channel and the pipeline under worst case climatic and dredge conditions where the two plumes overlap can lead to a significant extension of the impact zones along the pipeline route. This has demonstrated the need for careful management of the pipeline dredging. A number of management options are available to reduce the potential cumulative impacts, including:

- Avoiding overlapping plumes from other dredging activities, either by avoiding simultaneous dredging and/or dredging in areas along the same plume extension direction.
- Targeting seasons with the least risk of impacts, e.g. summer conditions when dredging east of Ashburton Island.
- Reducing total spills and spill rates, e.g. through the choice of methodology or adapting methods of spill reduction during the pipe laying. Examples include:
    - Placement of bottom with stabilisation with rock (depending on requirements to keep clear water for navigation)
    - Using a backhoe rather than a CSD in consolidated soils (may not be feasible in all conditions)
    - Targeting the initial filling with no overflow to critical sections along the pipeline route when using a TSHD.
    - Use pipe and locate barges and overflow away from critical areas if using a CSD with overflow to barges.
    - Limitations on overflow when dredging with a TSHD or CSD pumping to barges.

Modelling has been carried out to investigate the efficiency of sample management options. Two examples are briefly demonstrated below.

The modelling has again emphasized that cumulative impacts between pipeline dredging and simultaneous navigation channel dredging are potentially severe, and that pipeline dredging in isolation which is not being well managed from an environmental point of view also can have impacts on the nearby sensitive habitats such as Ashburton and Thevenard Island and Brewis Reef. The modelling has further demonstrated that there is good scope for managing the impacts through e.g. reduced spill dredging and directing the spill away from sensitive habitats.

1.1 TSHD Dredging for KP 2 to KP 18

The use of a TSHD is one of the options considered for this section of the trunkline corridor. The proposed trunkline route passes approximately 1 km east of Ashburton Island, which has high cover and diversity of hard corals. This location is also on a direct flow path to sensitive coral areas at Paroo Shoal and Saladin Shoal. There is also a large seagrass meadow to the west of Ashburton Island.

Figure 1.1 shows statistics over a 14 day winter period derived from simultaneous dredging of the navigation channel upstream of Ashburton (Scenario 7a) and TSHD dredging of the trunkline corridor over a 4.5 km stretch adjacent to Ashburton Island with an assumed production rate of 90,000 m^3/week. During the winter conditions, the plume from the pipeline dredging combines with the plume from the navigation channel dredging, leading to a relatively intense plume around Ashburton Island.

Figure 1.2 shows the same conditions with a pipeline dredge scenario targeting no overflow adjacent to Ashburton Island. The TSHD is assumed to operate in a similar fashion as the navigation channel Dredge Scenario 7a:

- Each cycle starts dredging in the centre of the targeted critical zone east of Ashburton island.
- The direction of dredging is altered for each trip, i.e. every other trip runs towards the shore, and every other trip runs seaward.
- The dredging progresses primarily in one direction. If any turning is included, the dredging with overflow is stopped short of the targeted reduced overflow zone.

This leads to a section in the order of 3.5 km long (assuming about 30 minutes filling before overflow and a dredge speed in the order of 2 knots) with no overflow and the only spillage from the suction head and propeller wash.

Comparing Figure 1.2 to Figure 1.1 illustrates that this method can reduce the plume intensity (the total spillage for the two simulations is the same, but the spillage is spread out along a much longer channel section for the “mitigated scenario”) and direct it away from the Ashburton Island area.

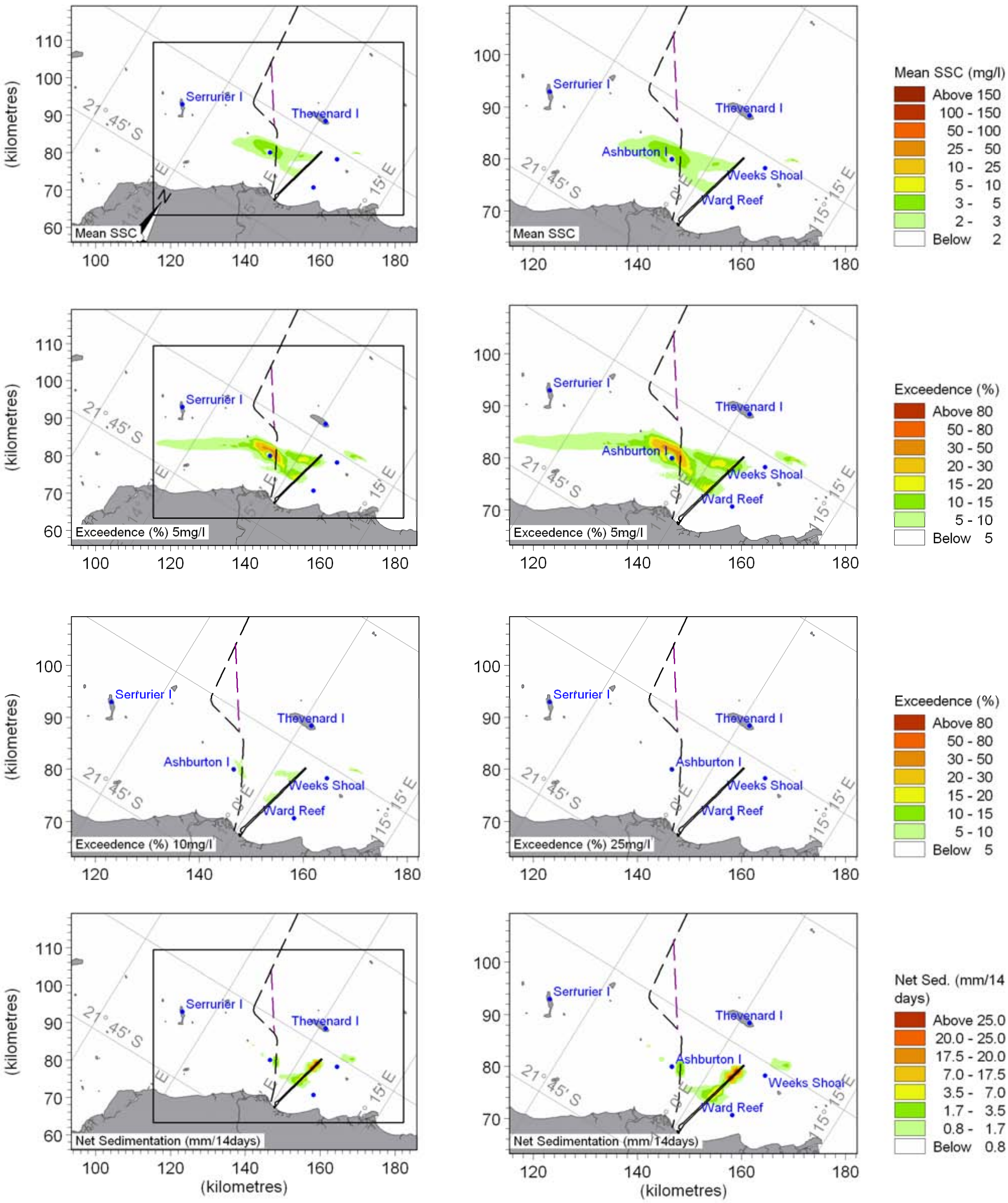

Figure 1.1 Plume statistics for simultaneous navigation channel Dredge Scenario 7a and TSHD dredging along 3.5 km section adjacent to Ashburton Island.

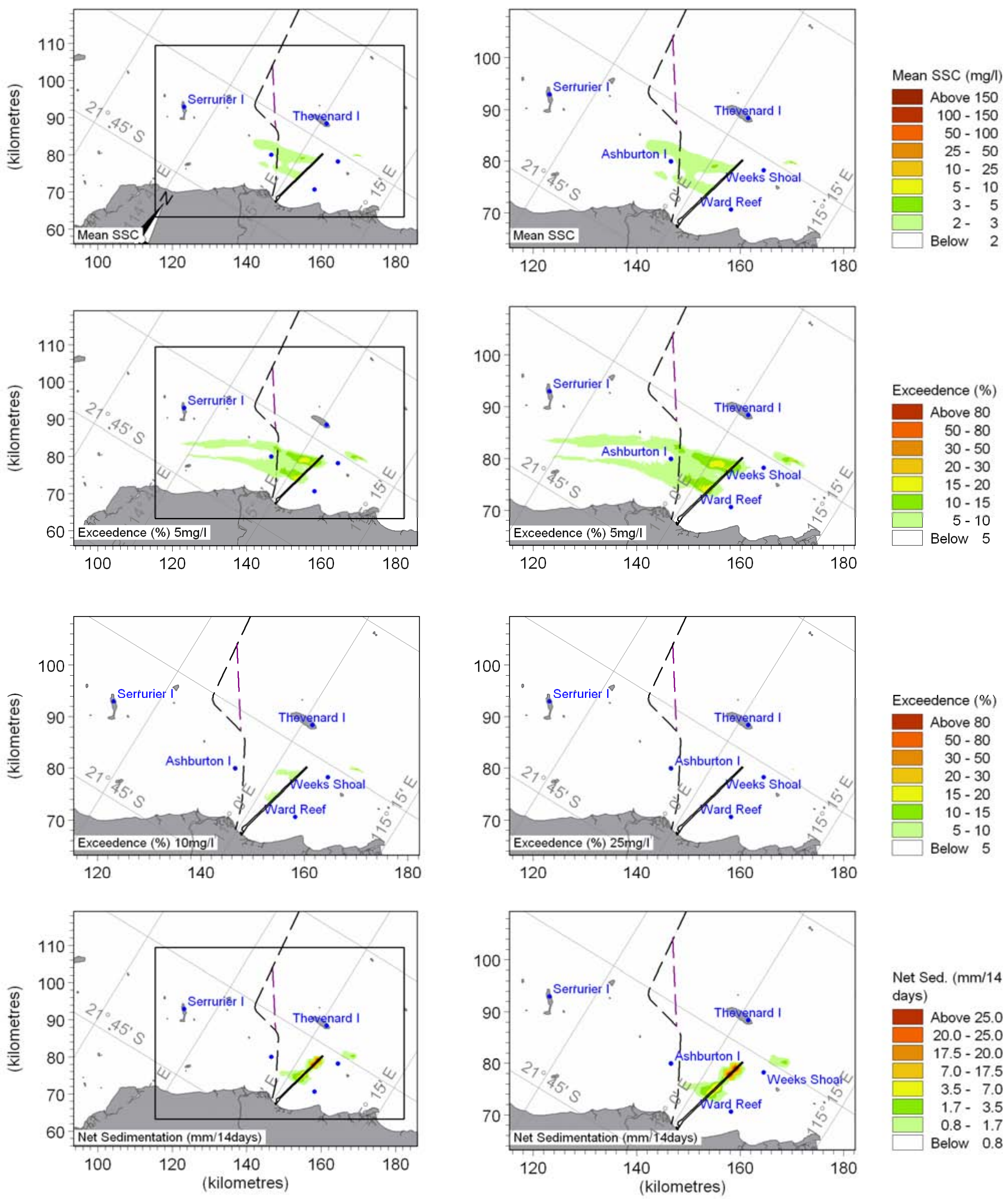

Figure 1.2 Plume statistics for simultaneous navigation channel Dredge Scenario 7a and TSHD dredging with targeted no-overflow adjacent to Ashburton Island.

1.2 Dredging for KP 18 to KP 25

Alternative routes are being considered after about KP 18, see sketch in Figure 1.3. Preliminary geotechnical information indicates "cemented" bottom conditions here, which if confirmed limits the possible methodologies available.

This whole area is considered relatively sensitive with the proximity to Bessieres Island/Brewis Reef as well as Thevenard Island

The "worst case" contingency scenario with a slow moving CSD pumping to adjacent barges with overflow has been modelled for Trunkline route Alternative 5, see Figure 1.3 for route. A weekly production rate in the order of 40,000 m^3 is assumed for the CSD, and spill rates per the corresponding channel dredging. This has been combined with navigation channel Dredge Scenario 4, which has large TSHDs working at outer end of the navigation channel and in the PLF.

Plume statistics for dredging during transitional conditions along the south-eastern part of the Alternative 5 layout, approximately from KP 20 to KP 23, combined with the channel Dredge Scenario 4 is shown in Figure 1.4. This illustrates a large area with a consistent plume immediately to the west of Thevenard Island and covering Brewis Reef. With this dredge methodology, the extension of dredging further seaward will further extend the plume to Thevenard Island.

An alternative dredge methodology using a Backhoe Dredger has been simulated for comparison. A weekly production rate in the order of 24,000 m^3 corresponding to a daily forward movement of about 85m has been assumed. Spill rates have been assumed very low as it is assumed the material is cemented and taken away in lumps with very limited spill. Figure 1.5 shows the combined channel Dredge Scenario 4 and the Backhoe excavation for the entire section from KP 18 to KP 25. The assumed spill rates from the BHD dredging are so low that the combined plumes from the backhoe and the channel dredging rarely exceeds 5 mg/l (less than 5% of the time).

A similar comparison has been carried out for a winter scenario in Figure 1.6 and Figure 1.7 and a summer scenario in Figure 1.8 and Figure 1.9. Comparing the climatic scenarios shows that the largest "cumulative impacts" due to mixing of plumes from the channel and pipeline dredging for this area tends to occur during transitional conditions when the plumes tend to hang around the area more, but also during winter when the channel dredge plume is carried close to the pipeline dredge plume and some interaction occurs. The summer scenario demonstrates that the isolated CSD plume from the pipeline dredging cannot be discounted.

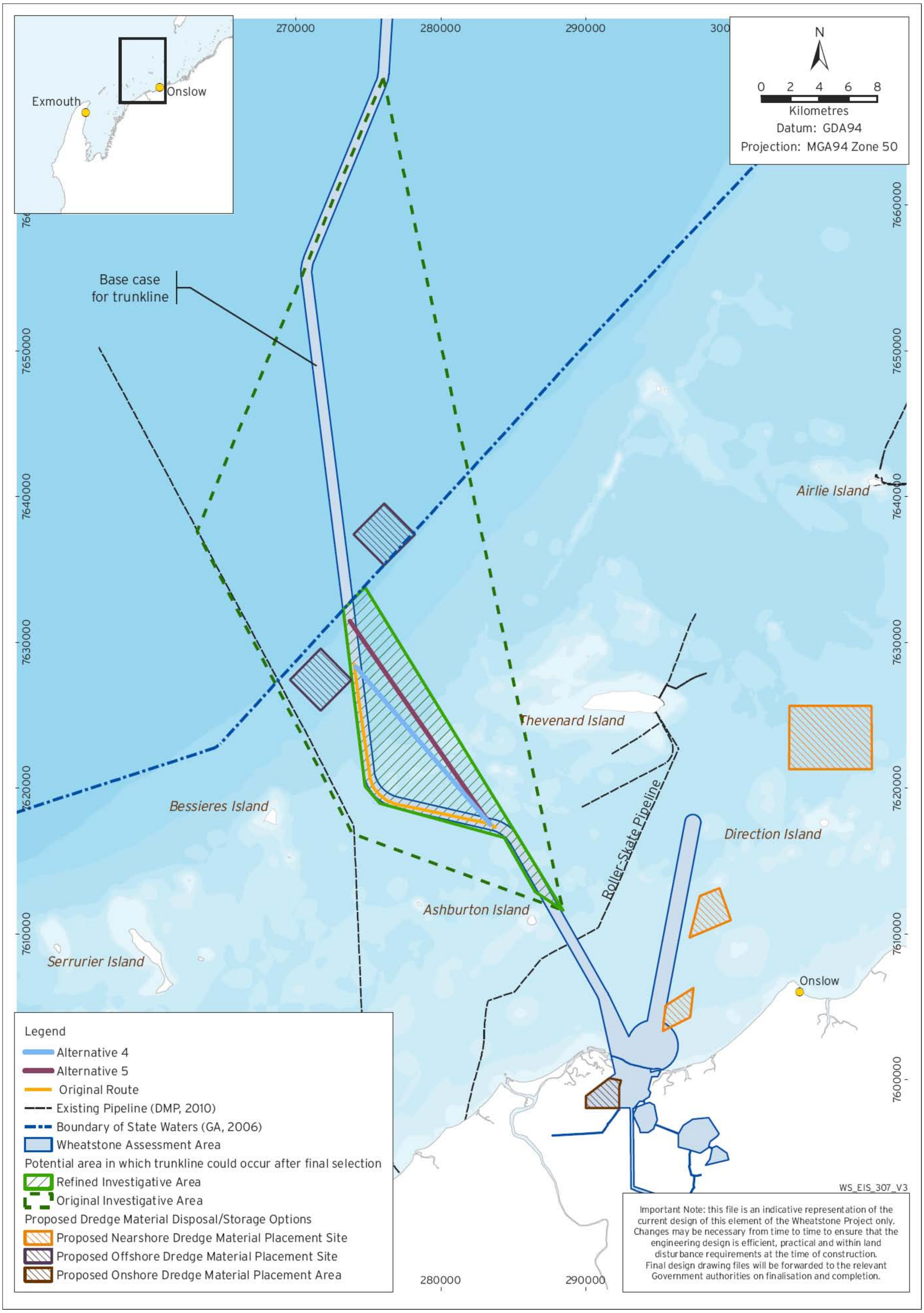

Figure 1.3 Alternative pipeline routes under consideration.

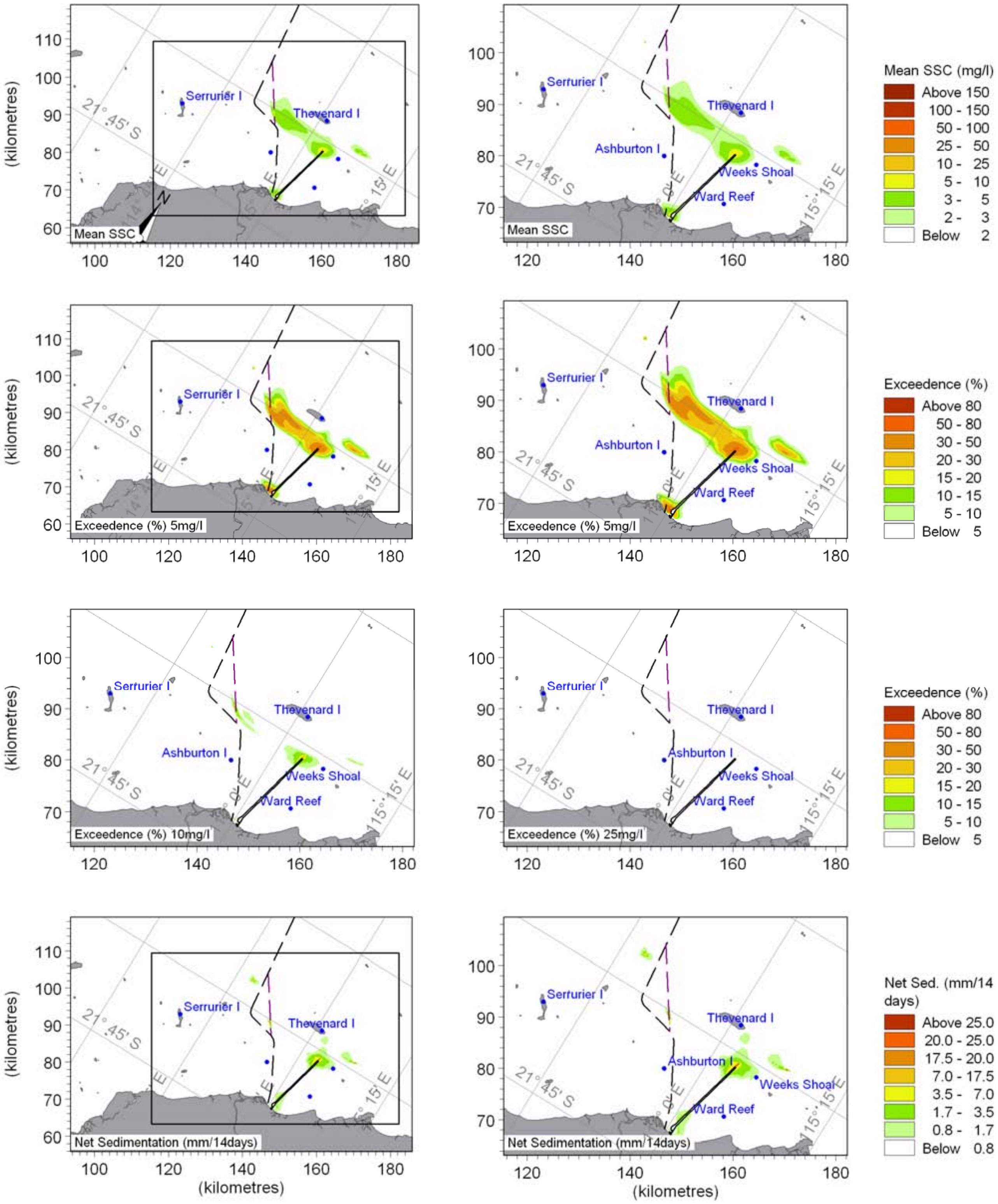

Figure 1.4 Plume statistics for simultaneous navigation channel Dredge Scenario 4 and CSD with adjacent overflow from barges dredging along Trunkline Alternative Route 5 (see Figure 1.3). Transitional conditions.

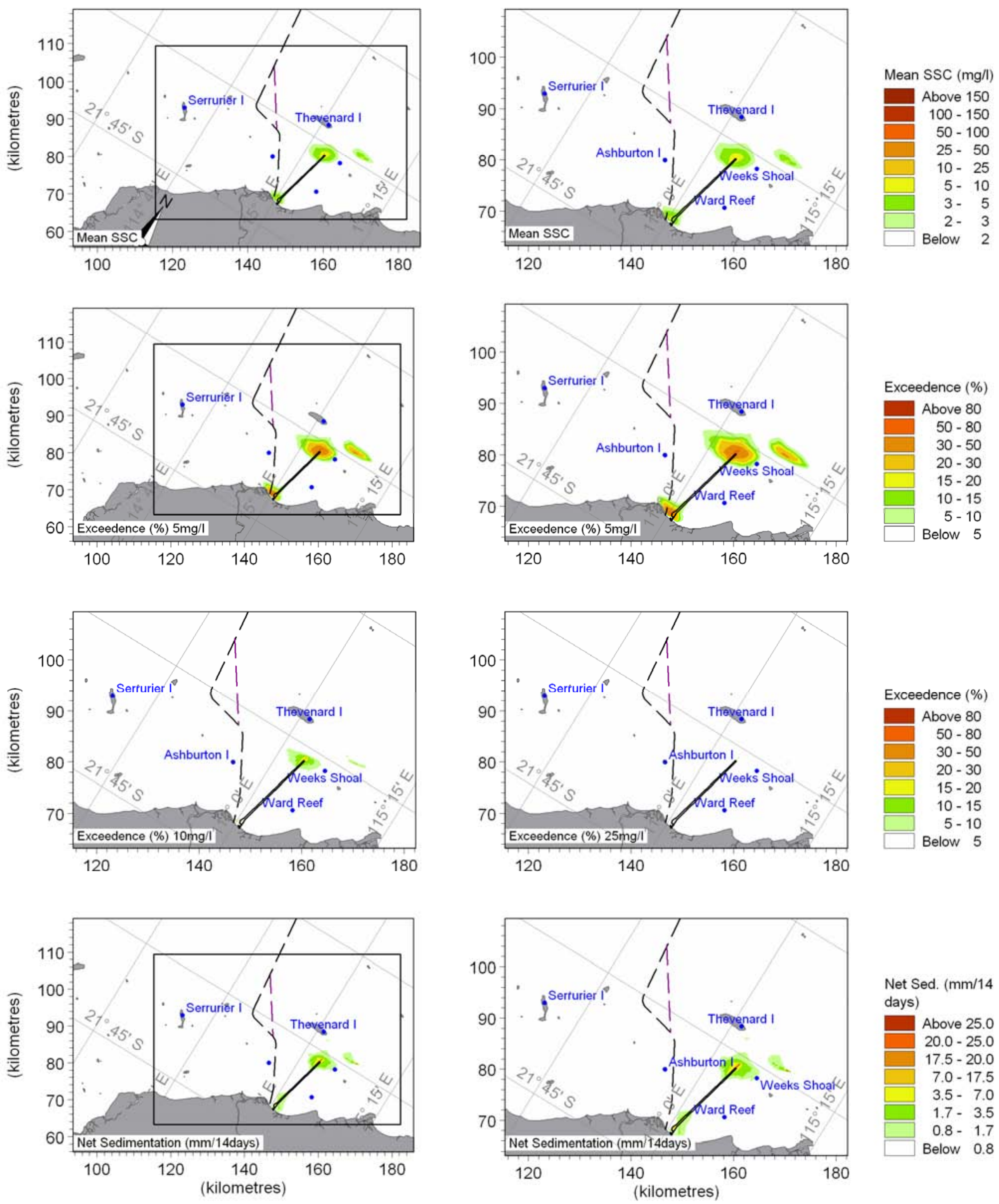

Figure 1.5 Plume statistics for simultaneous navigation channel Dredge Scenario 4 and BHD dredging with filling into adjacent barges from dredging along Trunkline Alternative Route 5 (see Figure 1.3). Transitional conditions.

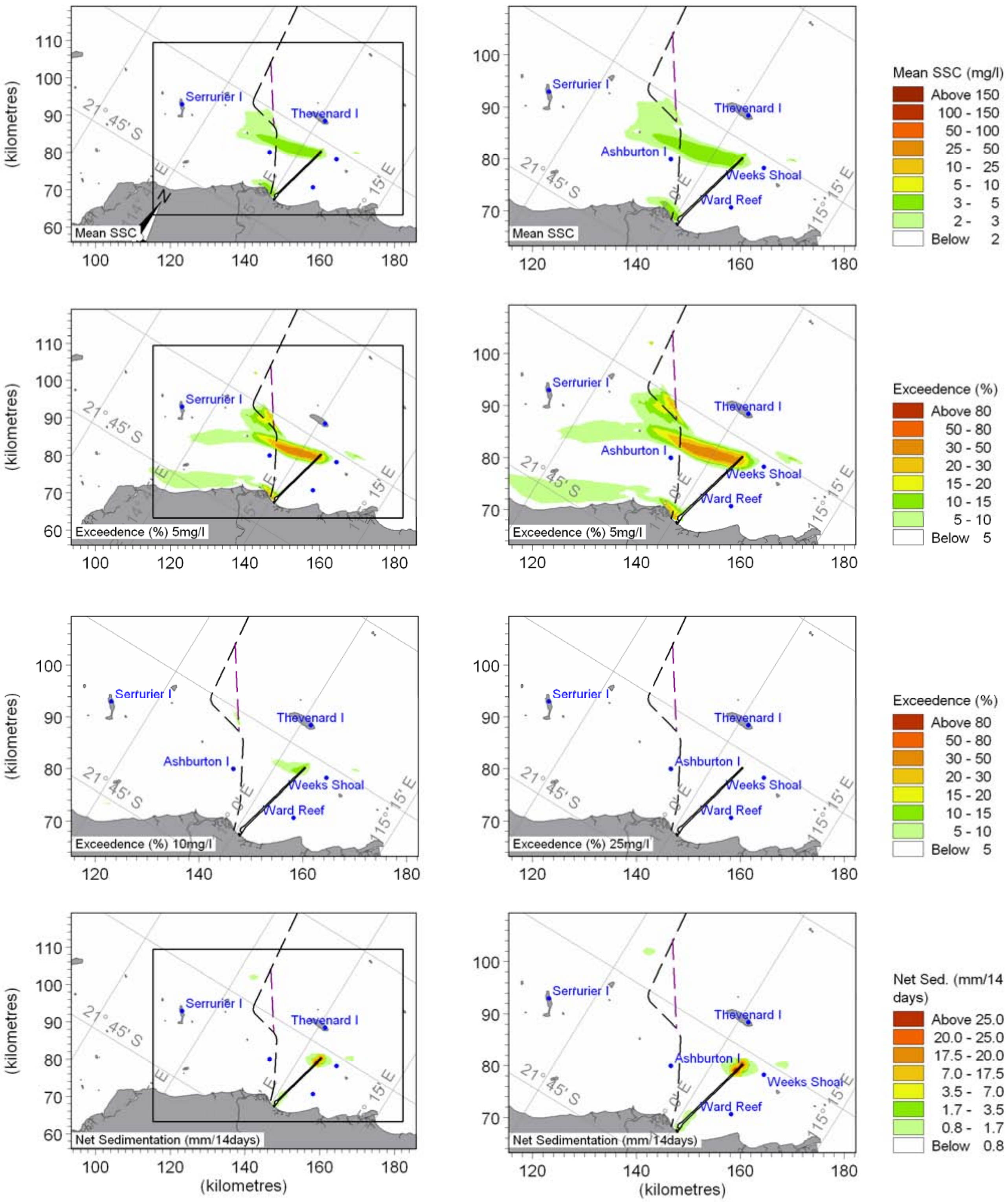

Figure 1.6 Plume statistics for simultaneous navigation channel Dredge Scenario 4 and CSD with adjacent overflow from barges dredging along Trunkline Alternative Route 5 (see Figure 1.3). Winter conditions.

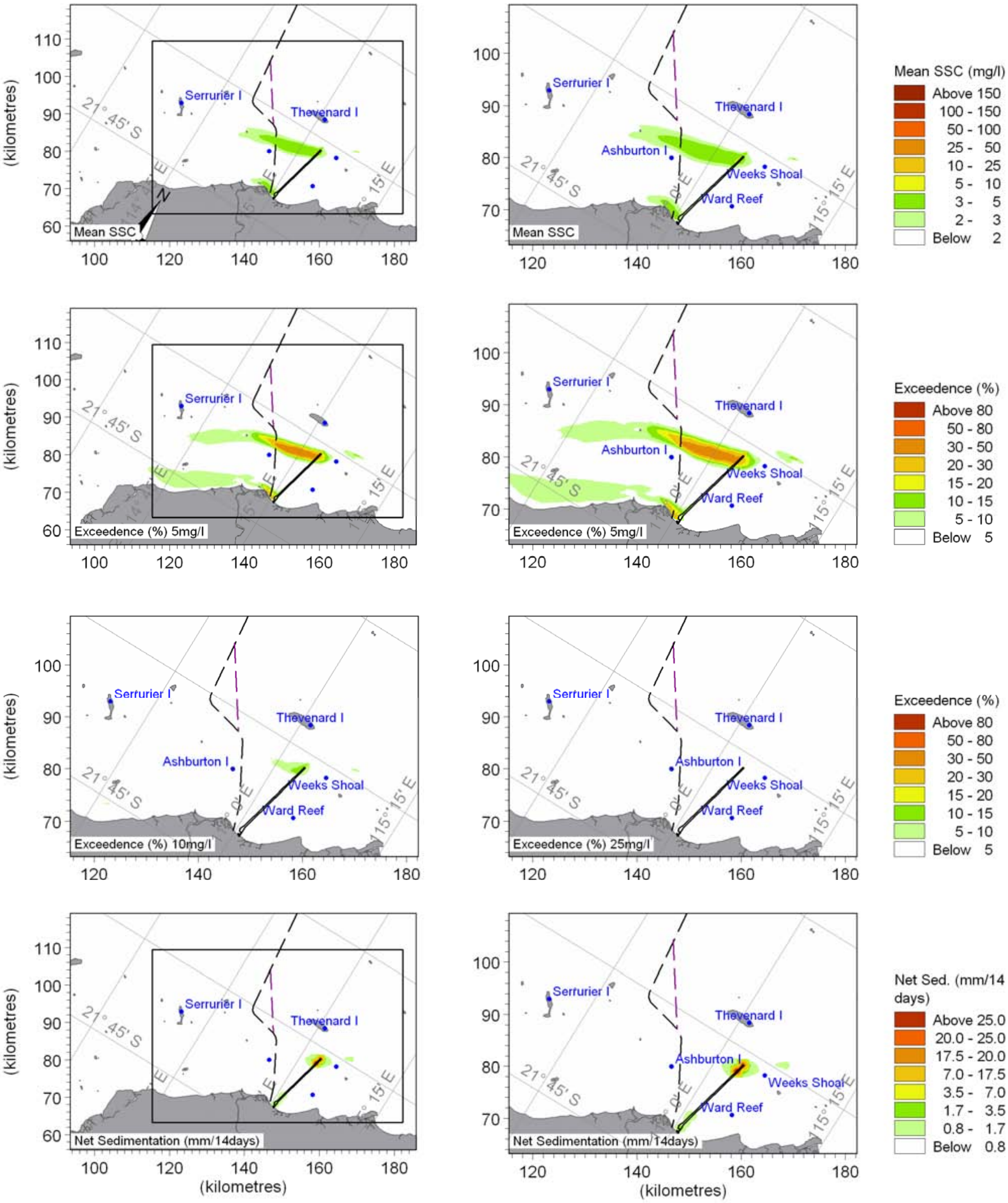

Figure 1.7 Plume statistics for simultaneous navigation channel Dredge Scenario 4 and BHD dredging with filling into adjacent barges from dredging along Trunkline Alternative Route 5 (see Figure 1.3). Winter conditions.

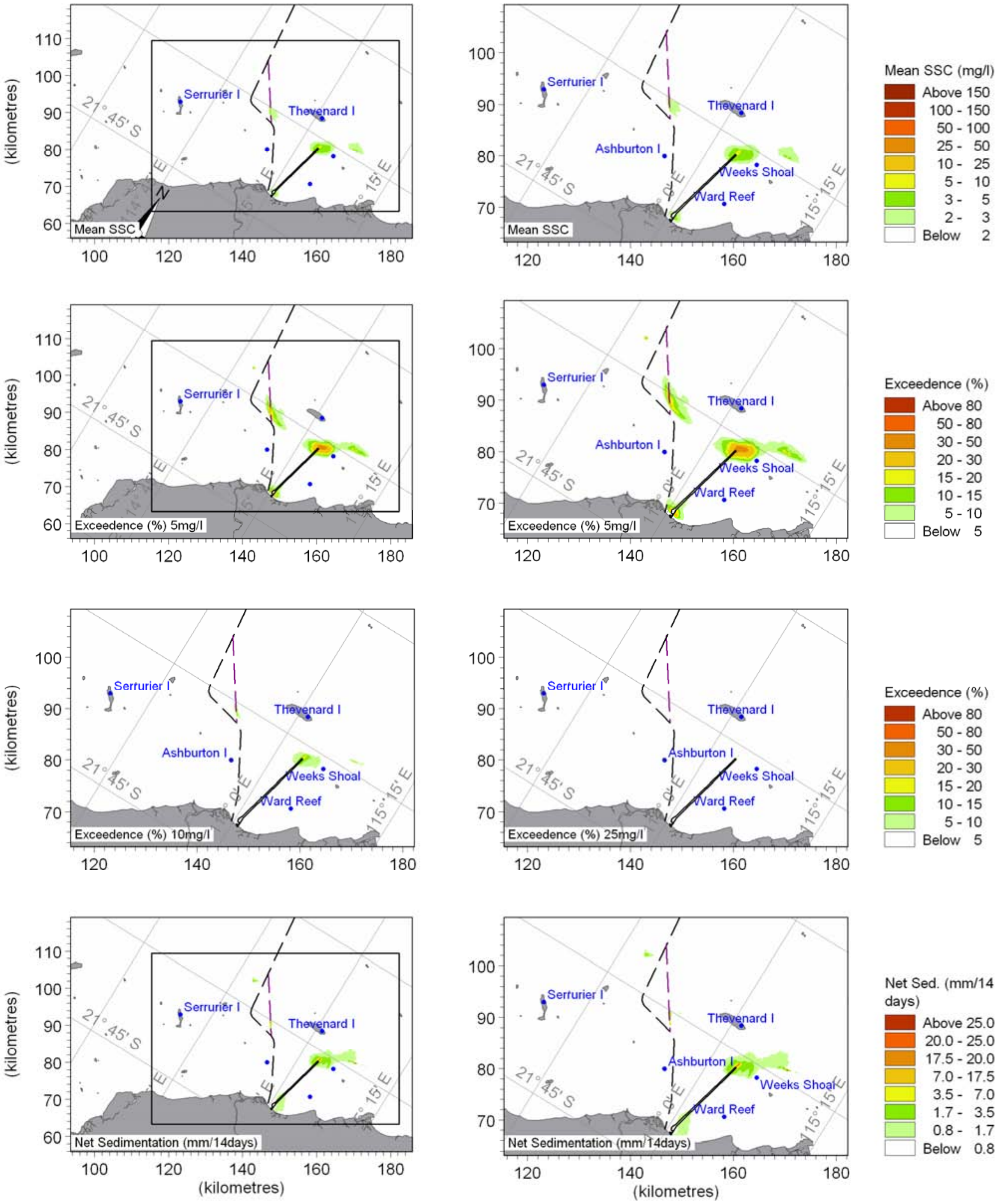

Figure 1.8 Plume statistics for simultaneous navigation channel Dredge Scenario 4 and CSD with adjacent overflow from barges dredging along Trunkline Alternative Route 5 (see Figure 1.3). Summer conditions.

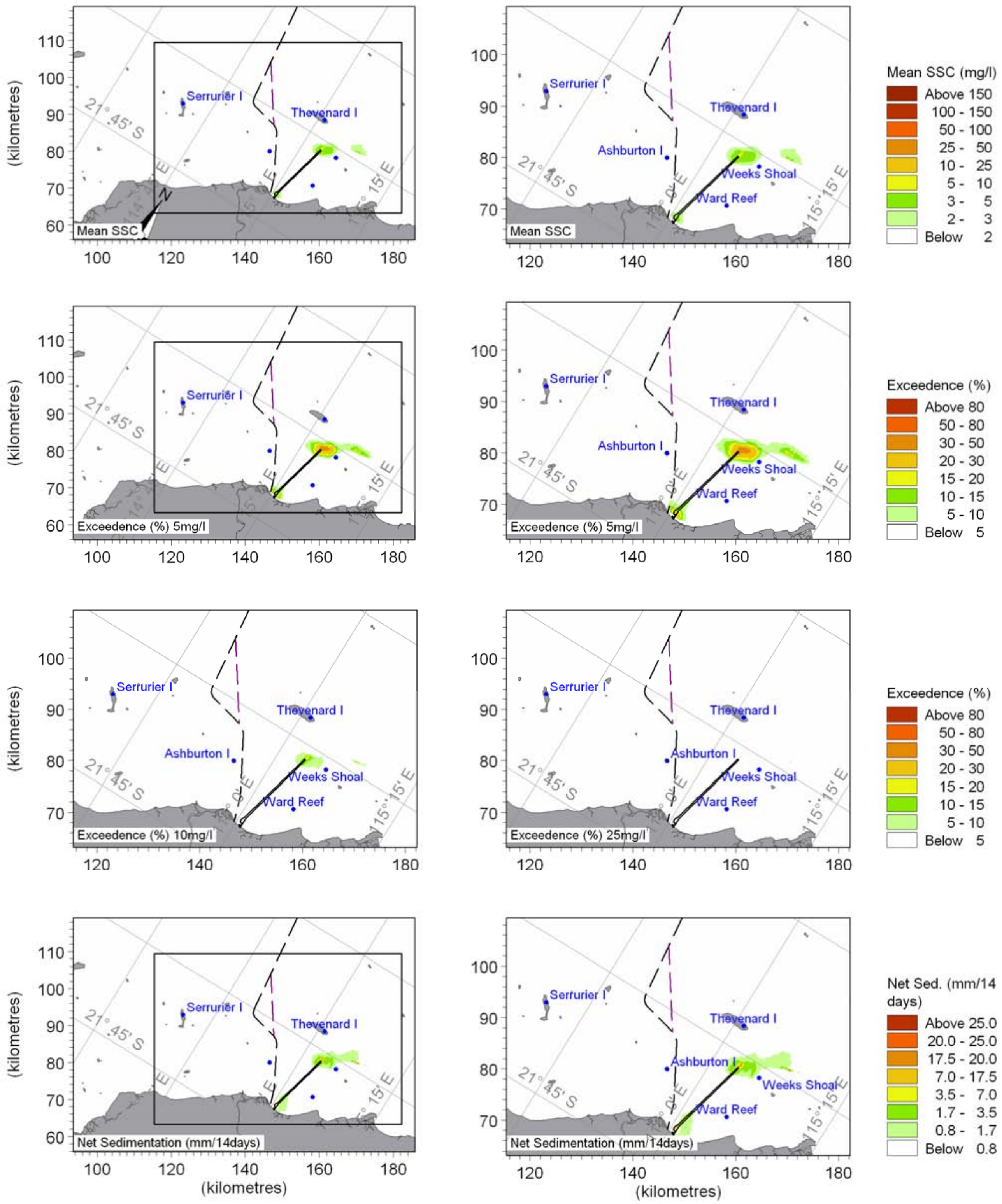

Figure 1.9 Plume statistics for simultaneous navigation channel Dredge Scenario 4 and BHD dredging with filling into adjacent barges from dredging along Trunkline Alternative Route 5 (see Figure 1.3). Summer conditions.

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Appendix FO

Updates to Hydrocarbon Spill Modelling

This report has been provided as part of the supplementary information for the Draft EIS/ERMP. This report updates the Draft EIS/ERMP Appendix Q2: Hydrocarbon Spill Modeling to further address public submissions submitted in relation to potential impacts to marine habitats from a hydrocarbon spill. Revisions to the assessment have arisen as a result of need to enlarge the model coverage (domain) to show the full extent of the predicted spills in relation to sensitive habitat in the Project area. Of the eight scenarios modeled for the Draft EIS/ERMP, remodeling based on an increase in the domain size for six of the scenarios was undertaken. Results for Scenario 2 and Scenario 6 remain unchanged. Summary updates for Scenarios 1, 3, 4, 5, 7A and 7B are given below:

- Scenario 1
  - The domain for Iago No. 1 Well has been extended to cover an area of approximately 2 200 km x 1 400 km. Simulations based on a hydrodynamic model with a grid resolution of 3645 m with results of spill modelling saved in an enhanced 1215 m grid resolution.
- Scenario 3
  - The domain for the trunkline Shipping Channel Crossing has been extended to cover an area of approximately 1 900 km x 1 180 km. Simulations are based on a hydrodynamic model with a grid resolution of 3645 m with results of spill modelling saved in an enhanced 405 m grid resolution.
- Scenario 4
  - The domain has been extended to cover an area of approximately 400 km x 250 km, with dynamic nesting of different grid resolutions (135 m, 405 m and 1215 m) to ensure an adequate and detailed description of shallow water hydrodynamics near the product loading facility. Results of spill simulations have been saved in a grid with a resolution of 405 m.
- Scenario 5
  - The domain has been extended to cover an area of 62 km x 26 km with dynamic nesting of different grid resolutions (15 m, 45 m and 135 m) to ensure an adequate and detailed description of shallow water hydrodynamics in and around the materials offloading facility. Results of spill simulations have been saved in a grid with a resolution of 45 m.
- Scenario 7 (A and B)
  - The domain has been extended to cover an area of approximately 1 900 km x 1 180 km. Simulations are based on a hydrodynamic model with a grid resolution of 3645 m, with results of spill modelling saved in an enhanced 405 m grid resolution.

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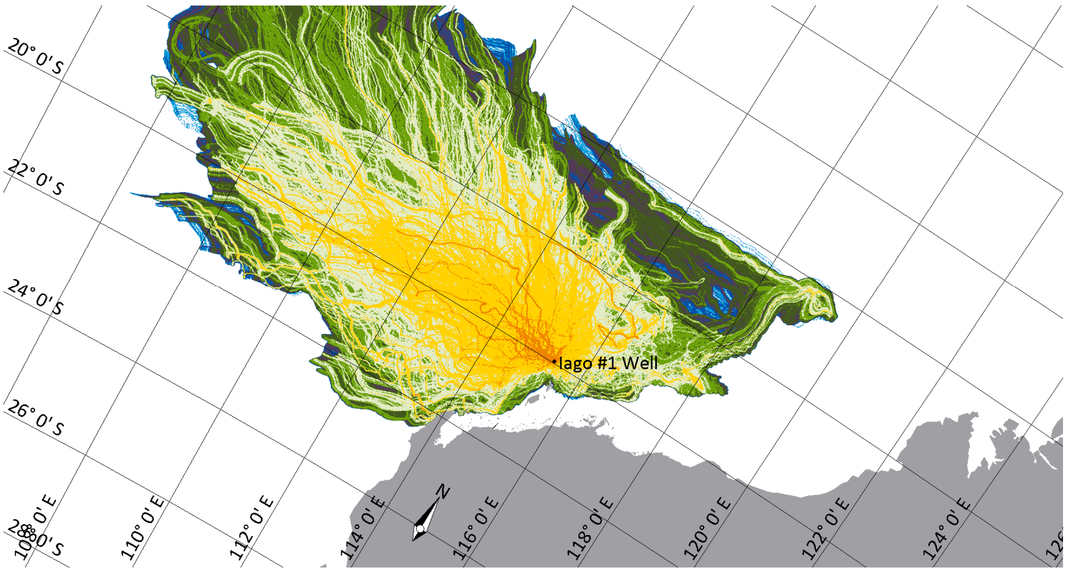
Wheatstone Project

Hydrocarbon Spill Modelling

Addendum to: Hydrocarbon Spill Modelling – May 2010



Chevron Australia Pty Ltd **October 2010**

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Wheatstone Project

Hydrocarbon Spill Modelling

Addendum to: Hydrocarbon Spill Modelling – May 2010

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Project Title	Project / Report No
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Authors Cesar Rocha Dr Kim Parsberg Jakobsen Claus Pedersen	Date October 20, 2010 Approved by Dr Kim Parsberg Jakobsen

Revision	Description	By	Checked	Approved	Date
	Proposal				

Key words	Classification
Wheatstone Diesel and Condensate Spill MIKE 21 Oil Spill Model	☐ Open ☐ Internal ☒ Proprietary

Distribution	No of copies
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CONTENTS

FIGURES AND TABLES

APPENDICES

1 INTRODUCTION

DHI was commissioned by Chevron Australia Pty Ltd to undertake oil spill modelling for the Wheatstone Project. A number of spill scenarios were modelled as part of the Wheatstone Project EIA.

Presented in Appendix Q2 of the Wheatstone Draft EIS/ERMP is an outline of the study approach, a short description of the oil spill processes and environmental properties, description of the spill scenarios and results of the assessment. The reader is directed to EIS/ERMP Appendix Q2 for more detailed information.

This addendum presents the results for revised spill scenarios that have been undertaken since the release of the Wheatstone Project EIA. The revisions to the scenarios focus on the increase in the size of the study area in order to address limitations in interpretation associated with the results presented in the EIA.

1.1 Background

For the assessment of impacts due to spill of hydrocarbons a probabilistic approach has been adopted. Thus for each spill scenario a large number of simulations with a large variety of normally occurring combinations of wind and currents have been performed. By combining the simulations an “envelope” of potentially affected areas is derived, being presented as a map providing information on the probability of a given area being impacted by a hydrocarbon spill.

The results in the present addendum mainly covers scenarios that have been revised in terms of model coverage (domain) as results in EIS/ERMP Appendix Q2 highlighted the potential spilled oil to impact areas outside the previously defined model domain.

2 CHANGES TO THE PREVIOUS SCENARIOS

Of the eight scenarios undertaken for the EIA, remodelling based on an increase in the domain size for six of the scenarios was undertaken. Results for Scenario 2 and Scenario 6 remain unchanged for the following reasons:

- The impacted area of Scenario 2 lies entirely within the model domain.

- For the spill inside the MOF (Scenario 6) mitigation measures are imposed (combating) and most of the spilled oil should remain inside the MOF (the impact due to lack of combating is included in Scenario 5, which has been re-run).

Changes to scenarios are described in subsequent sections.

2.1 Scenario 1

The revisions to Scenario 1 include:

- The domain for Iago #1 Well has been extended to cover an area of approximately 2,200km×1,400km. Simulations based on a hydrodynamic model with a grid resolution of 3645m with results of spill modelling saved in an enhanced 1215m grid resolution.
- MesoLaps wind fields used for both derivation of hydrodynamic conditions and for wind induced drift and weathering of condensate.
- Number of simulations increased from 36 to 72 to improve the base for the statistical analysis. Previous simulations covered the years of 2006 through 2008, while the new simulations also include the period of 2002 through 2004.

2.2 Scenario 3

- The domain for the Shipping Channel Crossing has been extended to cover an area of approximately 1,900km×1,180km. Simulations are based on a hydrodynamic model with a grid resolution of 3645m with results of spill modelling saved in an enhanced 405m grid resolution.
- MesoLaps wind fields used for both derivation of hydrodynamic conditions and for wind induced drift and weathering of condensate.

2.3 Scenario 4

- The domain has been extended to cover an area of approximately 400km×250km with dynamic nesting of different grid resolutions (135m, 405m and 1215m) to ensure an adequate and detailed description of shallow water hydrodynamics near the PLF. Results of spill simulations have been saved in a grid with a resolution of 405 m
- MesoLaps wind fields used for both derivation of hydrodynamic conditions and for wind induced drift and weathering of condensate.

2.4 Scenario 5

- Domain has been extended to cover an area of 62km×26km with dynamic nesting of different grid resolutions (15m, 45m and 135m) to ensure an adequate and detailed description of shallow water hydrodynamics in and around the MOF. Results of spill simulations have been saved in a grid with a resolution of 45 m.

2.5 Scenario 7 (A and B)

- Domain has been extended to cover an area of approximately 1,900km×1 180km. Simulations are based on a hydrodynamic model with a grid resolution of 3645 m with results of spill modelling saved in an enhanced 405 m grid resolution
- MesoLaps wind fields used for both derivation of hydrodynamic conditions and for wind induced drift and weathering of condensate.

2.6 Summary

The revised scenarios with information on spill simulations are summarised in the Table 2.1.

Table 2.1 Overview of revised scenarios and spill simulations.

Scenario Number	**1**	**3**	**4**	**5**	**7a**	**7b**
Scenario Id	A	F	G	H	J	J
Location	Iago #1 Well	Shipping channel crossing	PLF	MOF	Tanker Grounding Point A	Tanker Grounding Point B
Spill Duration	90 days	5 days	1 minute	Instantaneous	5 days	5 days
Simulation Duration	100 days	15 days	10 days	10 days	15 Days	15 Days
HD model grid resolution	3645 m	3645 m	1215 m	135 m	3645m	3645m
Output grid resolution	1215 m	405 m	405 m	45 m	405m	405m
Number of Simulations	72	324	324	324	324	324

Key

3 KEY FINDINGS

The key findings are presented in the following sections with figures presented in Appendix A to F.

While these results present the maximum extent of the slick for the different spill scenarios, the reader is directed to EIS/ERMP Appendix Q2 for a more detailed description of impacts in close proximity to the spill locations.

3.1 Scenario 1

Figures associated with Scenario 1 are presented in Appendix A.

For the revised scenario slightly higher concentrations are observed in the offshore area. The change is attributed to the increased number of scenarios considered compared to that reported in the EIA as well as seasonal variability.

For previous simulations with different wind conditions (EIS/ERMP Appendix Q2) the oil slick reached the coastline during summer and transitional periods. However, at the location of the well the MesoLaps wind fields have a stronger south-westerly wind during summer and transitional periods and the oil slick is no longer predicted to reach the coastline.

The oil slick is predicted to stay within the domain for more than 95% of the simulations and maps show the maximum exposure for the given threshold of oil concentration.

Note: Legend for the '*time of exposure'* plots has been extended to accommodate for the longer duration of simulations.

3.2 Scenario 3

Figures associated with Scenario 3 are presented in Appendix B.

The revised scenario results in an exposure that is very similar to what was reported in EIS/ERMP Appendix Q2. However, the difference in wind forcing results in a lower south-westerly oil slick excursion during the summer period.

The risk of the slick reaching the shore and entering the Exmouth Bay is apparent.

3.3 Scenario 4

Figures associated with Scenario 4 are presented in Appendix C.

The oil slick disperses around 200km towards the northeast during the summer period and it will during the winter period disperse towards southwest entering Exmouth Gulf. During the transitional period there is low a risk of the oil slick passing west of Barrow Island.

Due to the proximity to the coastline the oil slick may reach the coastline in a short period of time (i.e. less than 6 hours).

3.4 Scenario 5

Figures associated with Scenario 5 are presented in Appendix D.

Approximately 40km of the surrounding coastline may be impacted by a spill. During the summer period the oil slick may move up to 30km along the coast line in a north-easterly direction. Although the impact on the coastline is eminent the plume is not expected to reach the Exmouth Bay area.

3.5 Scenario 7

Figures associated with Scenario 7a and Scenario 7b are presented in Appendix E and F respectively.

Impacts are due to the large spill significant and the oil slick may impact up to 300km of the coastline. During transitional and winter periods the oil slick will likely enter Exmouth Gulf. Due to the stronger south-westerly winds during the summer period (prescribed by the MesoLaps wind fields) the oil slick is not predicted to reach the Exmouth Headland.

Note: Legend for the '*maximum oil concentration'* plots has been extended to accommodate for higher concentrations.

R E S U L T S

A D D E N D U M A

Scenario 1 – Condensate Spill at Iago #1 Well

Key Results

A SCENARIO 1

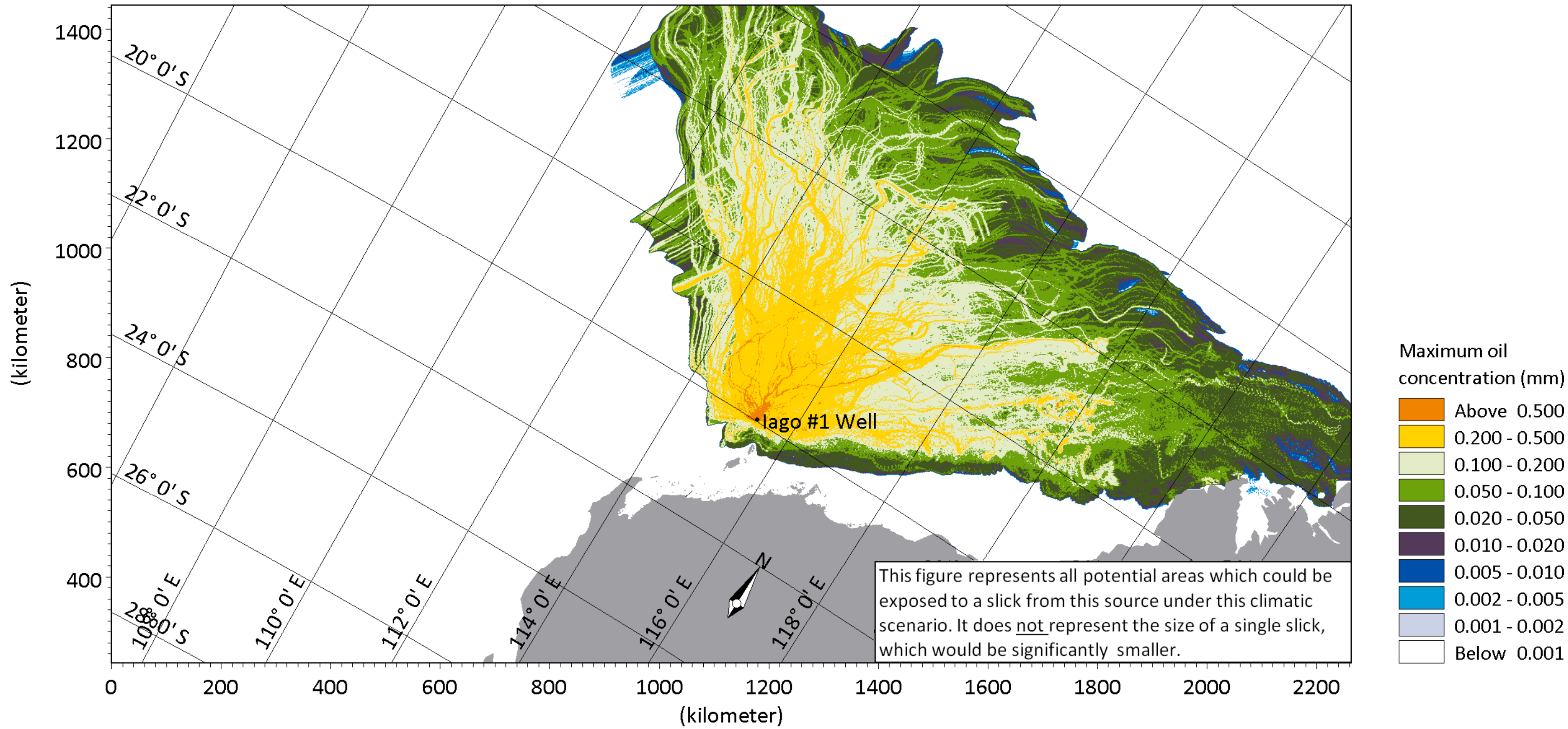

Figure A.1 Maximum oil concentration for condensate spill at Iago #1 Well (summer).

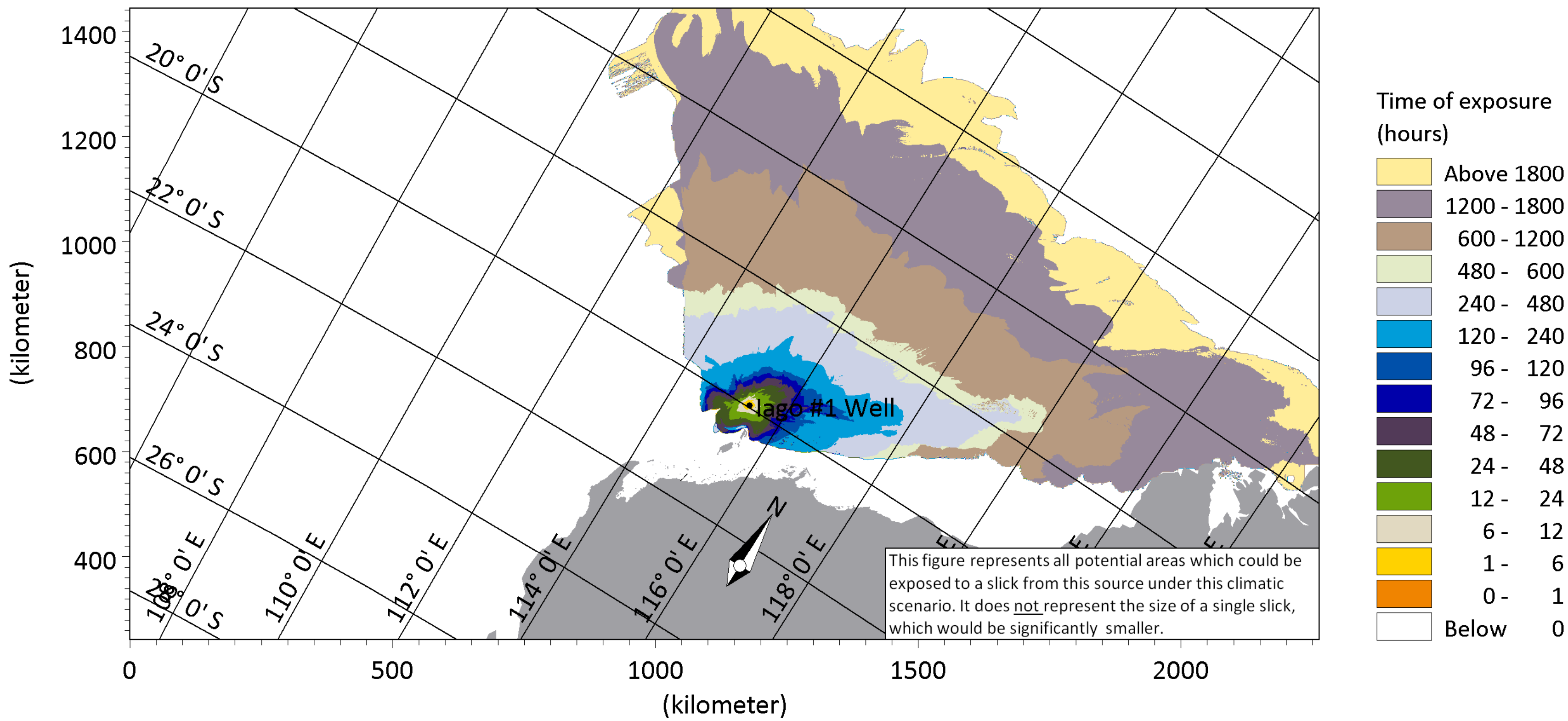

Figure A.2 Minimum time of exposure for condensate spill at Iago #1 Well (summer).

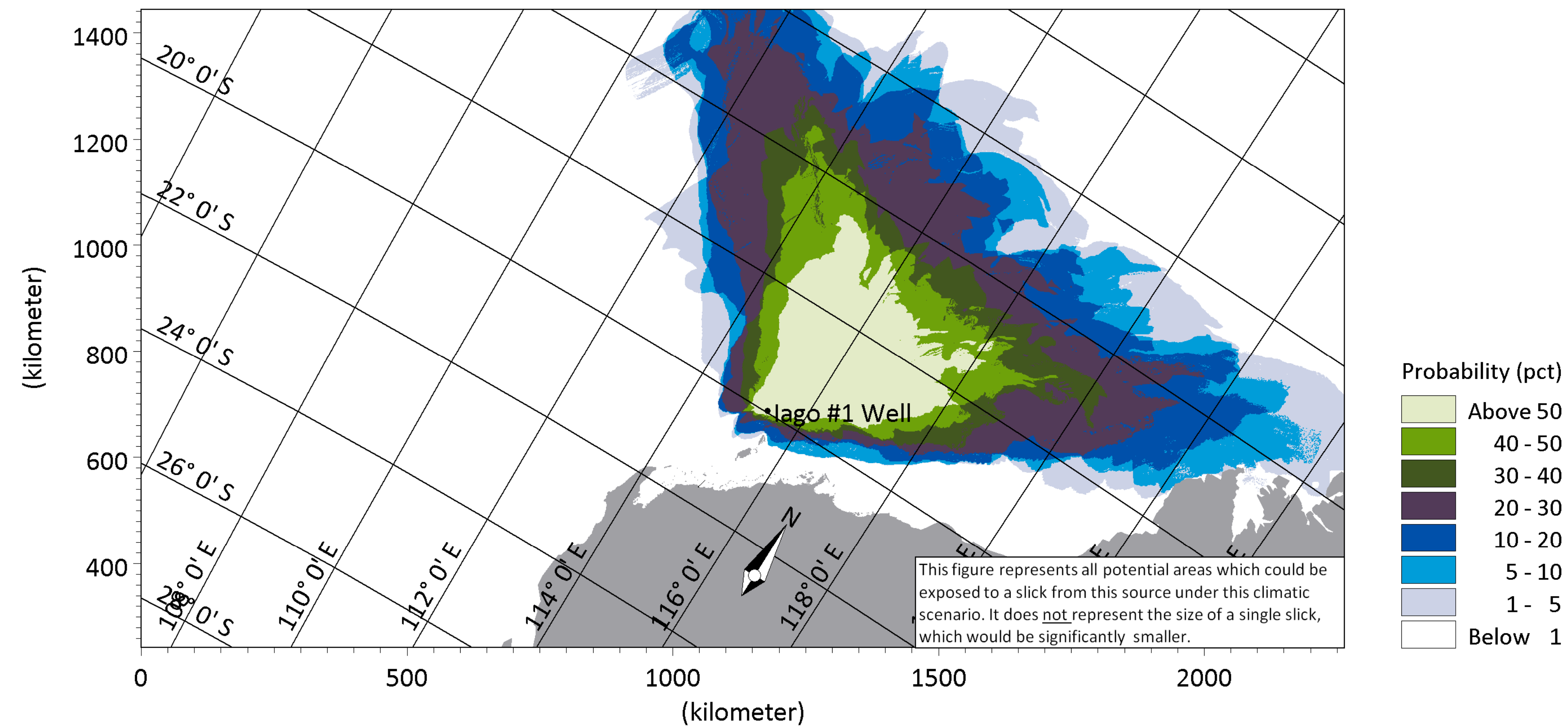

Figure A.3 Probability of exposure for condensate spill at Iago #1 Well (summer).

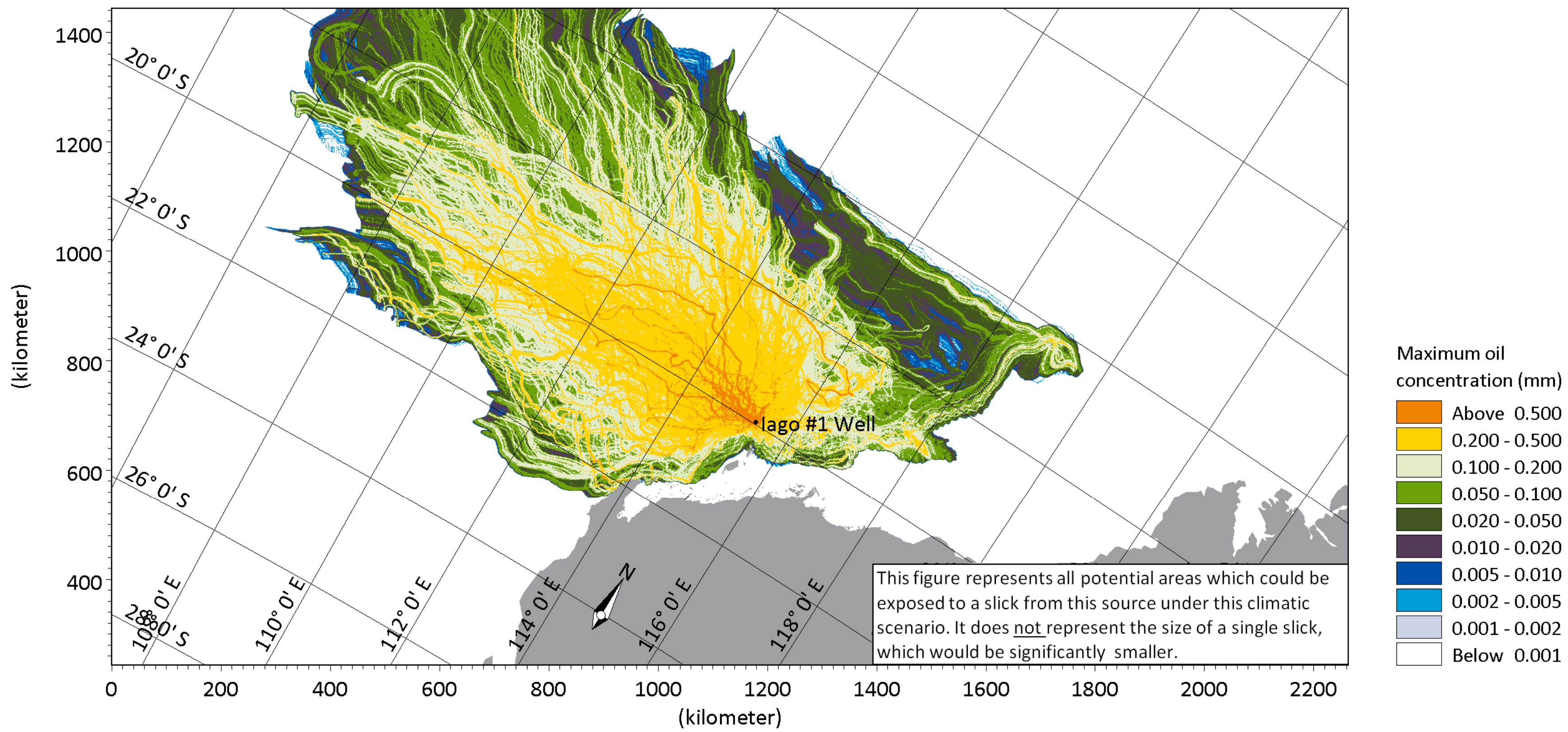

Figure A.4 Maximum oil concentration for condensate spill at Iago #1 Well (transitional).

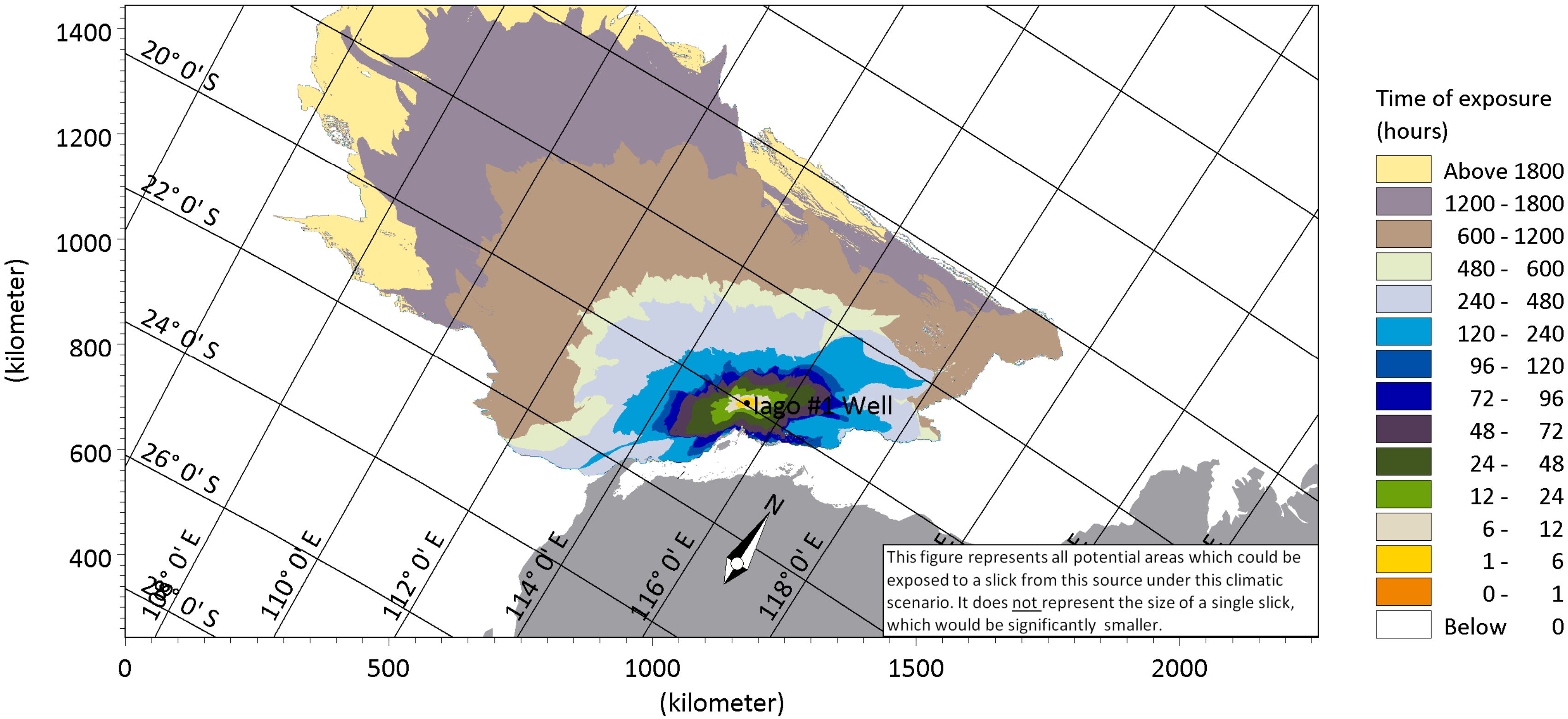

Figure A.5 Minimum time of exposure for condensate spill at Iago #1 Well (transitional).

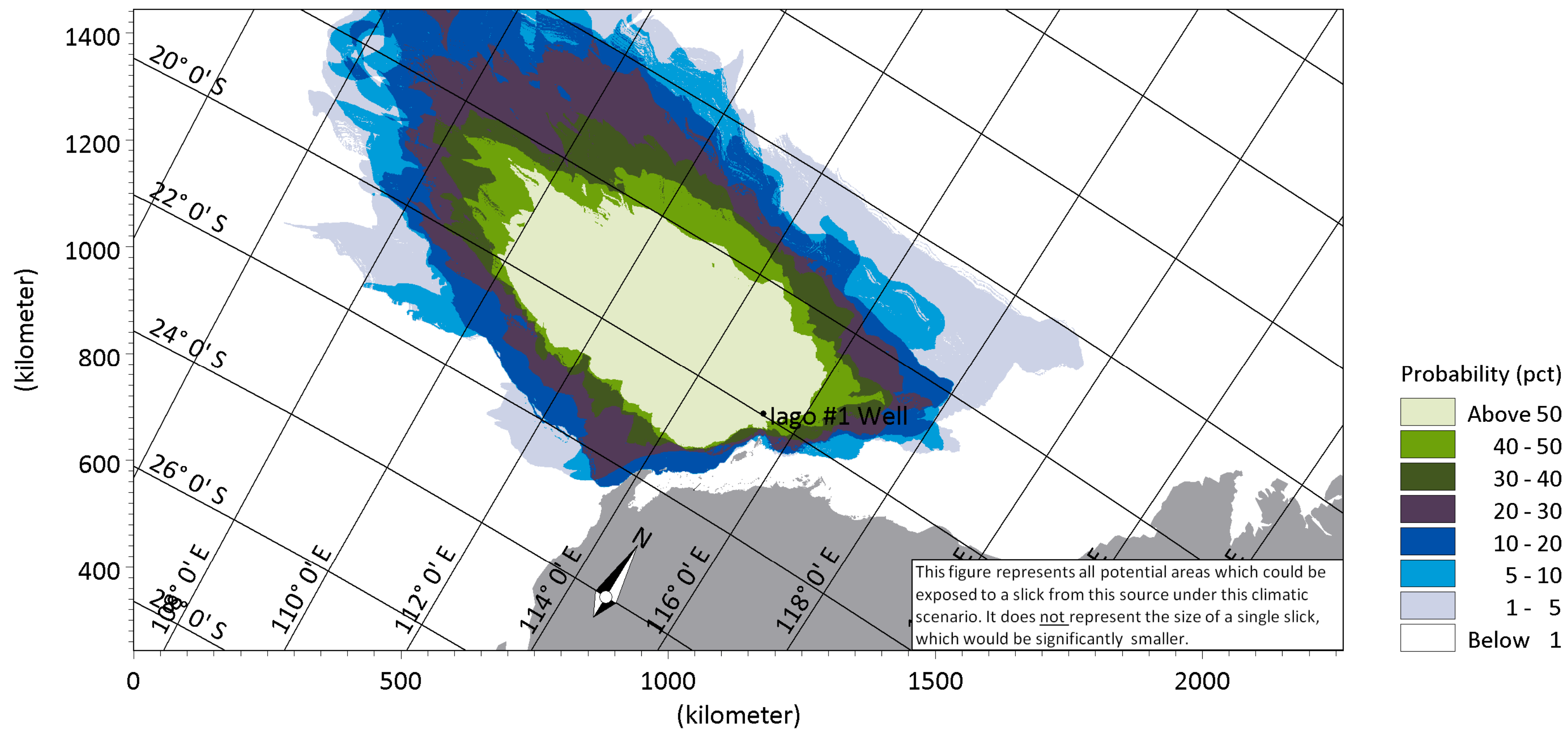

Figure A.6 *Probability of exposure for condensate spill at Iago #1 Well (transitional).*

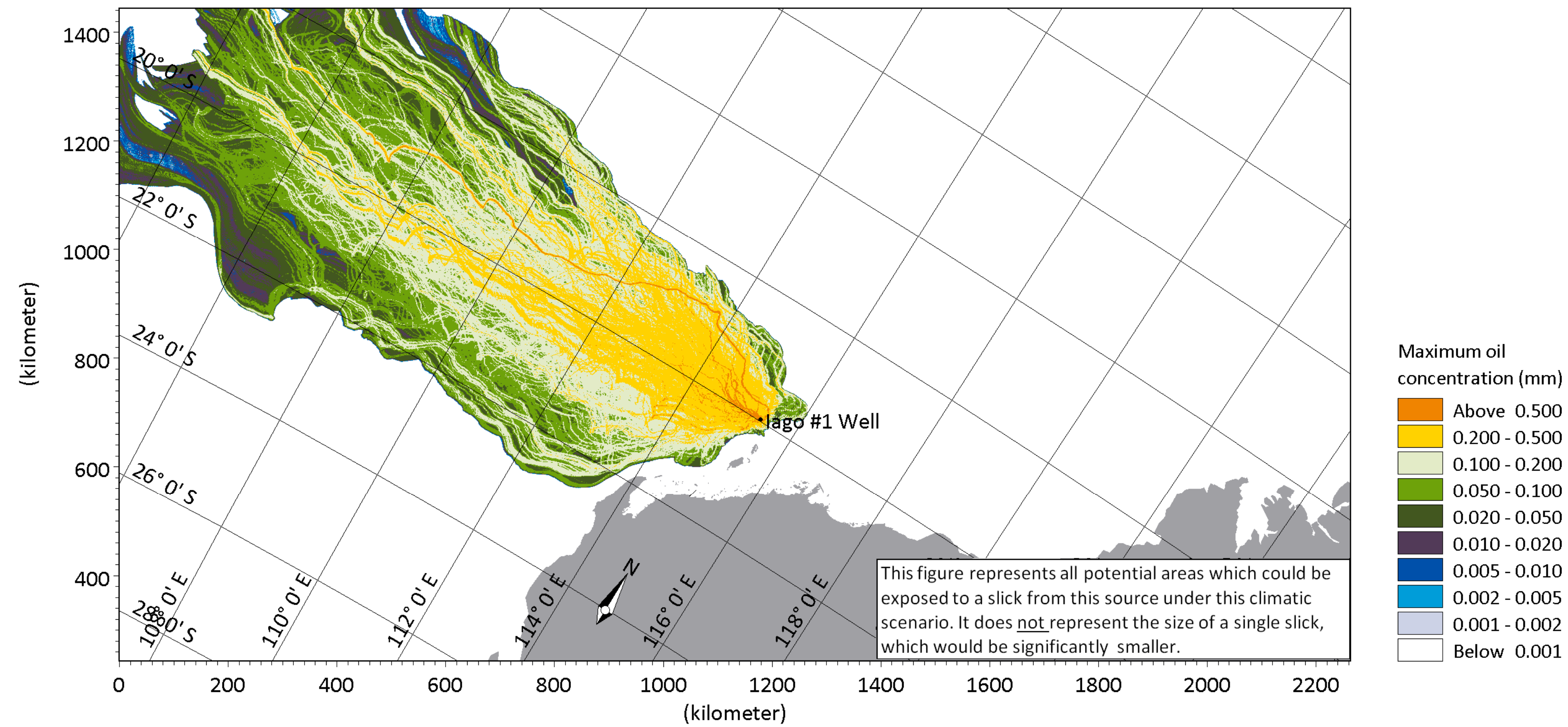

Figure A.7 Maximum oil concentration for condensate spill at Iago #1 Well (winter).

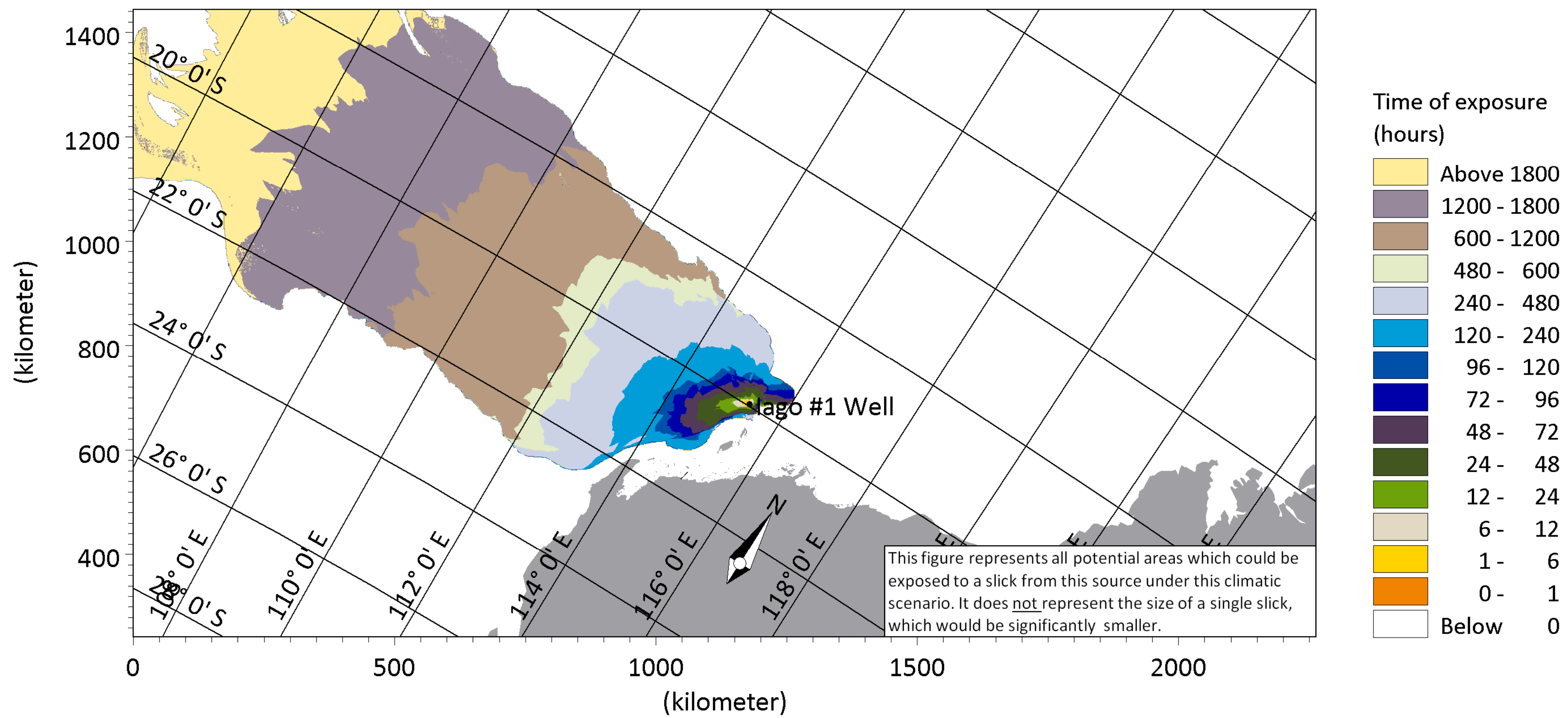

Figure A.8 Minimum time of exposure for condensate spill at Iago #1 Well (winter).

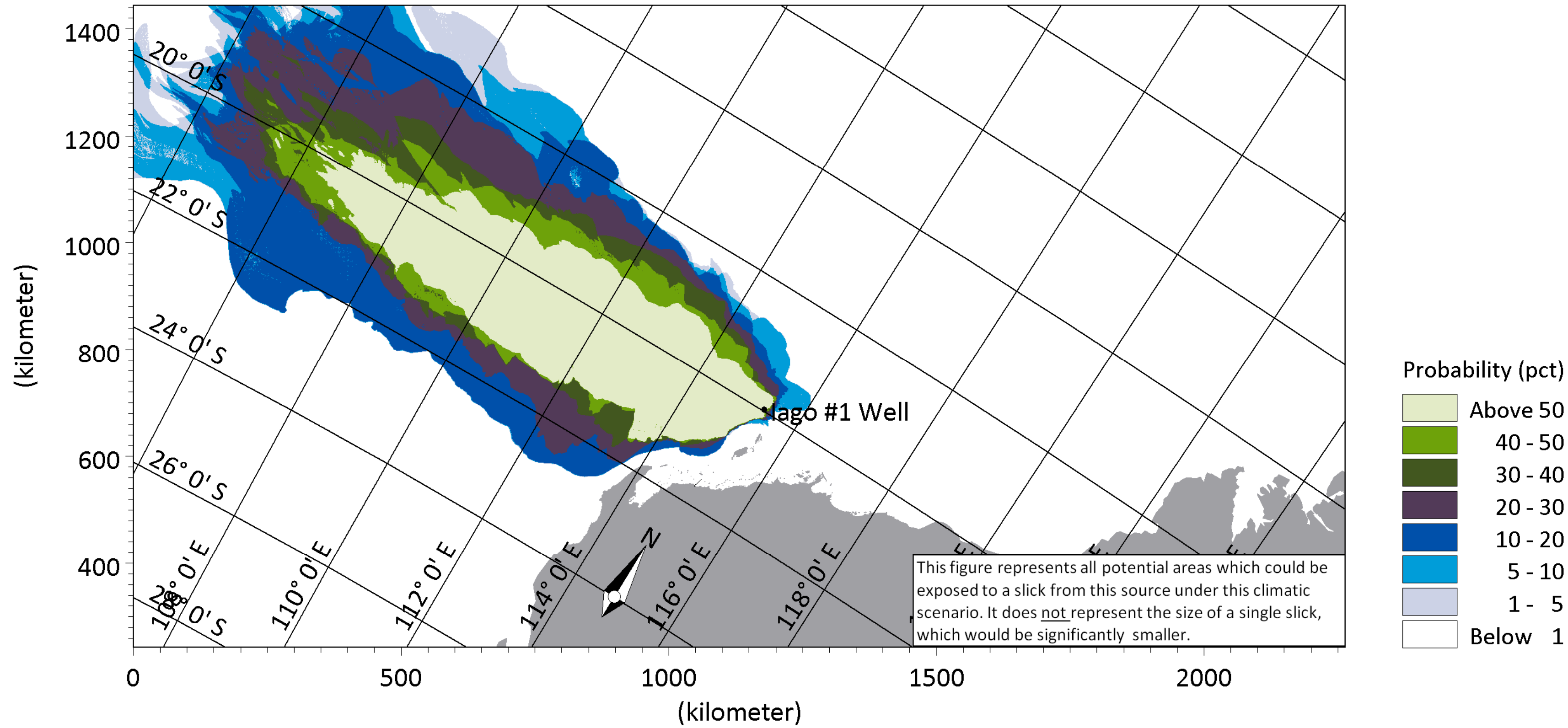

Figure A.9 Probability of exposure for condensate spill at Iago #1 Well (winter).

A D D E N D U M   B

Scenario 3 – Condensate Leak at Shipping Channel

Key Results

B SCENARIO 3

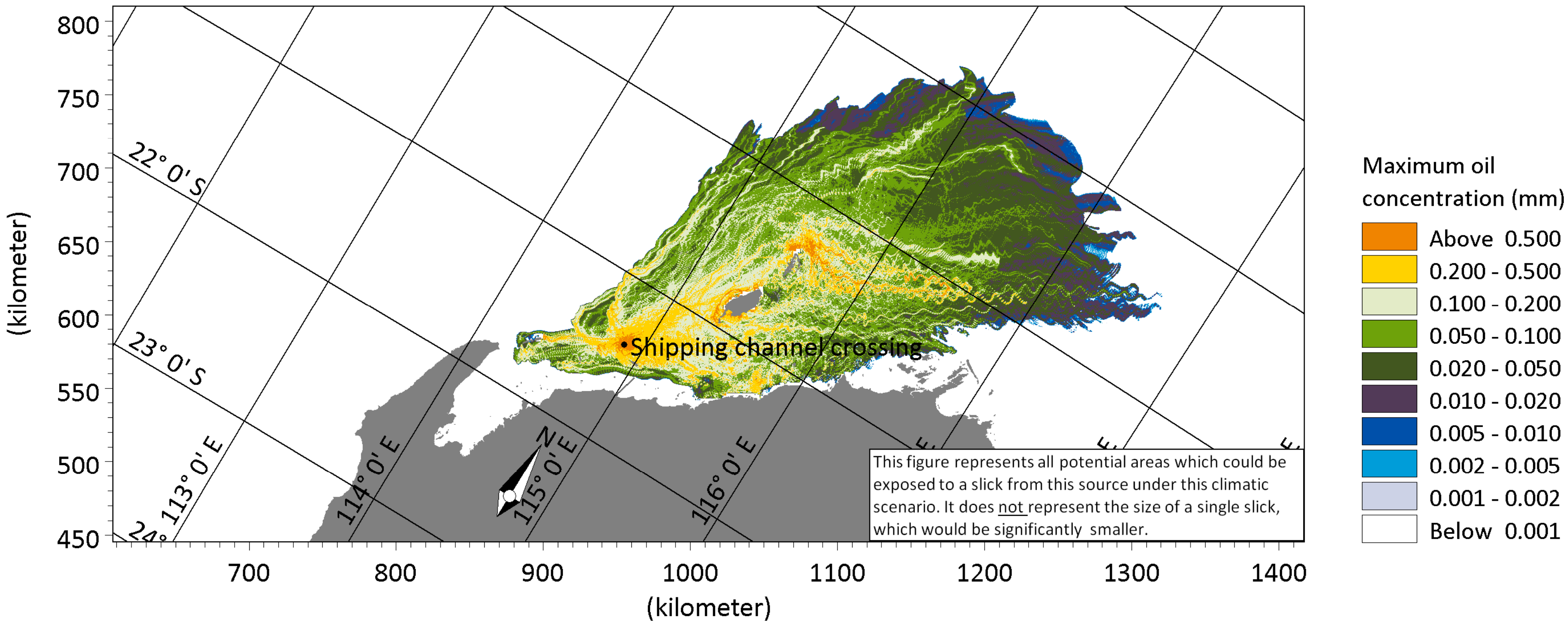

Figure B.1 Maximum oil concentration for condensate leak at shipping channel (summer)

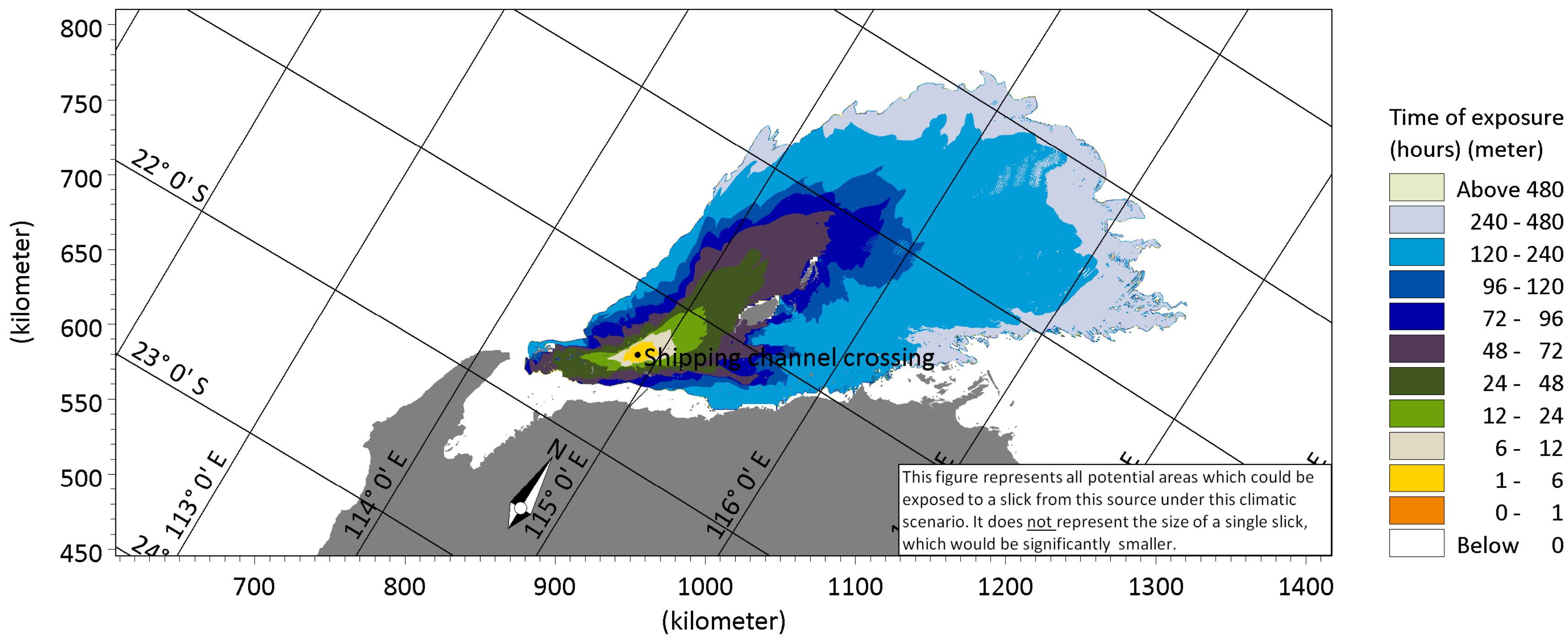

Figure B.2 Minimum time of exposure for condensate leak at shipping channel (summer).

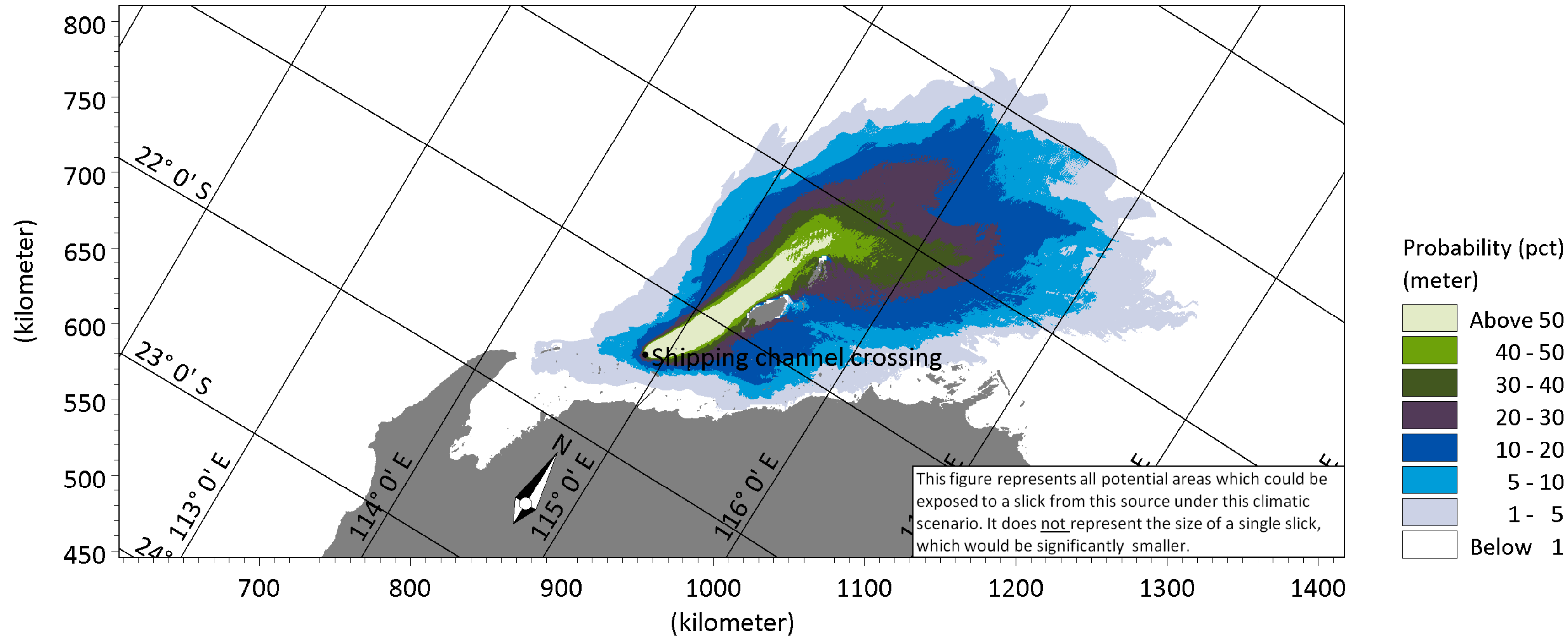

Figure B.3 Probability of exposure for condensate leak at shipping channel (summer).

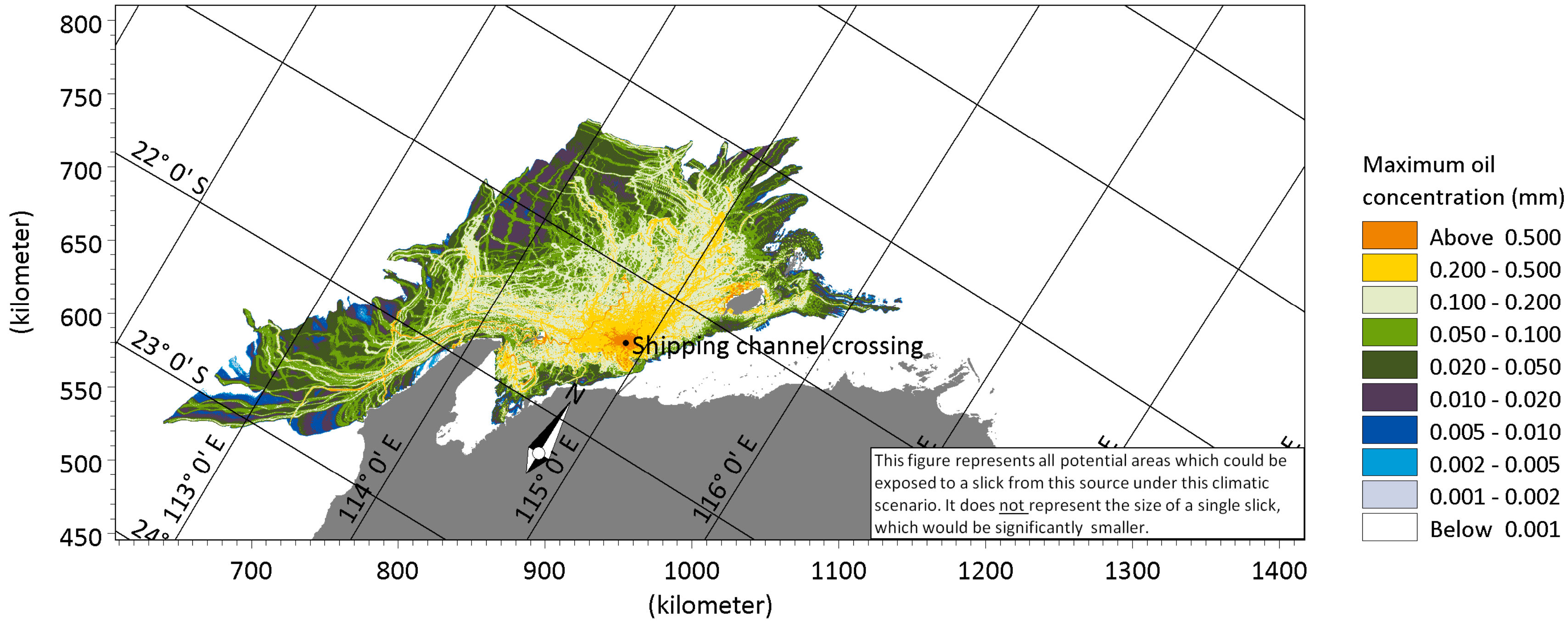

Figure B.4 Maximum oil concentration for condensate leak at shipping channel (transitional).

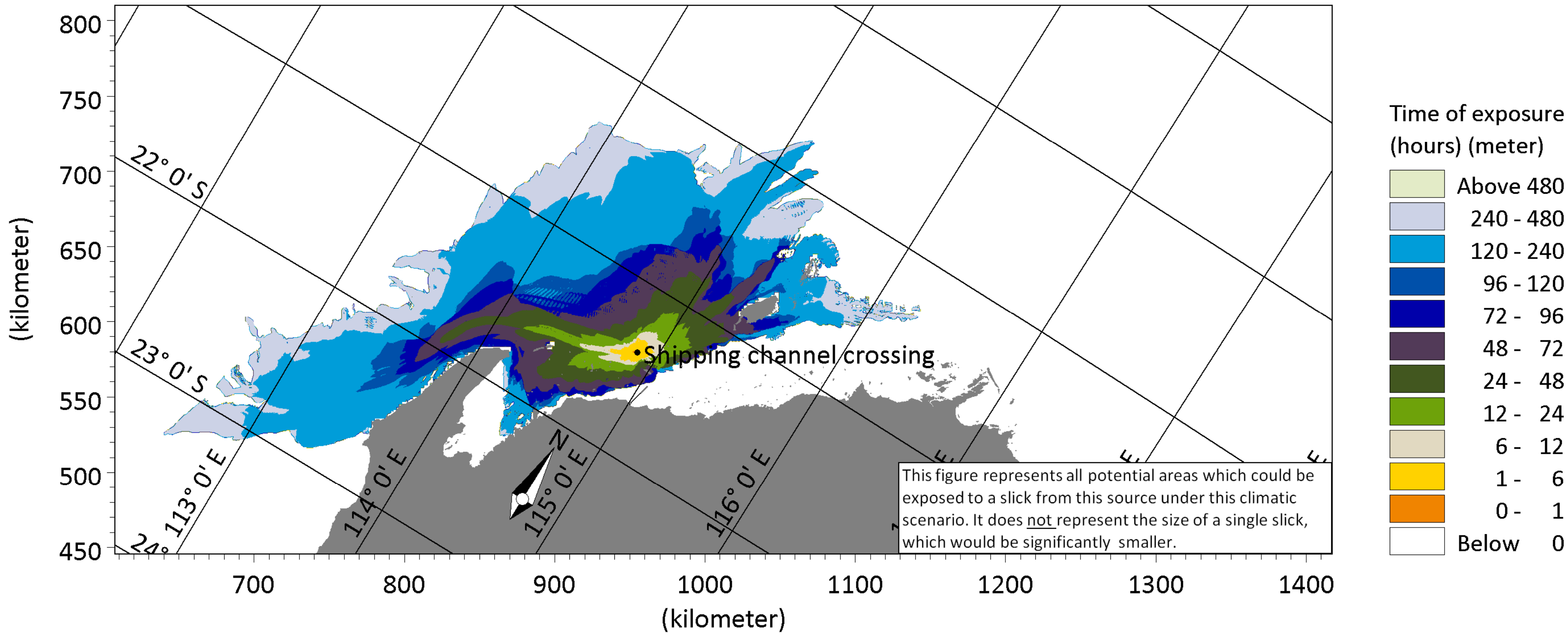

Figure B.5 time of exposure for condensate leak at shipping channel (transitional).

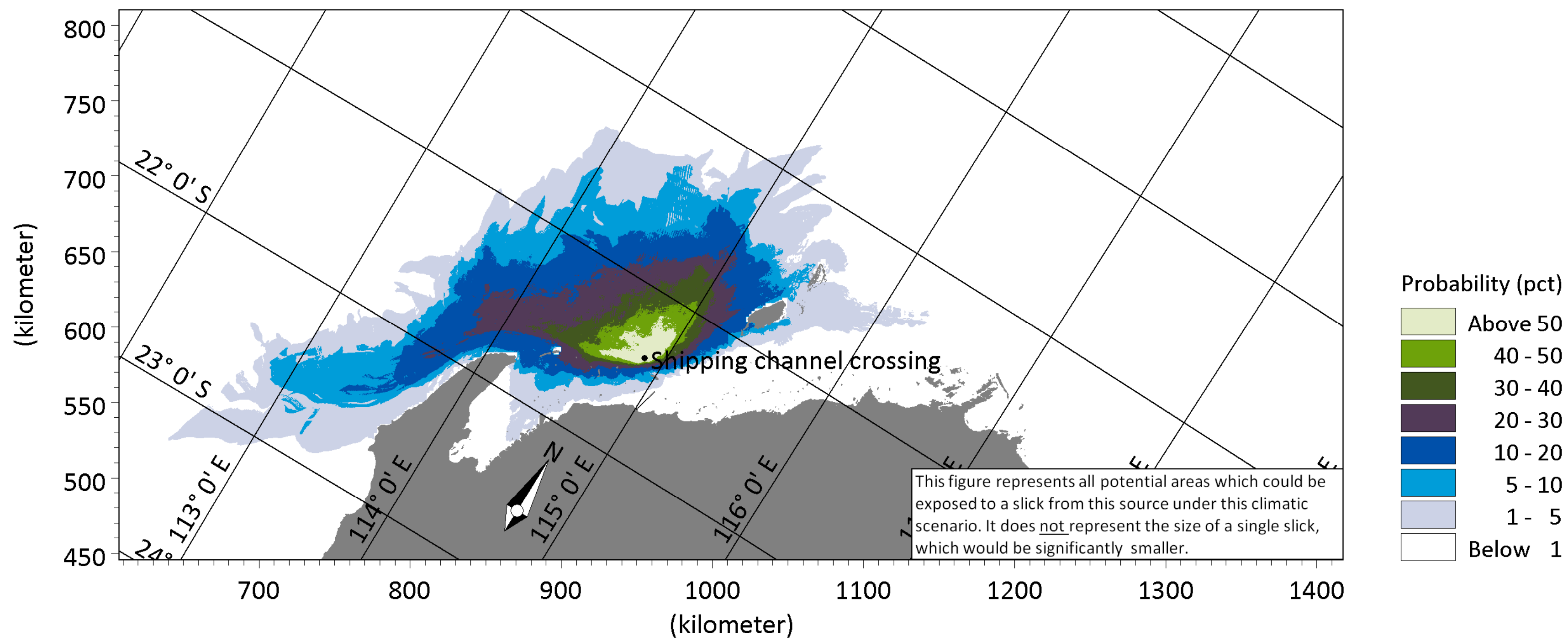

Figure B.6 Probability of exposure for condensate leak at shipping channel (transitional).

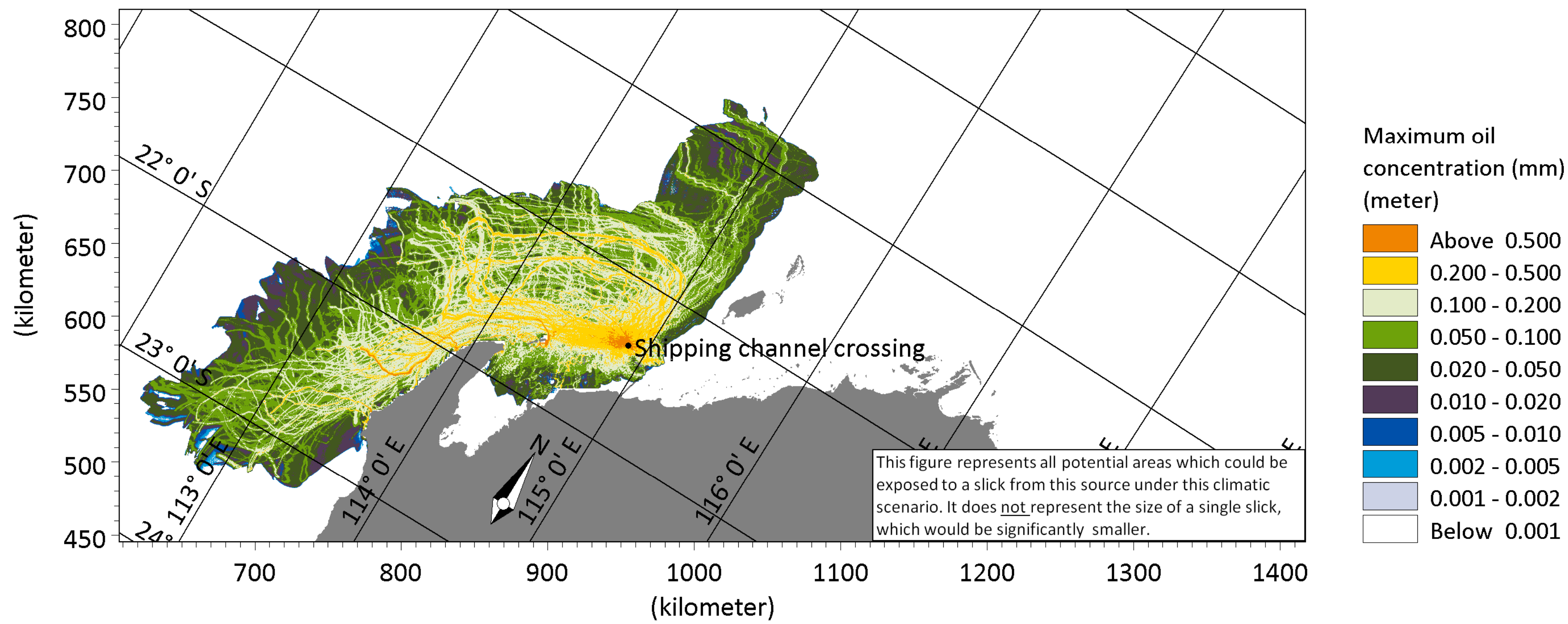

Figure B.7 Maximum oil concentration for condensate leak at shipping channel (winter).

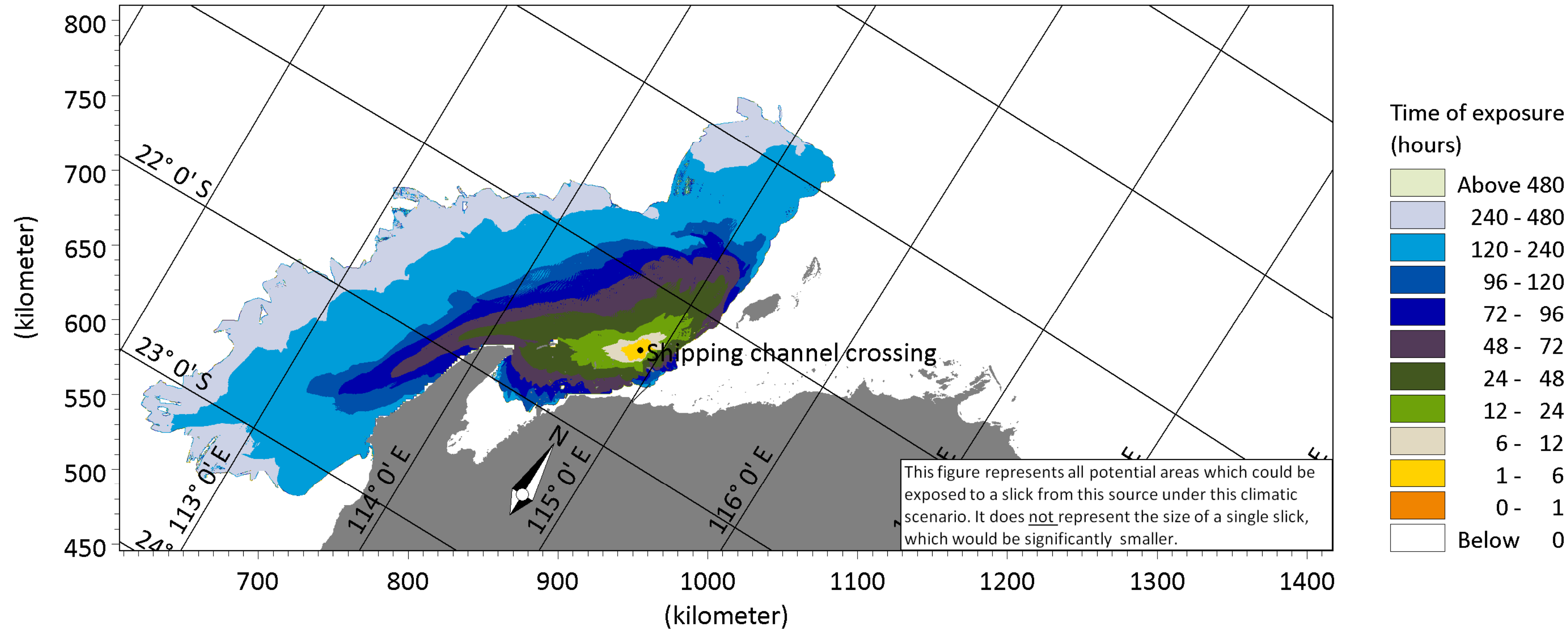

Figure B.8 Minimum time of exposure for condensate leak at shipping channel (winter).

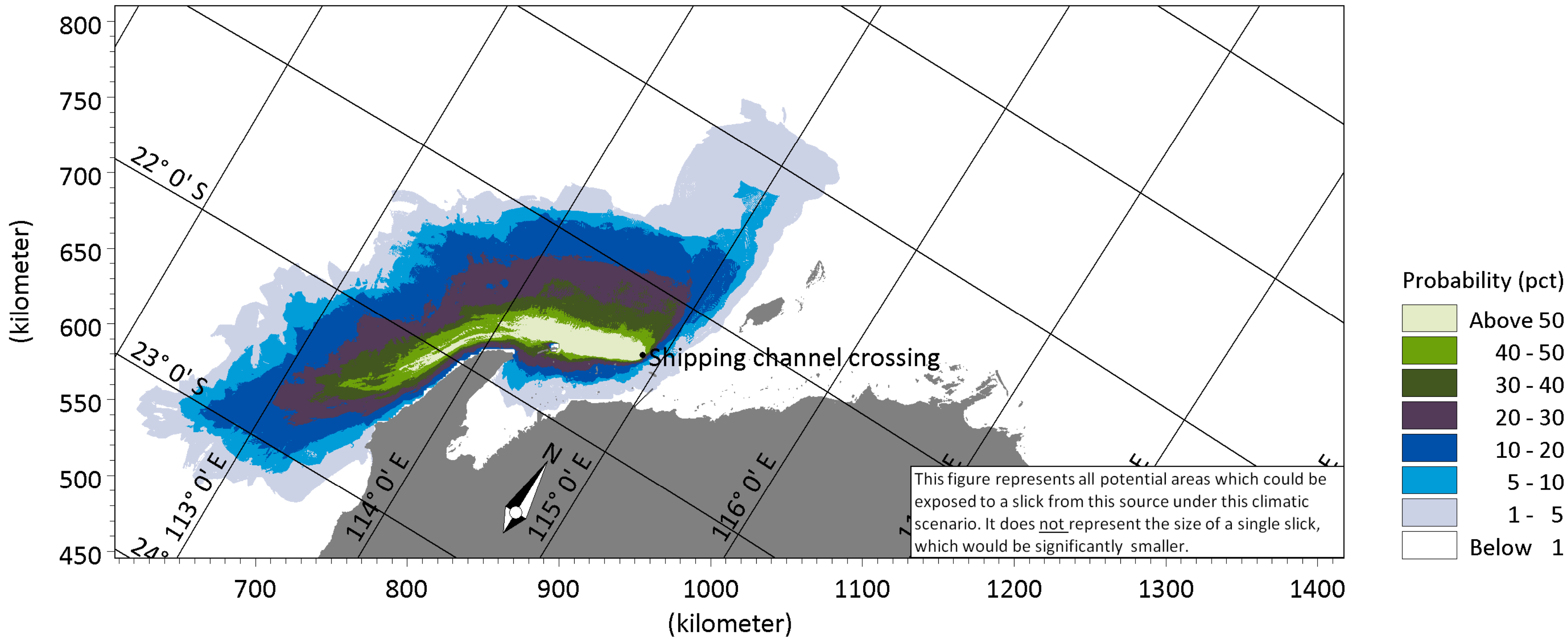

Figure B.9 Probability of exposure for condensate leak at shipping channel (winter).

A D D E N D U M   C

Scenario 4 – Condensate Spill at PLF

Key Results

C SCENARIO 4

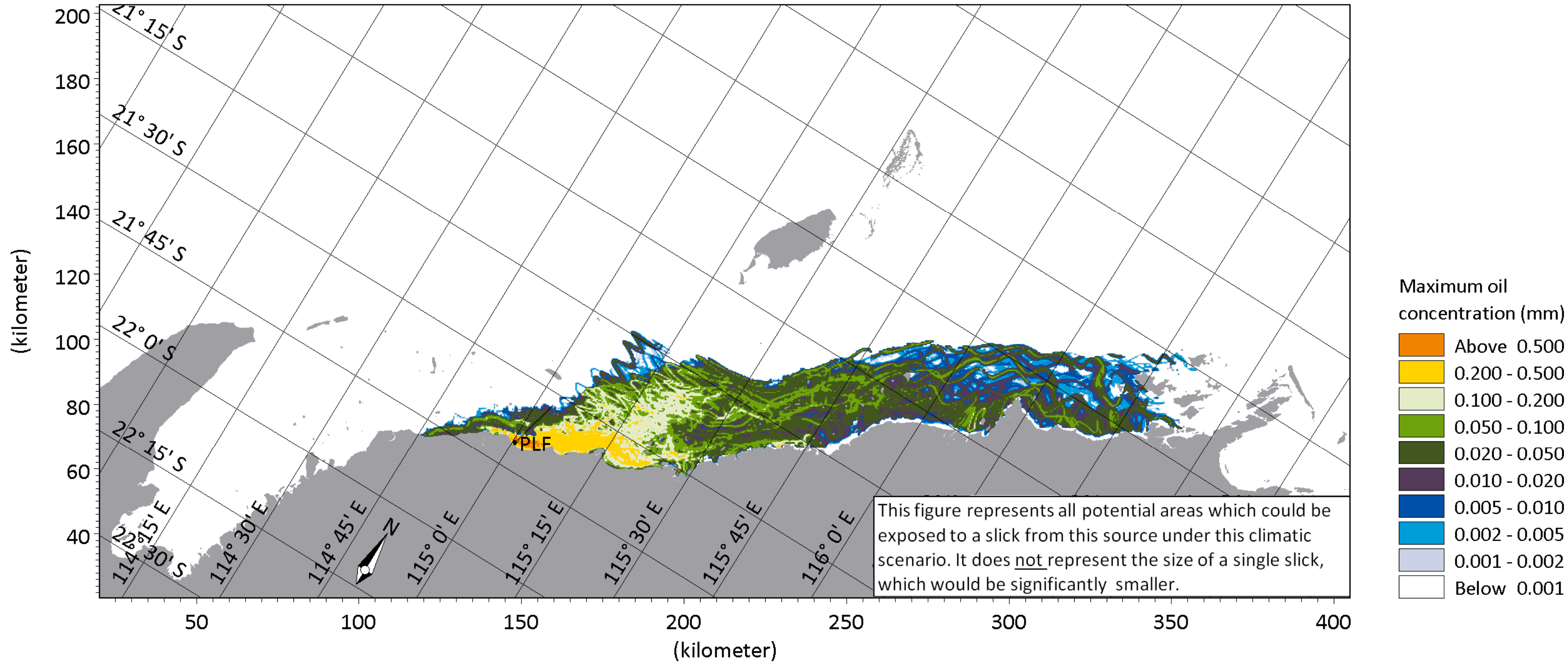

Figure C.1 Maximum oil concentration for condensate spill at PLF (summer).

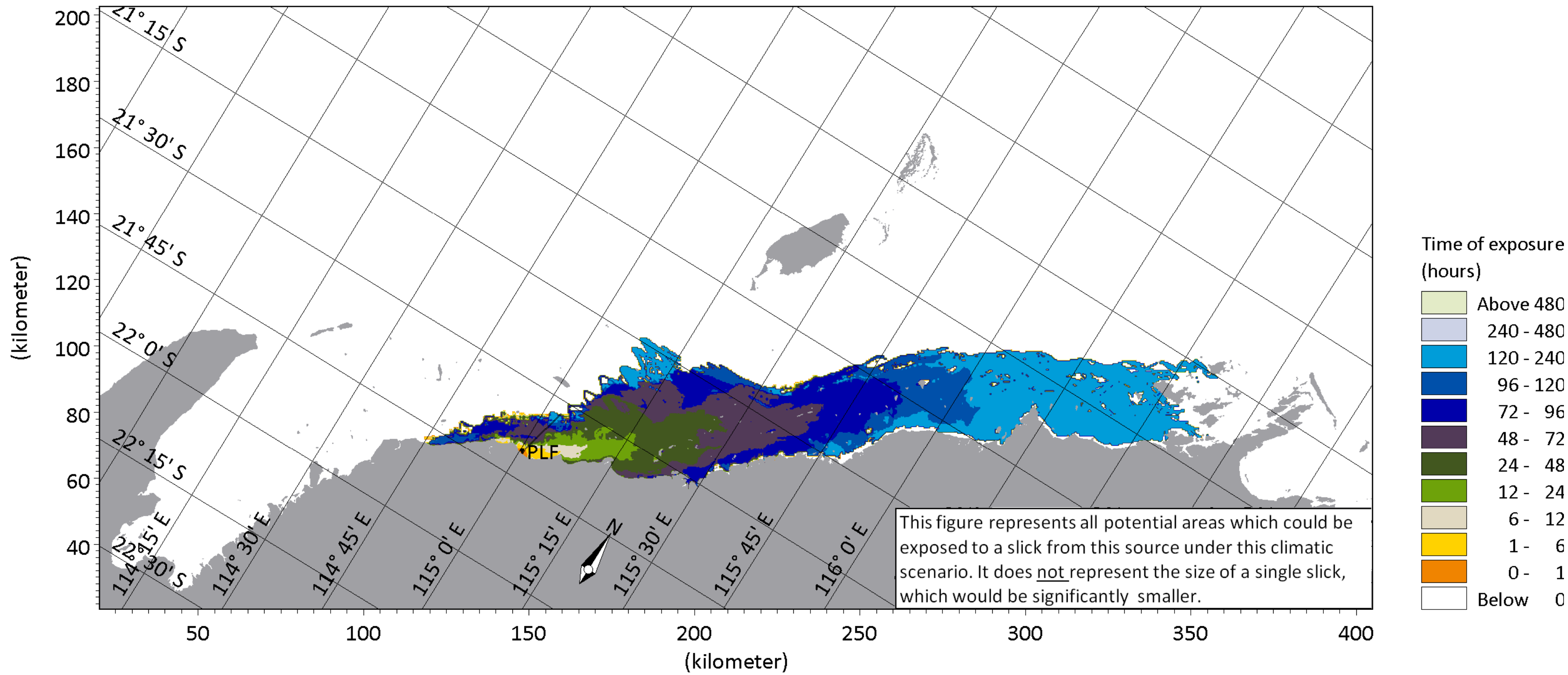

Figure C.2 Minimum time of exposure for condensate spill at PLF (summer).

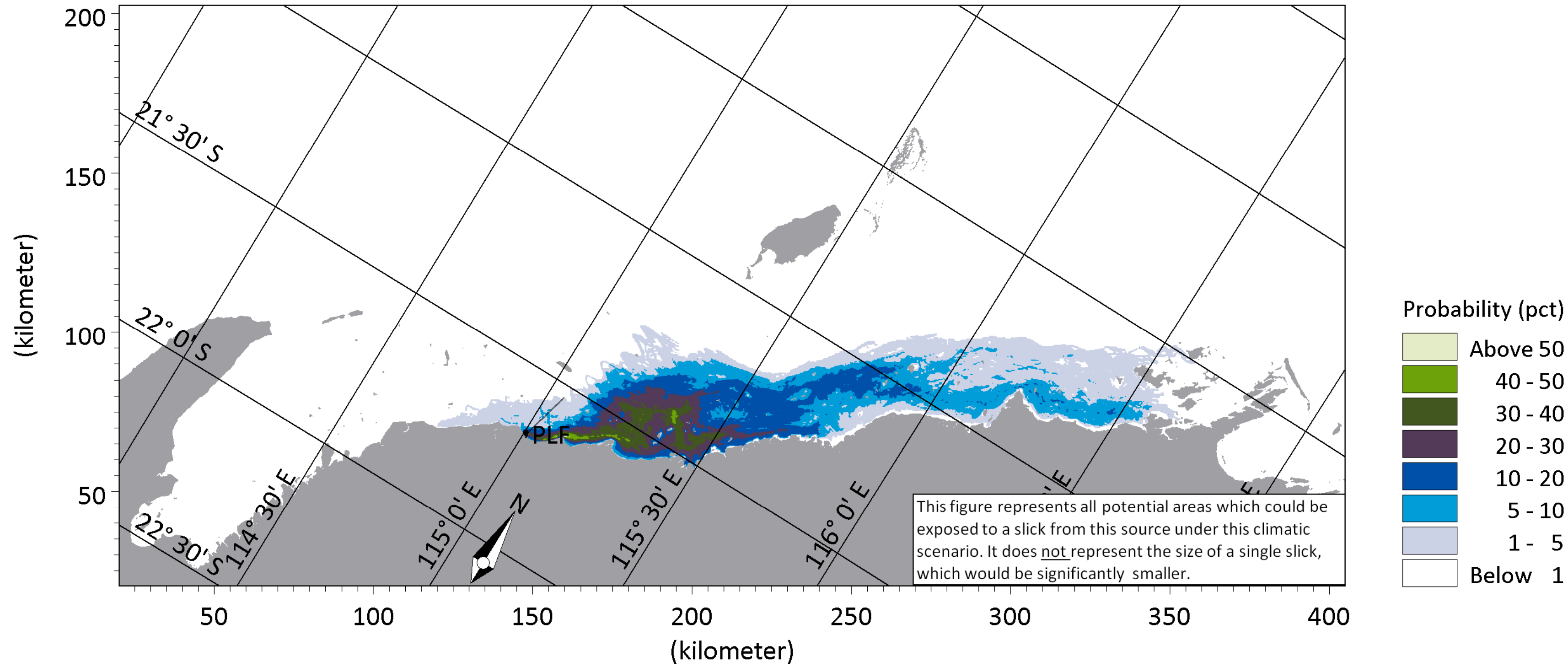

Figure C.3 Probability of exposure for condensate spill at PLF (summer).

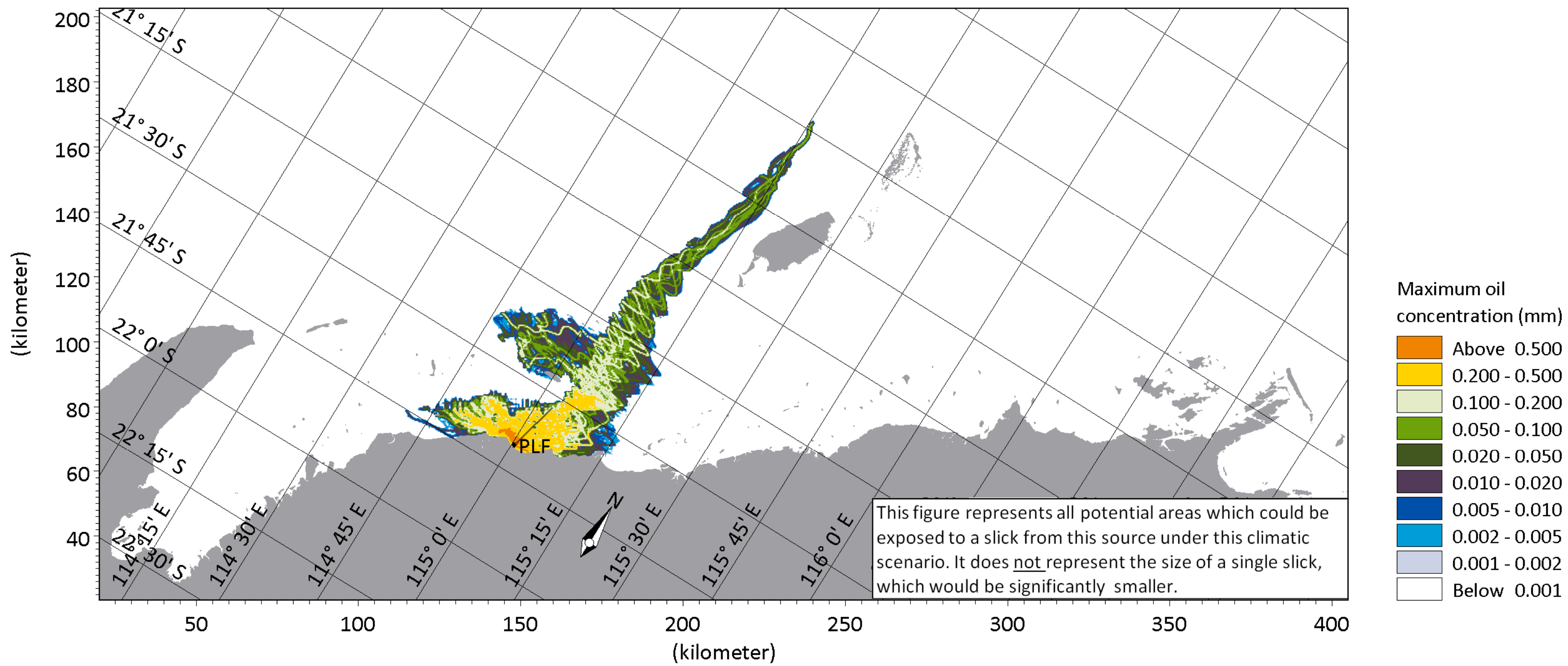

Figure C.4 Maximum oil concentration for condensate spill at PLF (transitional).

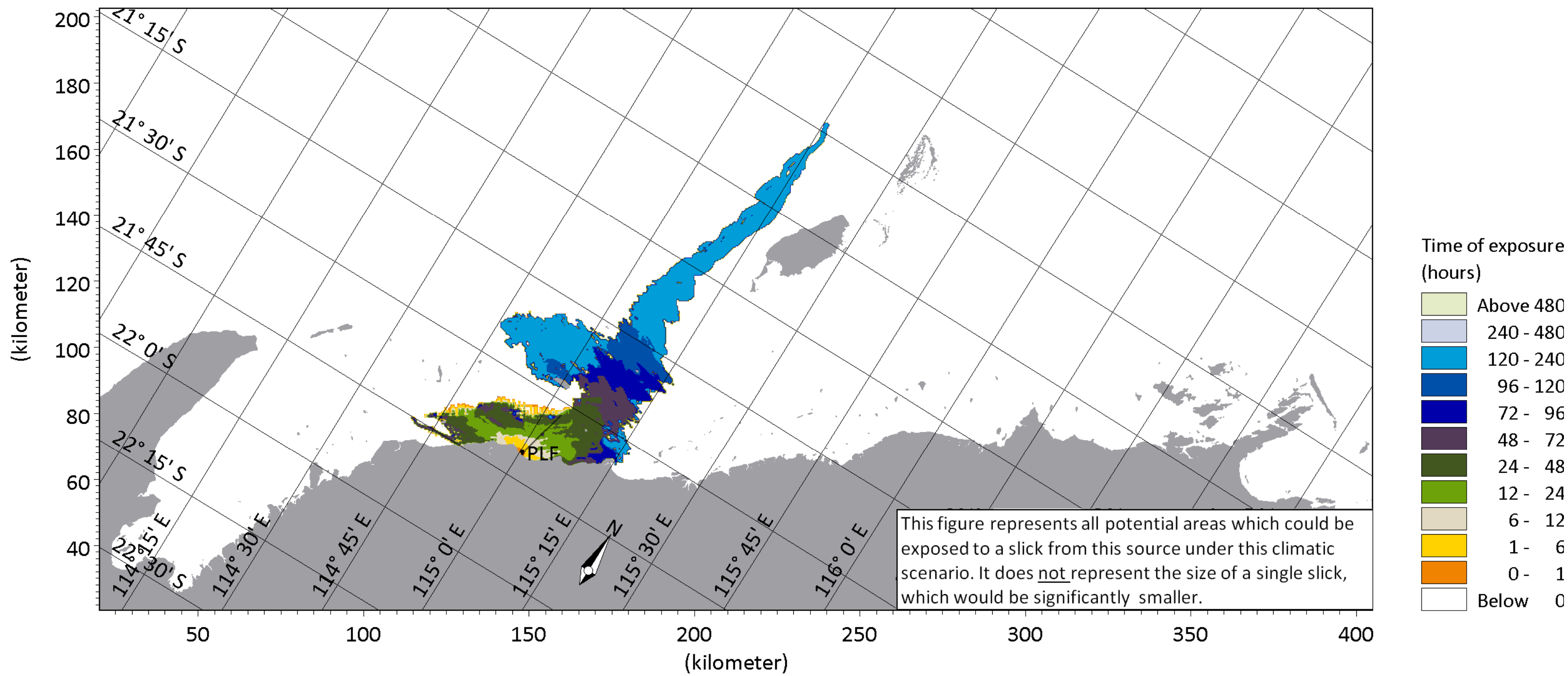

Figure C.5 Minimum time of exposure for condensate spill at PLF (transitional)

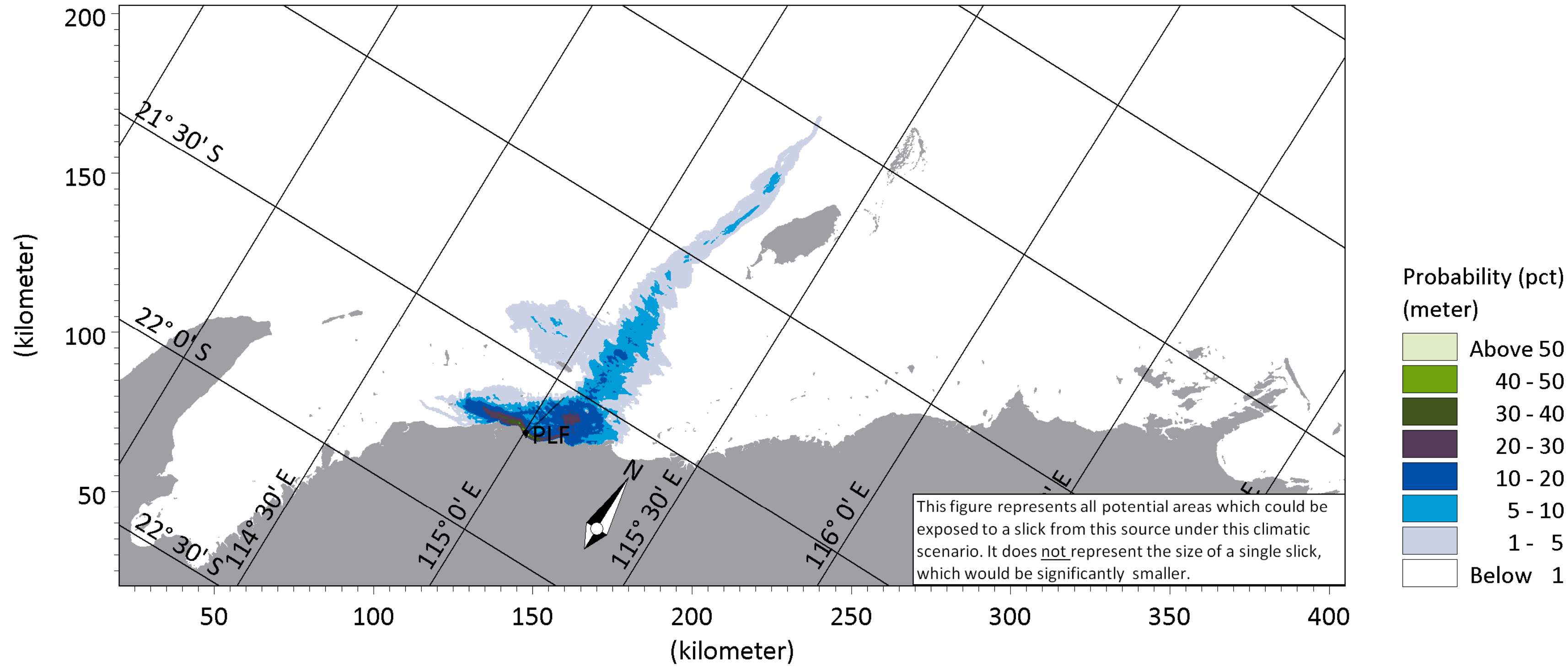

Figure C.6 Probability of exposure for condensate spill at PLF (transitional)

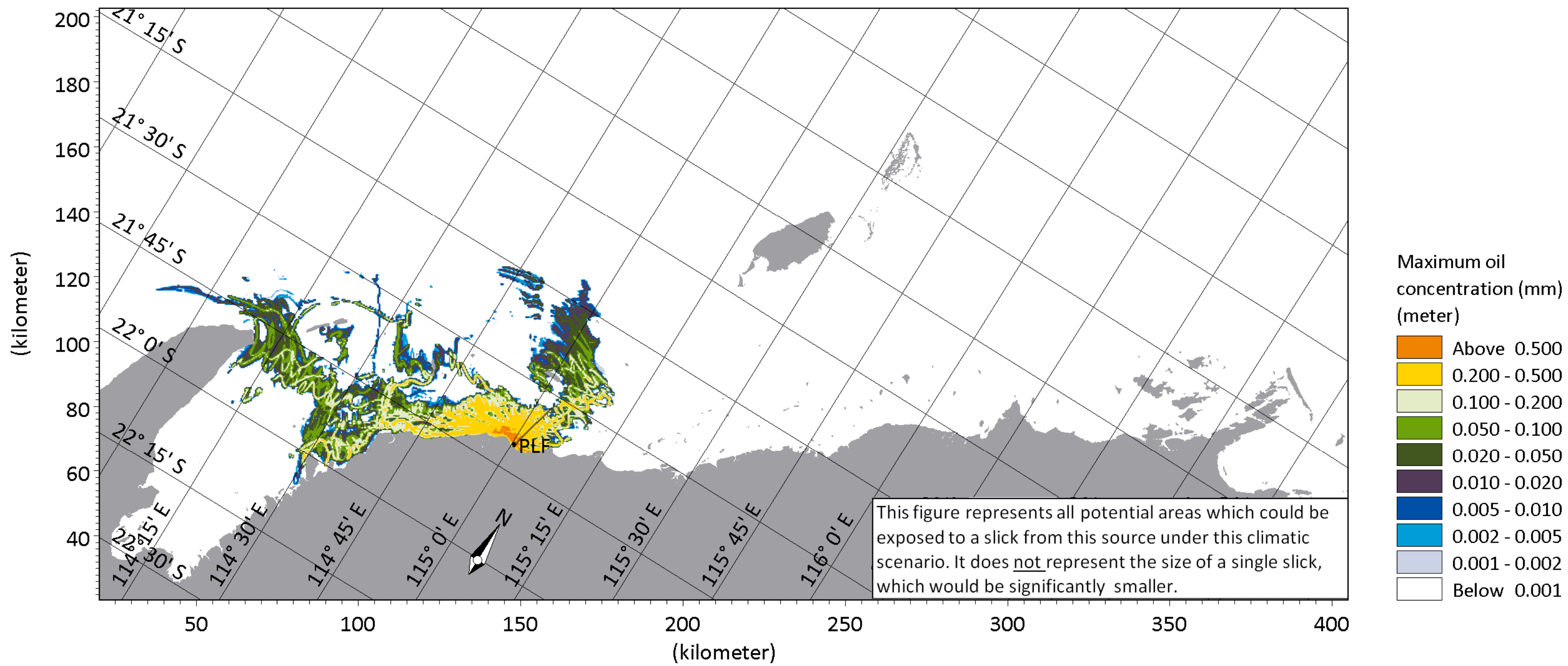

Figure C.7 Maximum oil concentration for condensate spill at PLF (winter).

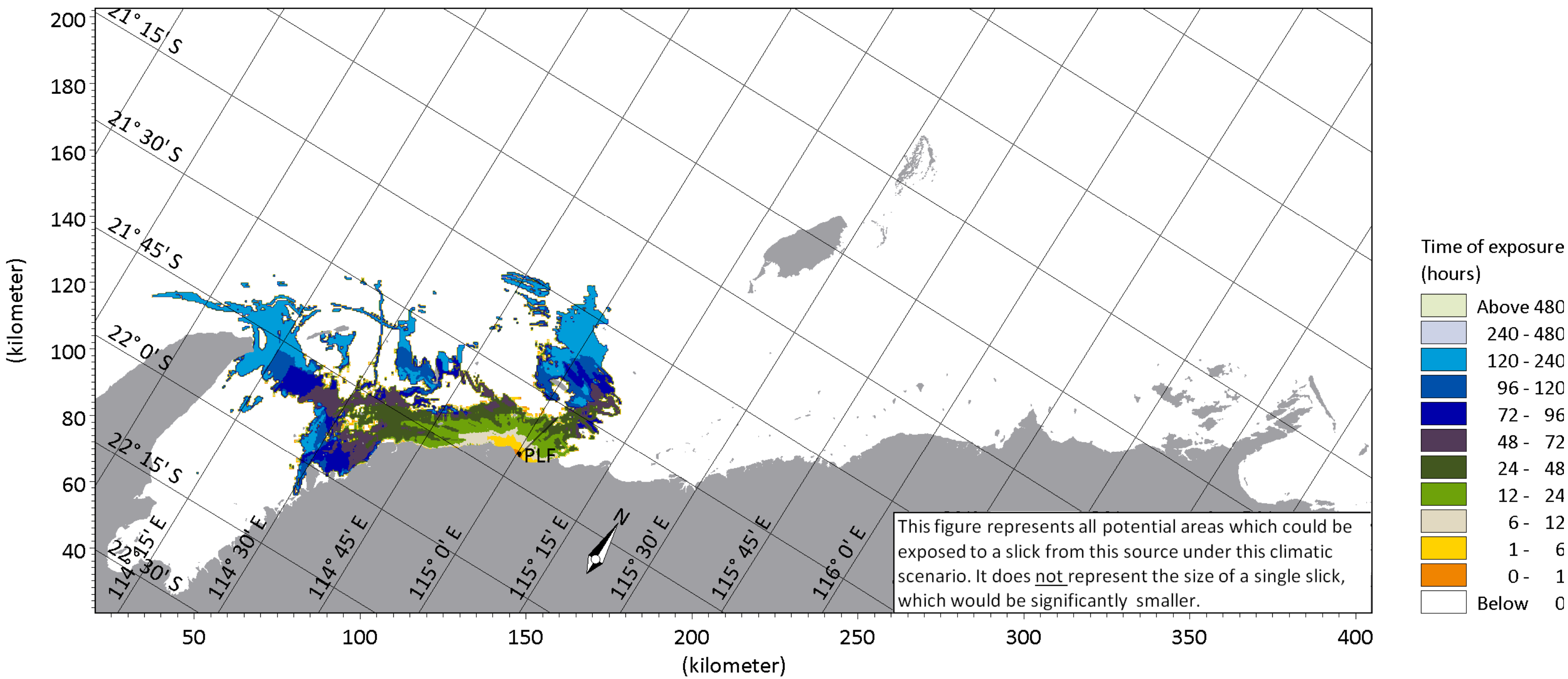

Figure C.8 Minimum time of exposure for condensate spill at PLF (winter)

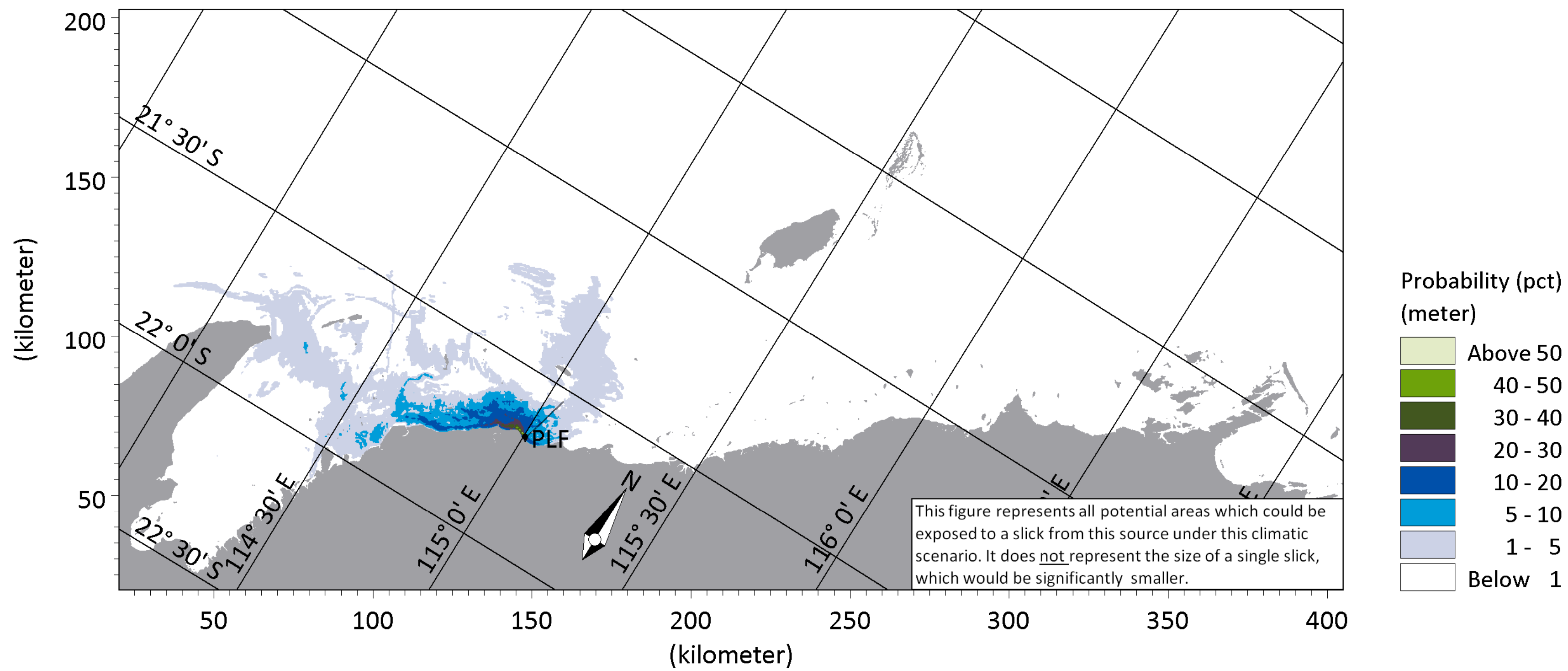

Figure C.9 Probability of exposure for condensate spill at PLF (winter).

A D D E N D U M   D

Scenario 5 – Diesel Spill at MOF

Key Results

D SCENARIO 5

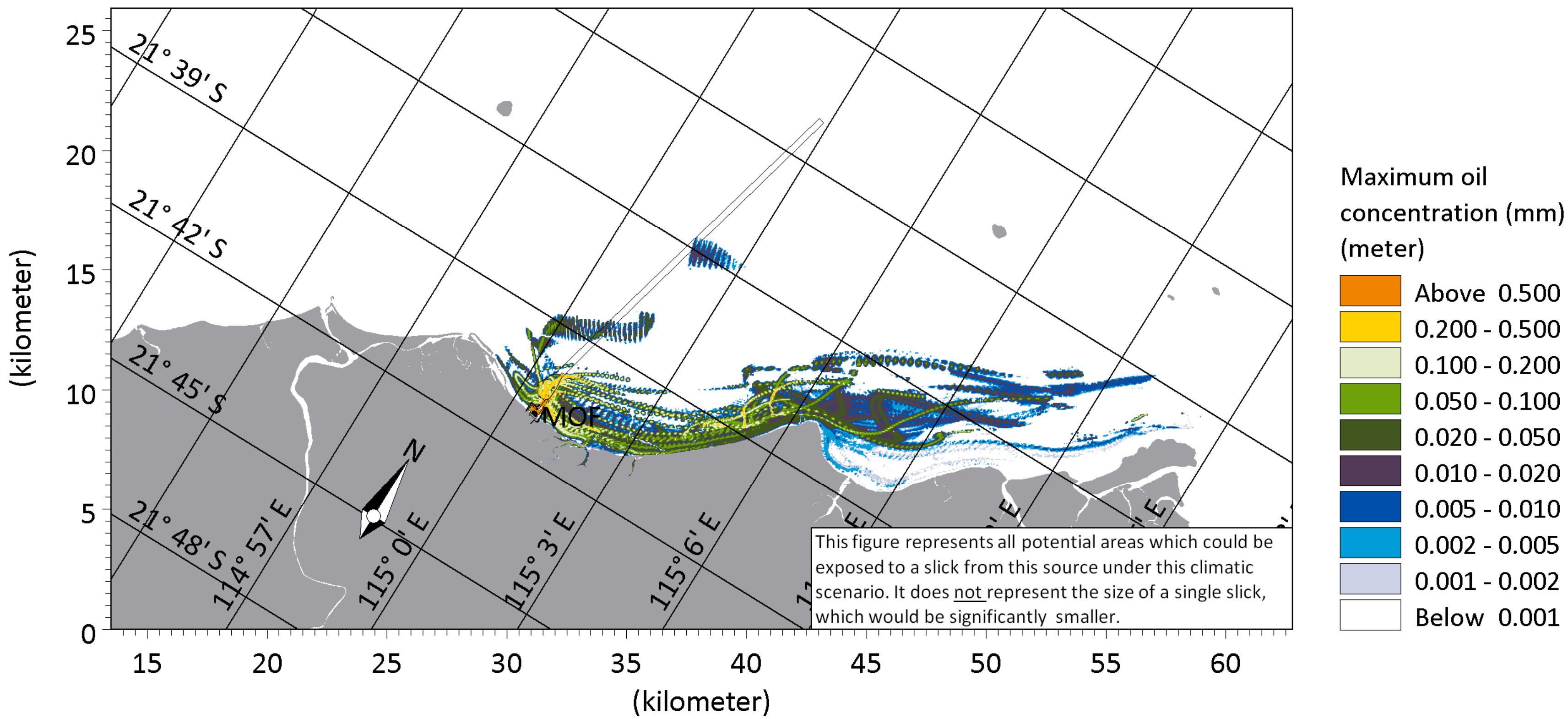

Figure D.1 Maximum oil concentration for diesel Spill at MOF (summer).

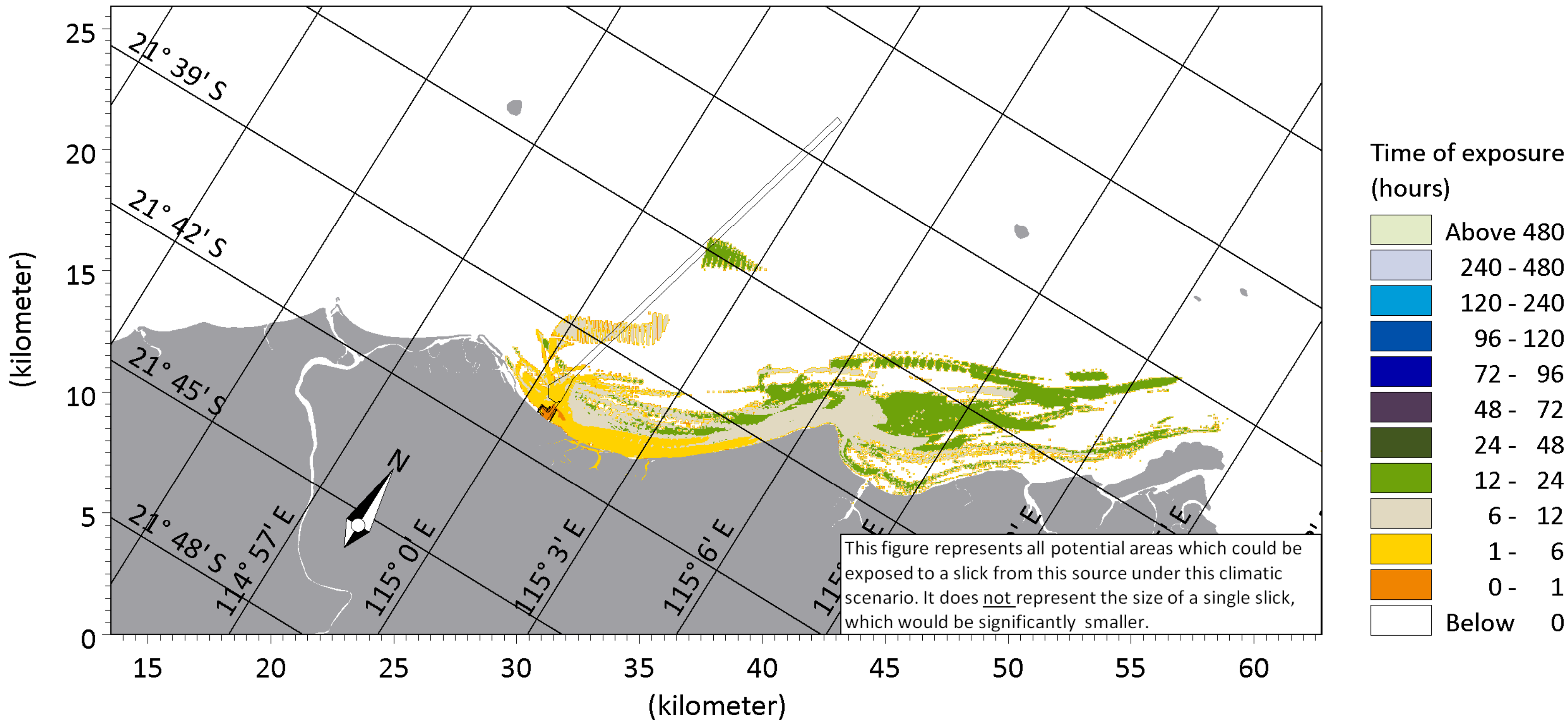

Figure D.2 Minimum time of exposure for diesel Spill at MOF (summer).

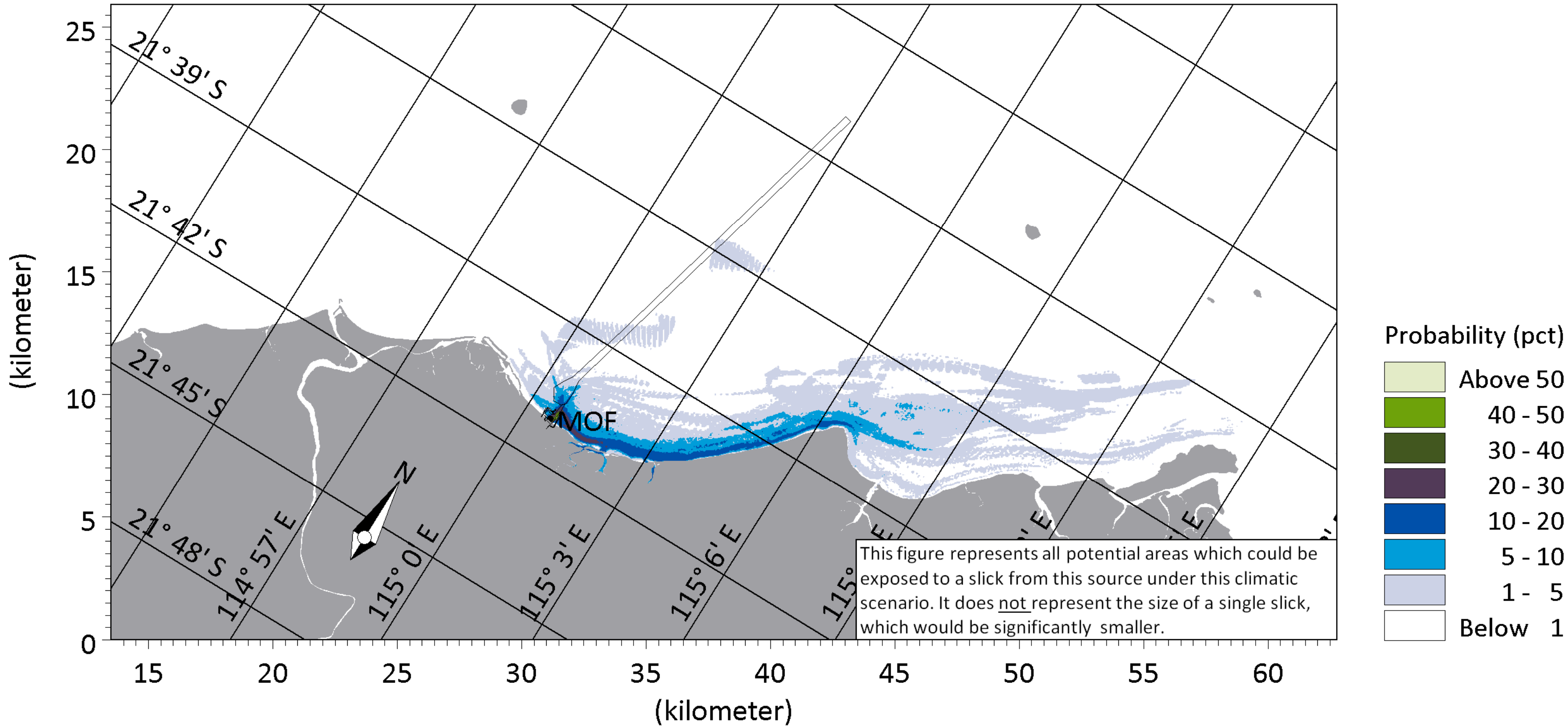

Figure D.3 Probability of exposure for diesel Spill at MOF (summer).

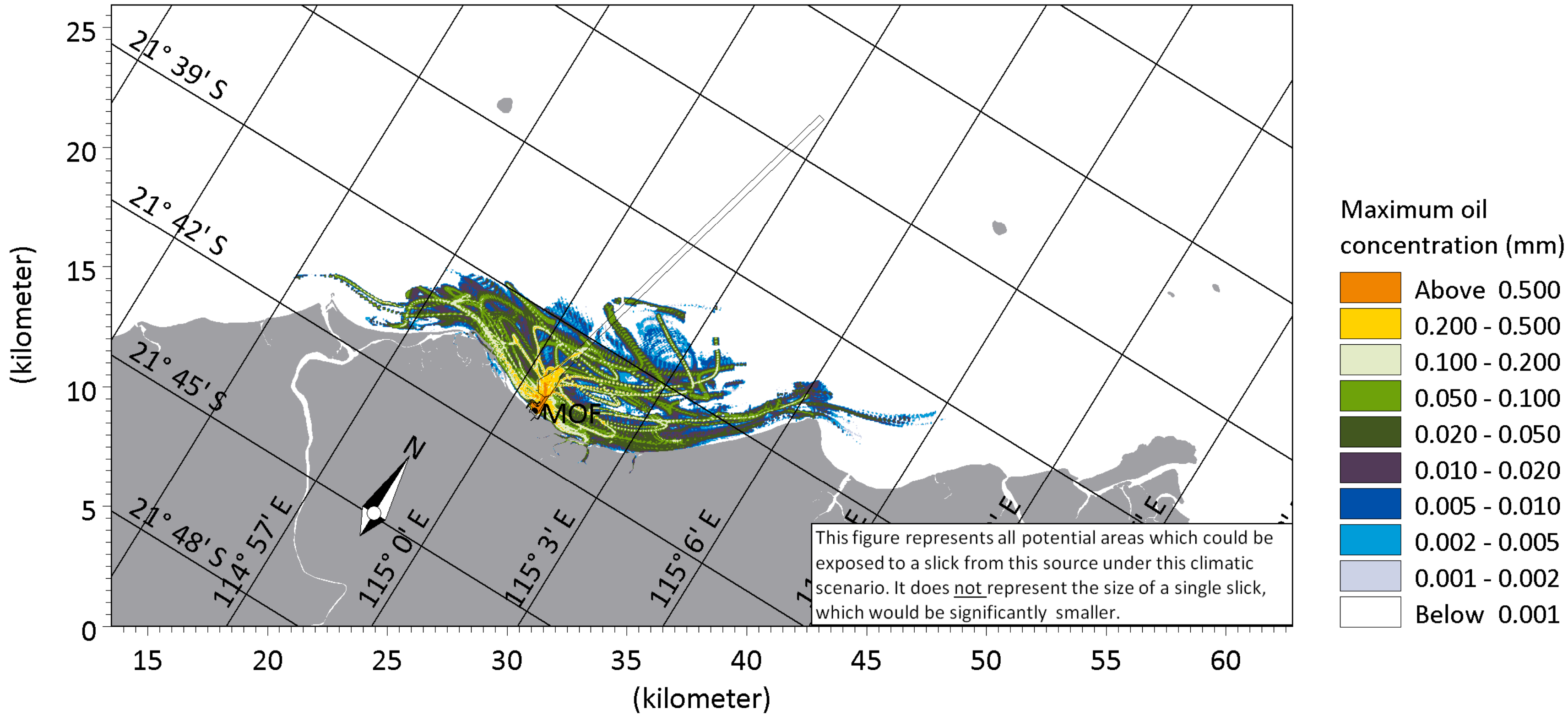

Figure D.4 Maximum oil concentration for diesel Spill at MOF (transitional).

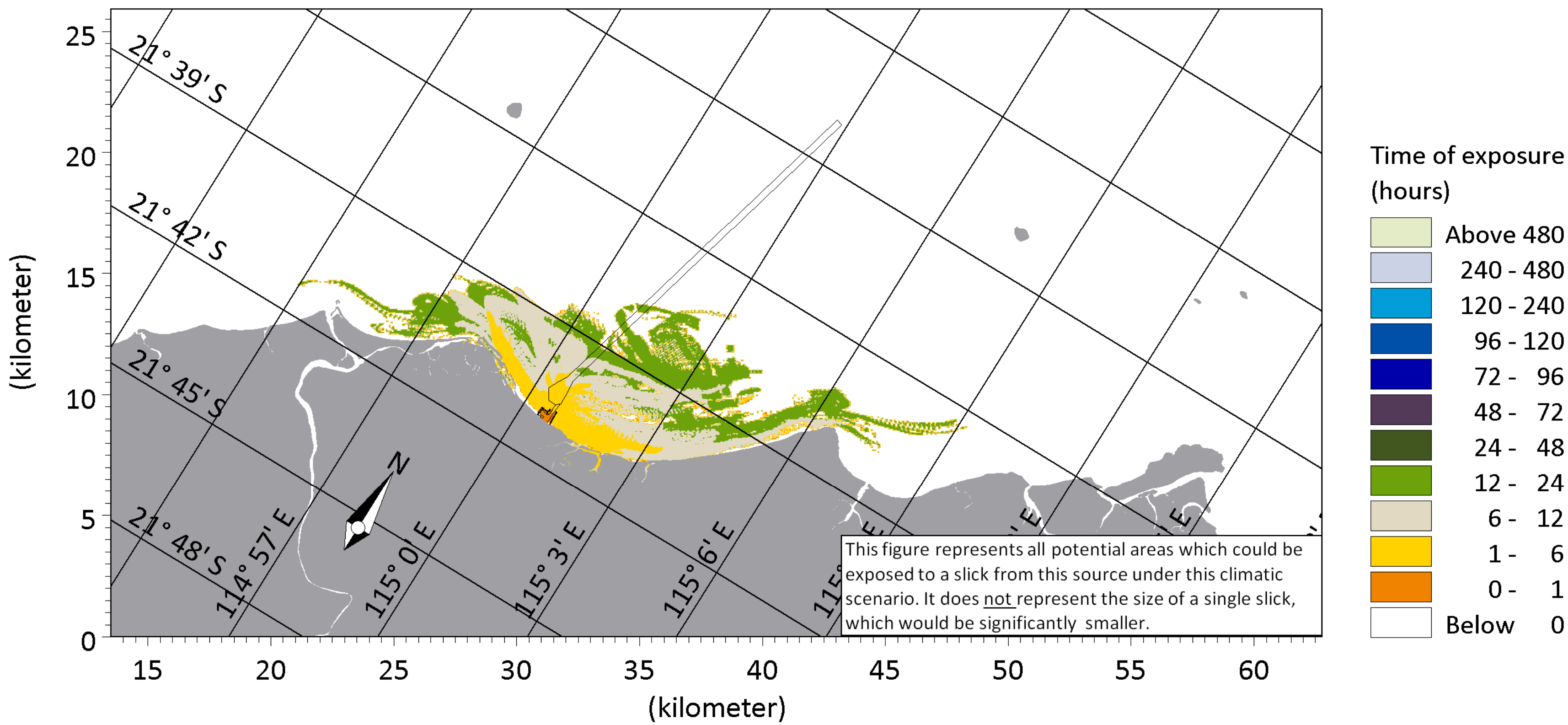

Figure D.5 Minimum time of exposure for diesel spill at MOF (transitional).

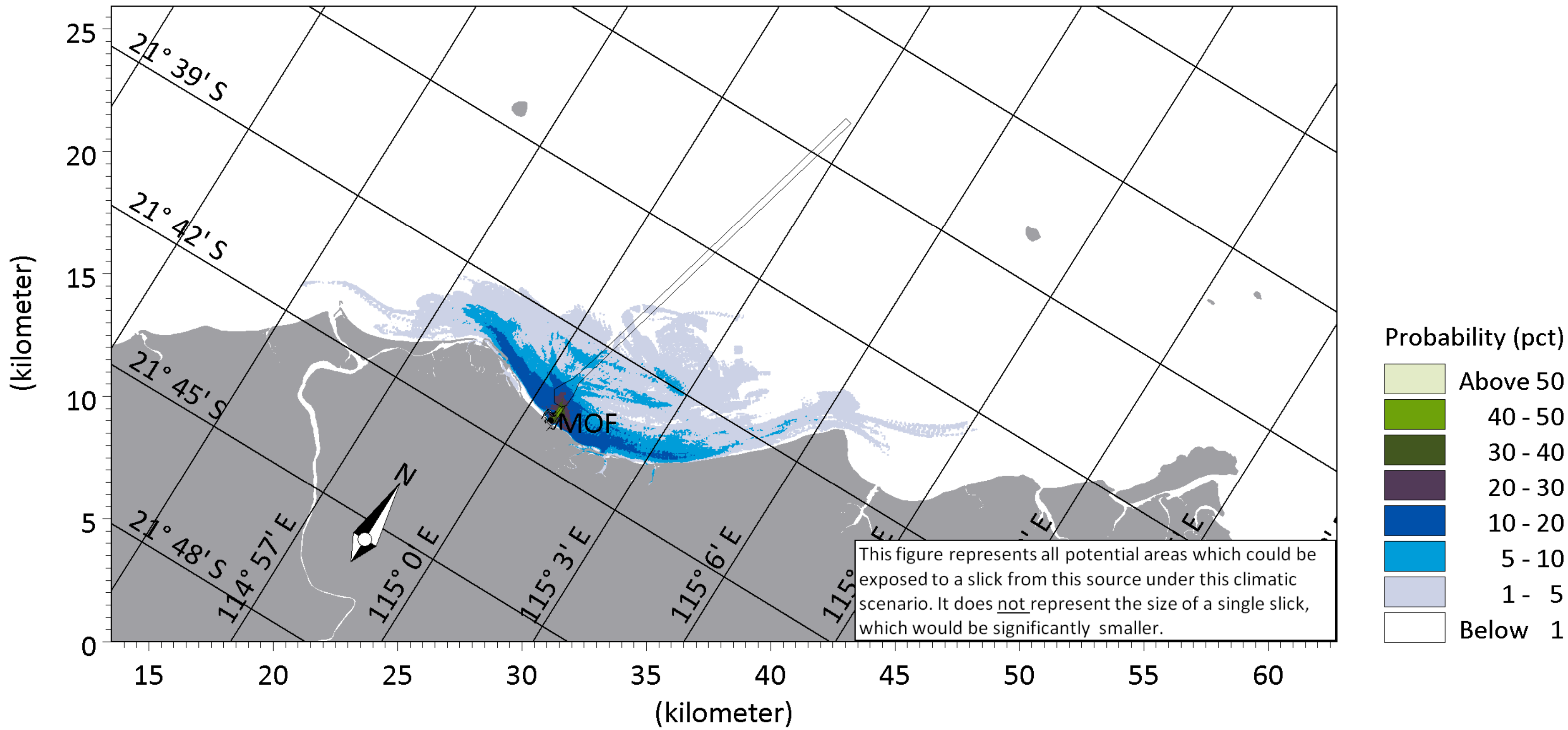

Figure D.6 Probability of exposure for diesel Spill at MOF (transitional).

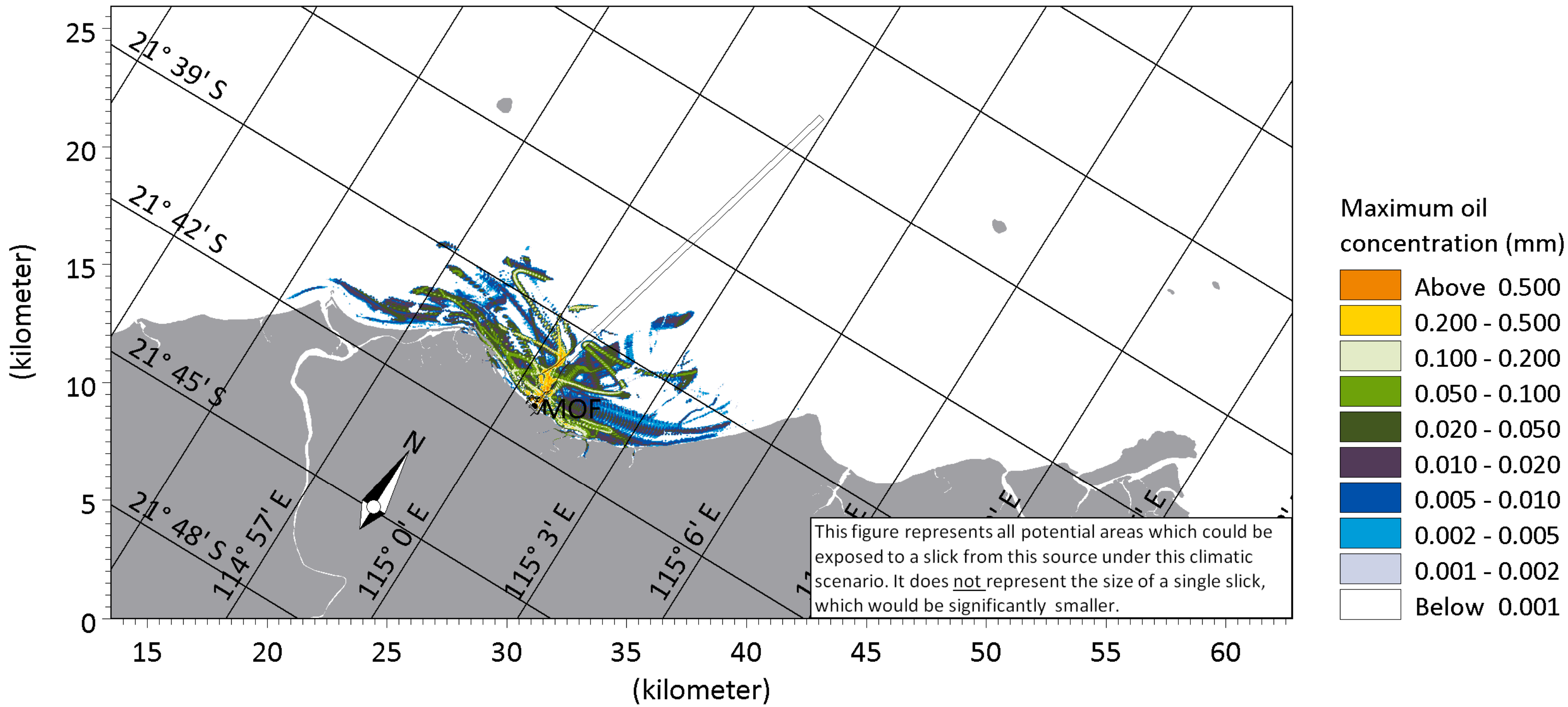

Figure D.7 Maximum oil concentration for diesel spill at MOF (winter)

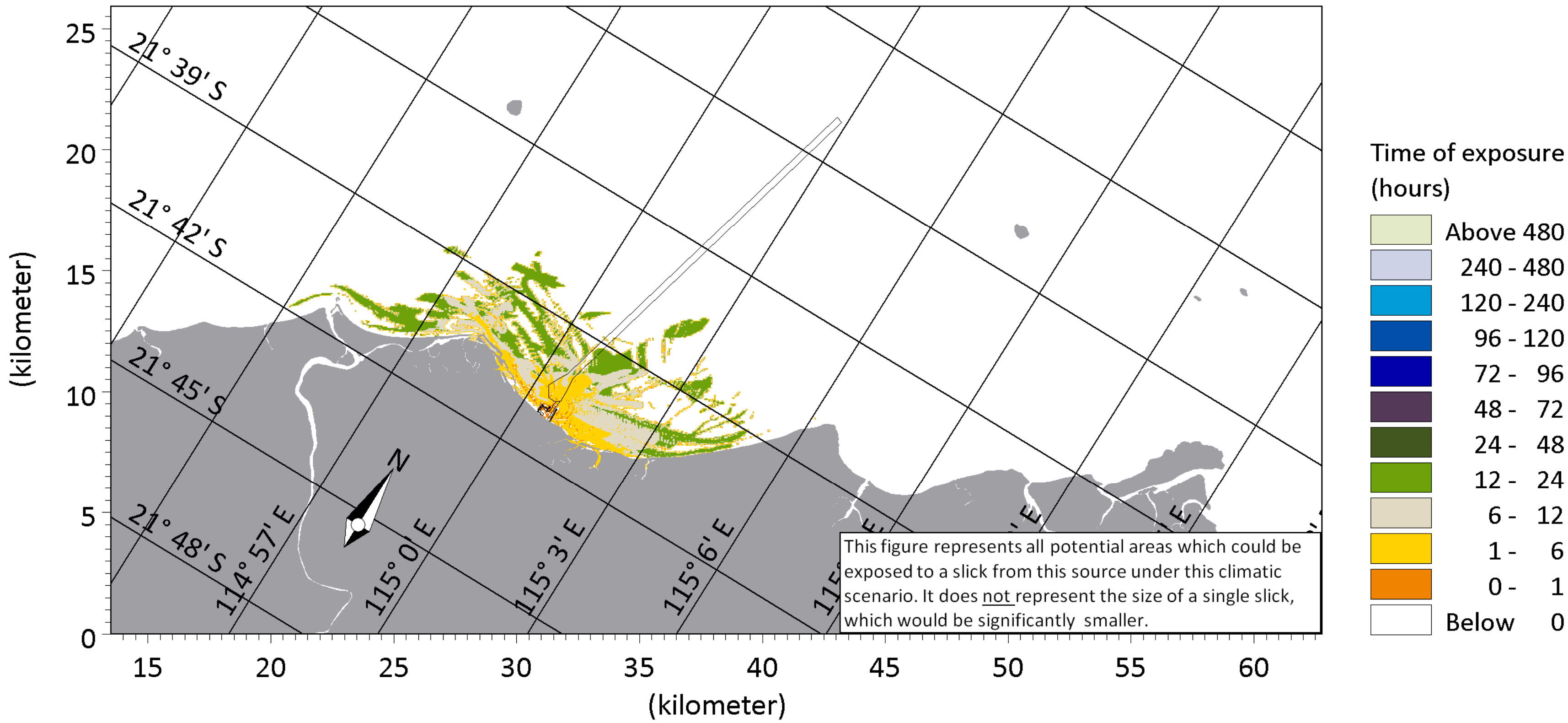

Figure D.8 Minimum time of exposure for diesel spill at MOF (winter).

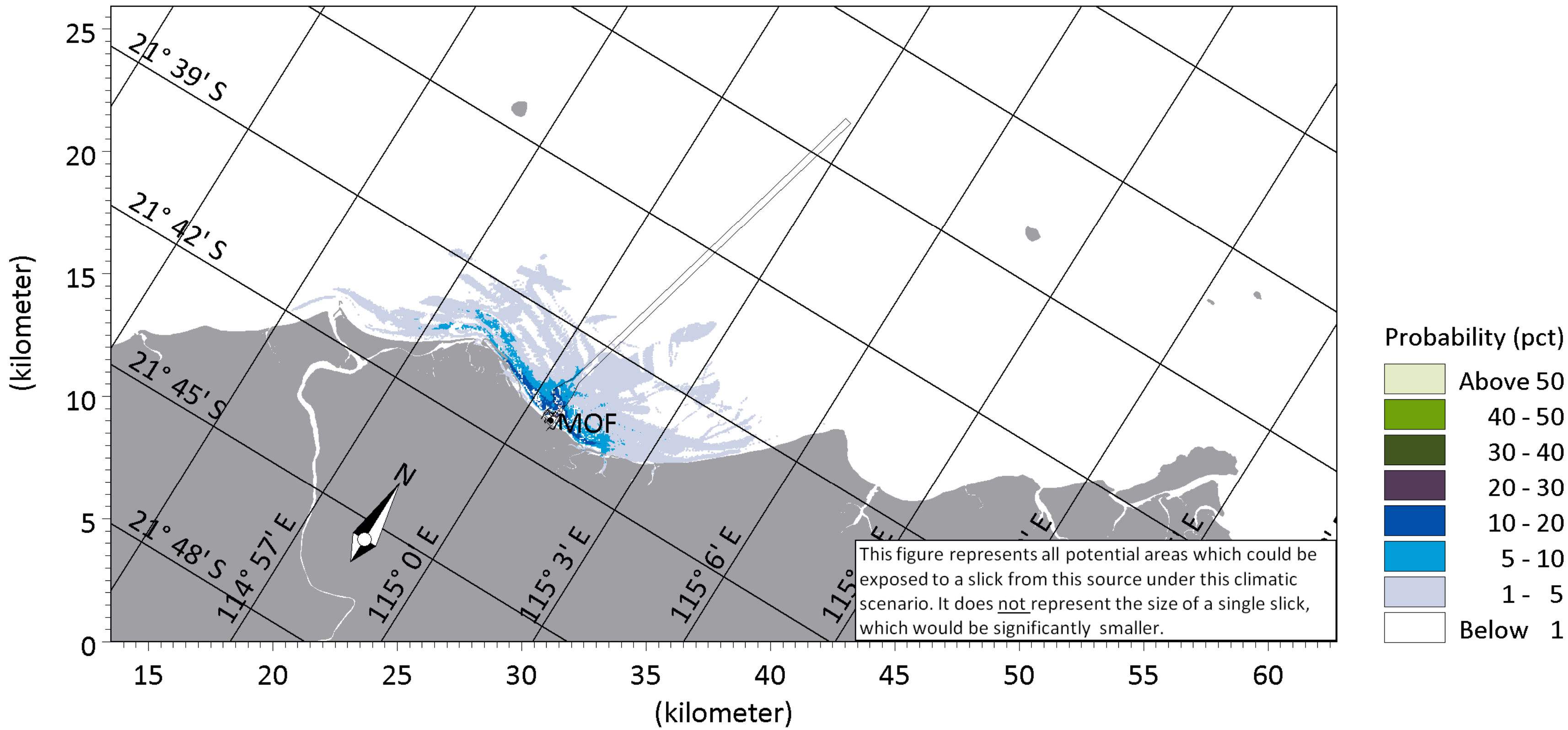

Figure D.9 Probability of exposure for diesel Spill at MOF (winter).

A D D E N D U M   E

Scenario 7a – Tanker Grounding

Key Results

E SCENARIO 7

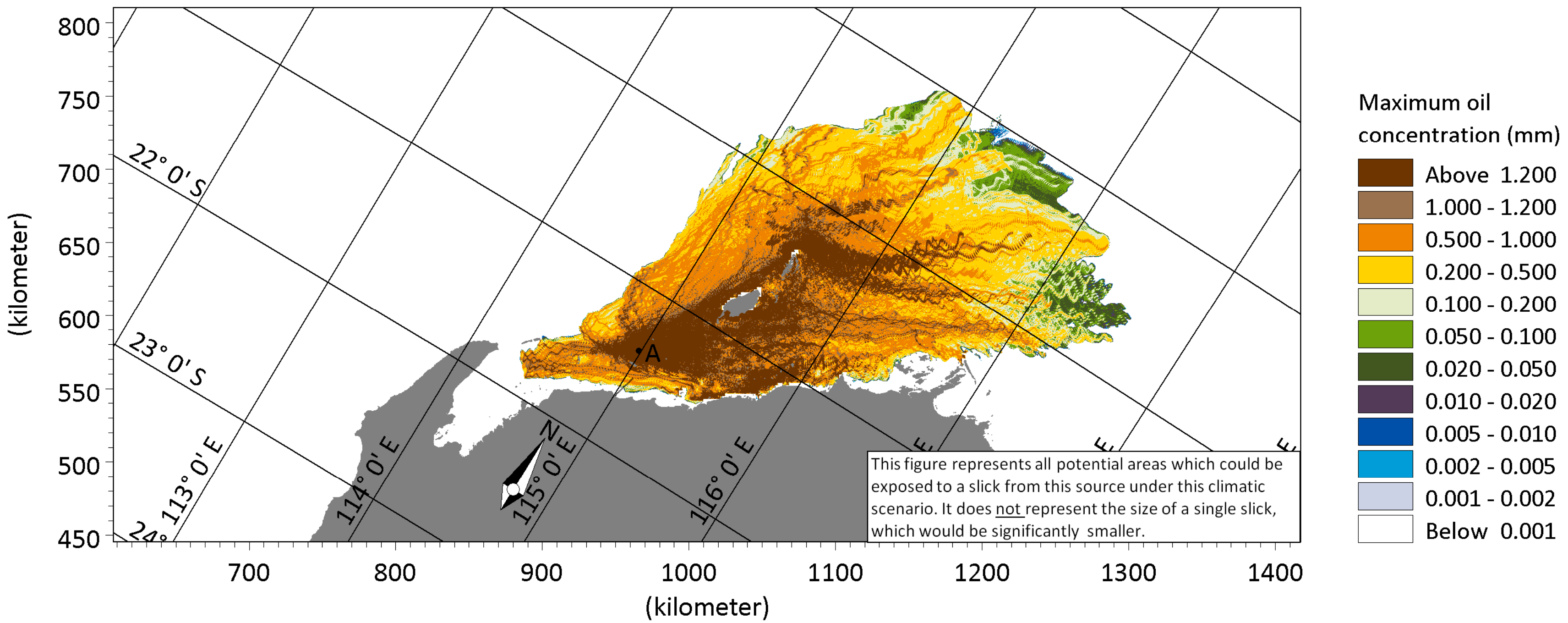

Figure E.1 Maximum oil concentration for spill near entrance of northern approach channel (summer).

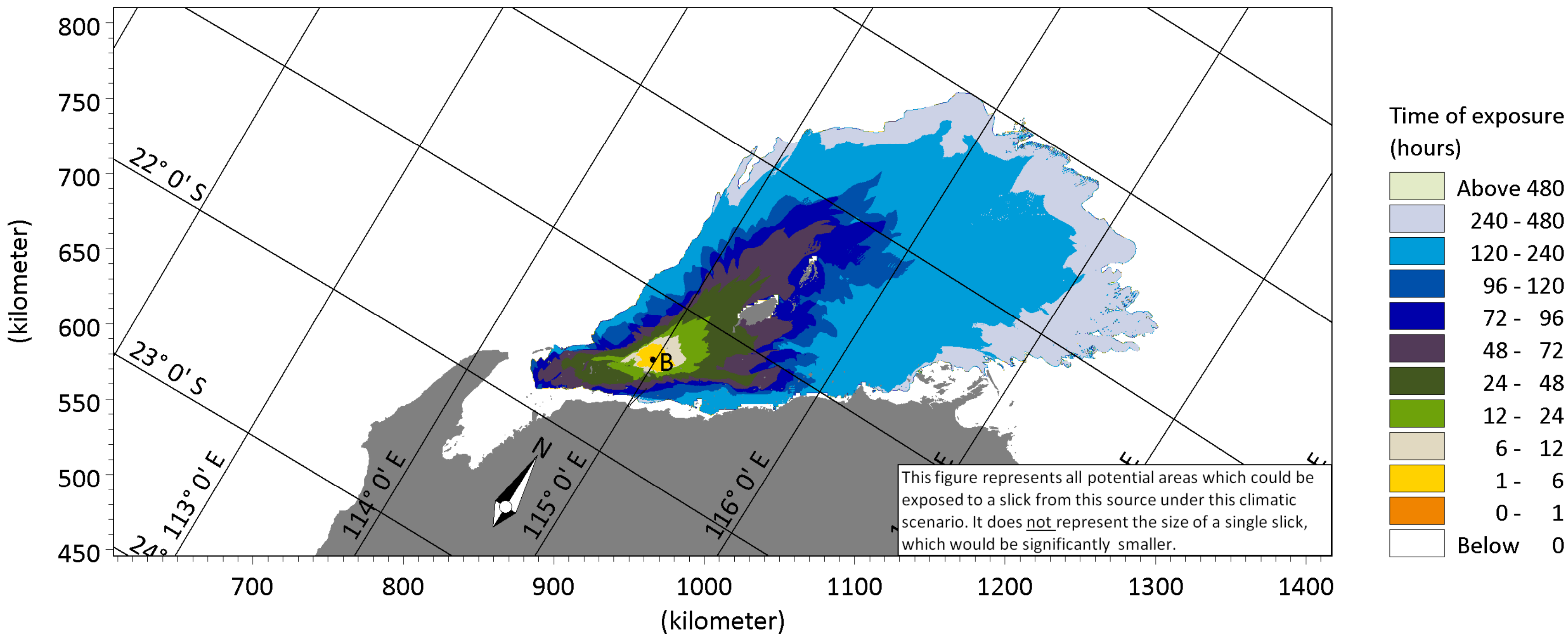

Figure E.2 Minimum time of exposure for spill near entrance of northern approach channel (summer).

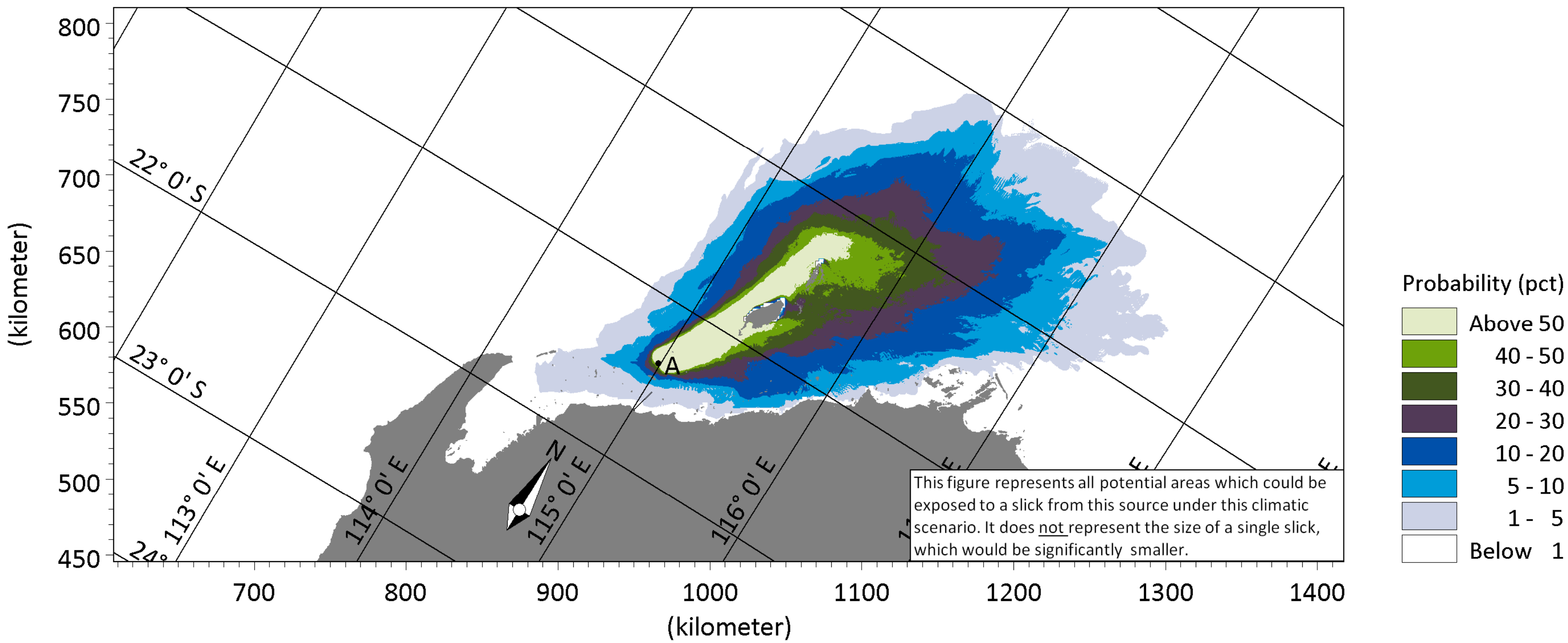

Figure E.3 Probability of exposure for spill near entrance of northern approach channel (summer).

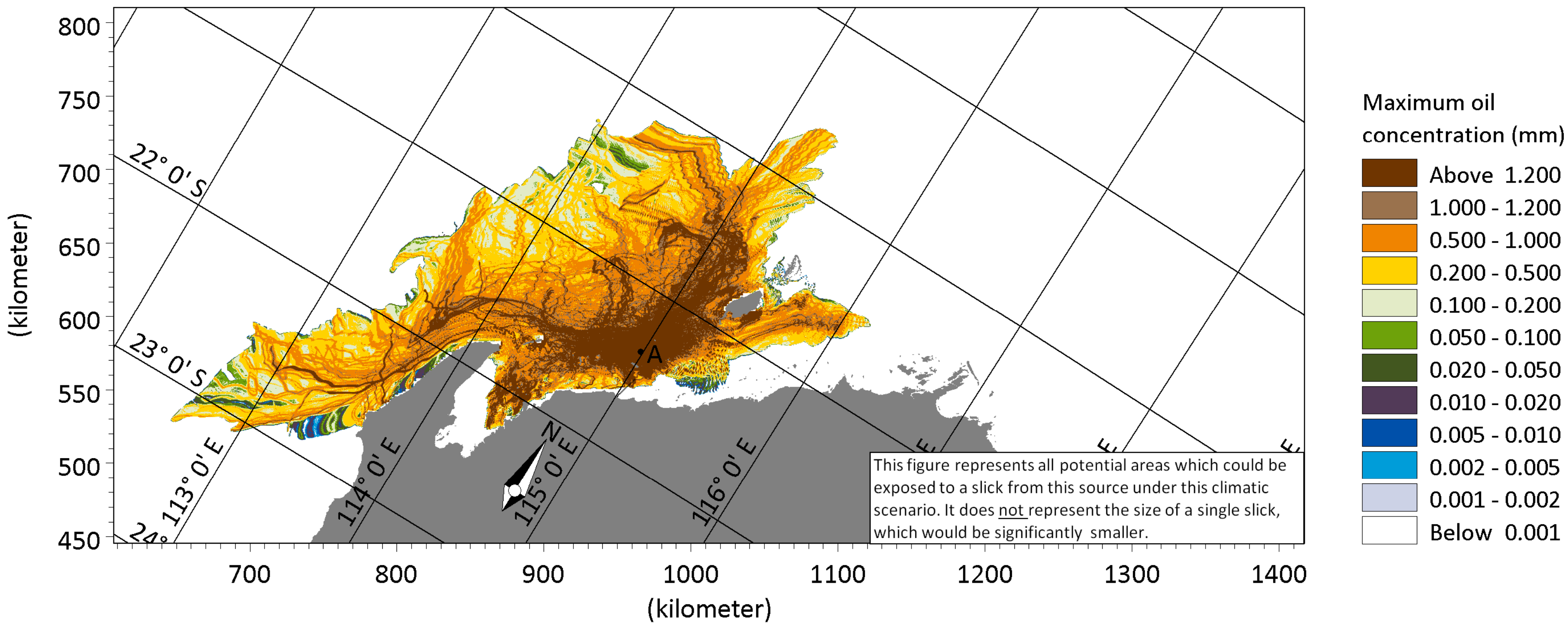

Figure E.4 Maximum oil concentration for spill near entrance of northern approach channel (transitional).

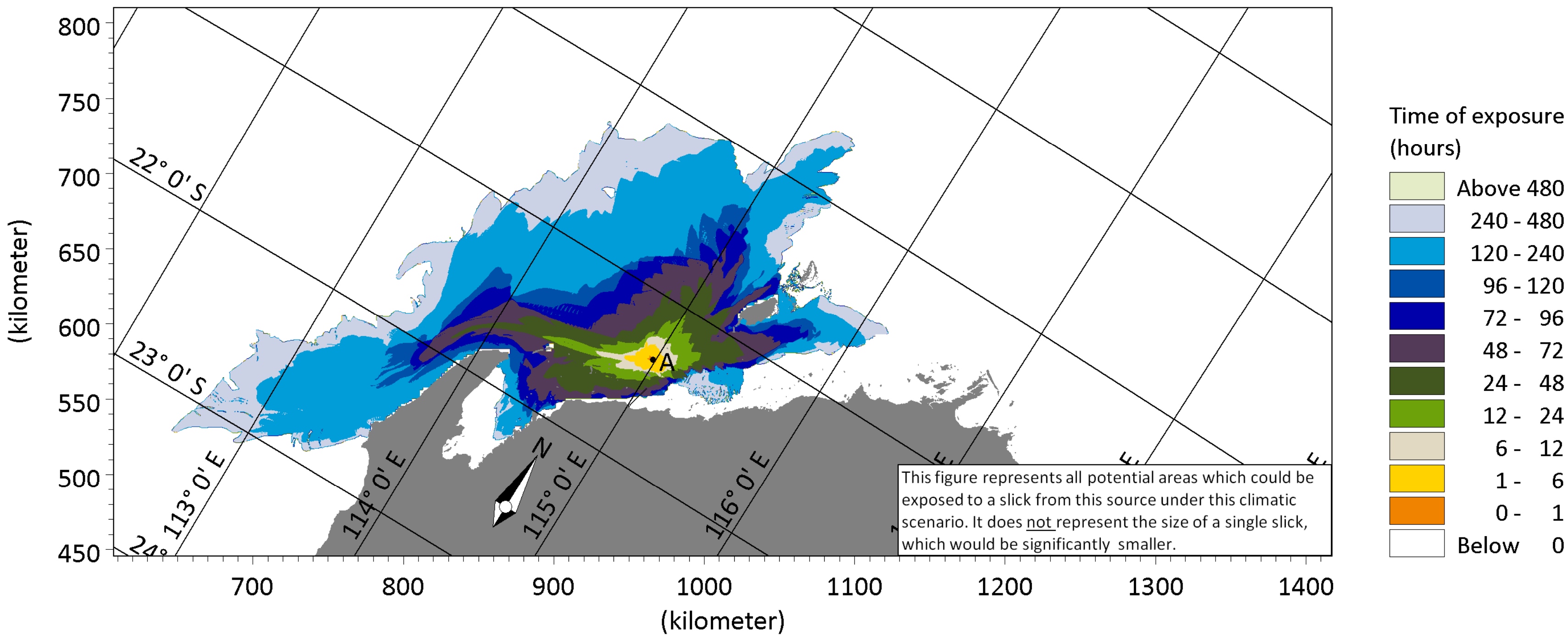

Figure E.5 Minimum time of exposure for spill near entrance of northern approach channel (transitional).

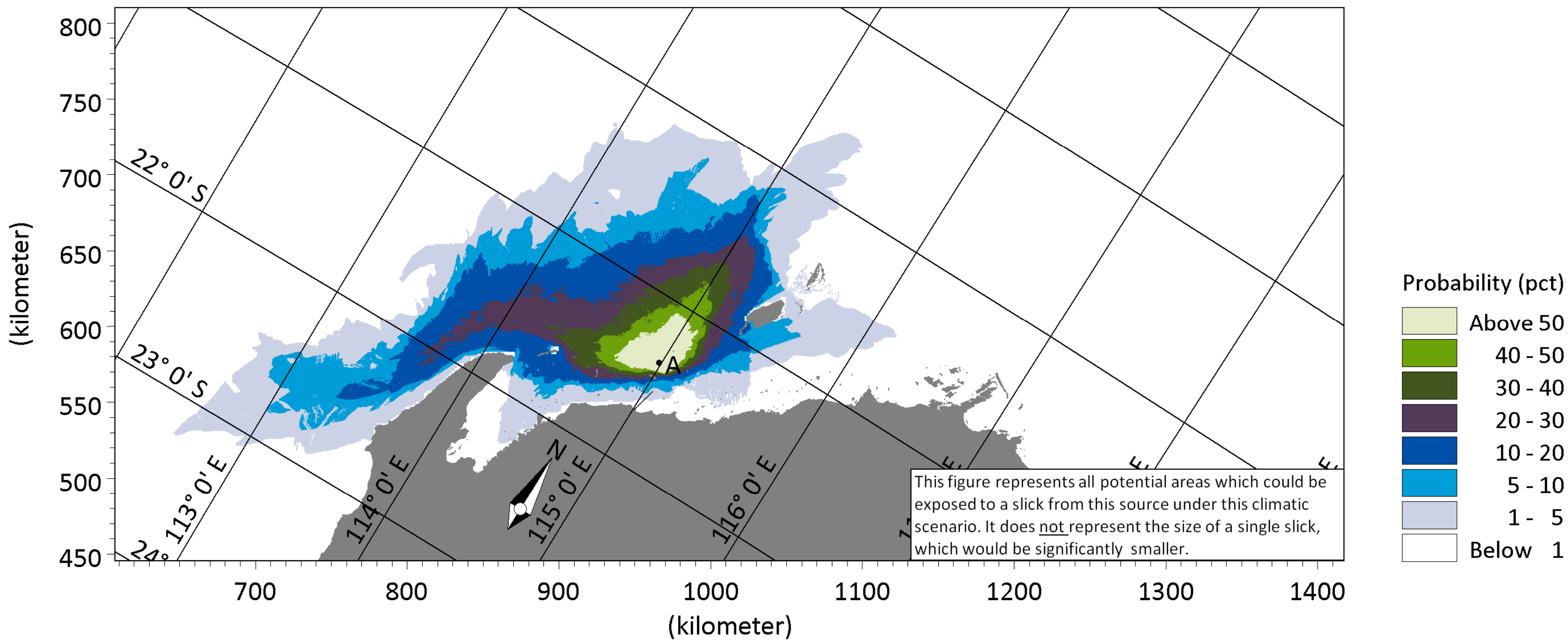

Figure E.6 Probability of exposure for spill near entrance of northern approach channel (transitional).

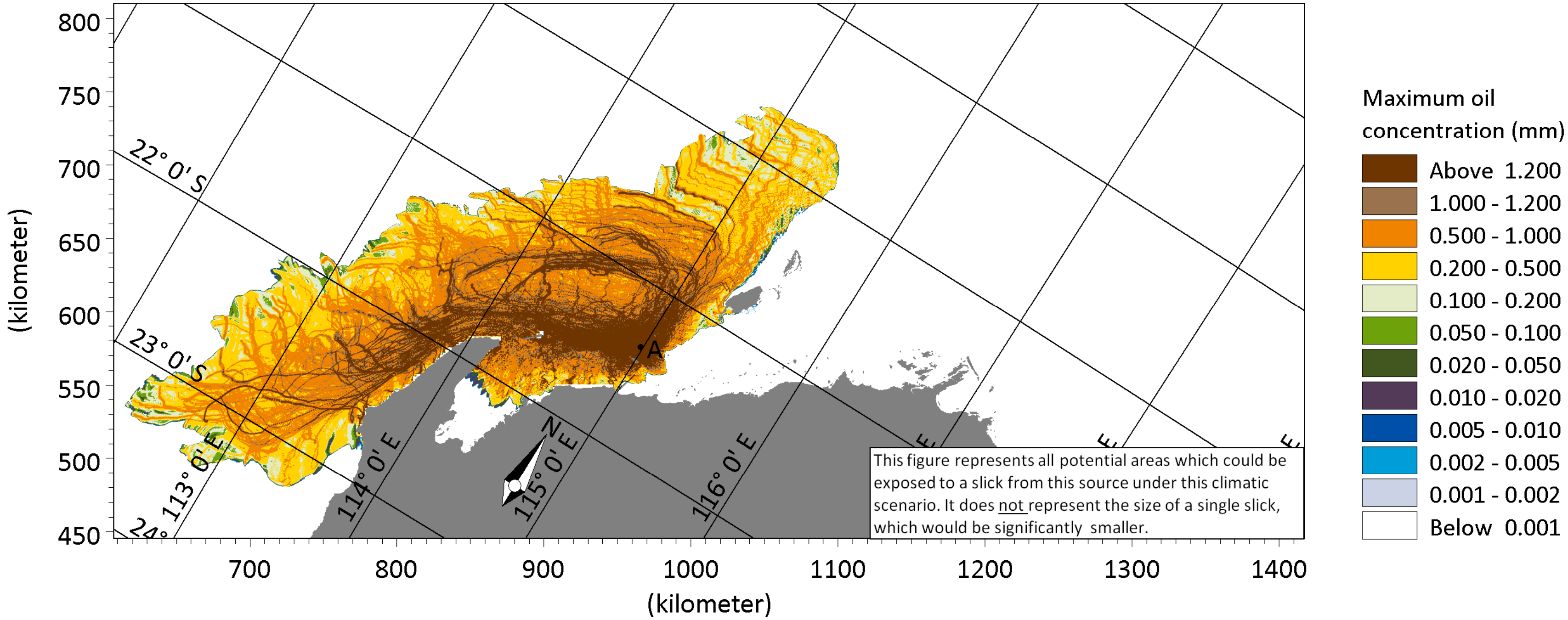

Figure E.7 Maximum oil concentration for spill near entrance of northern approach channel (winter).

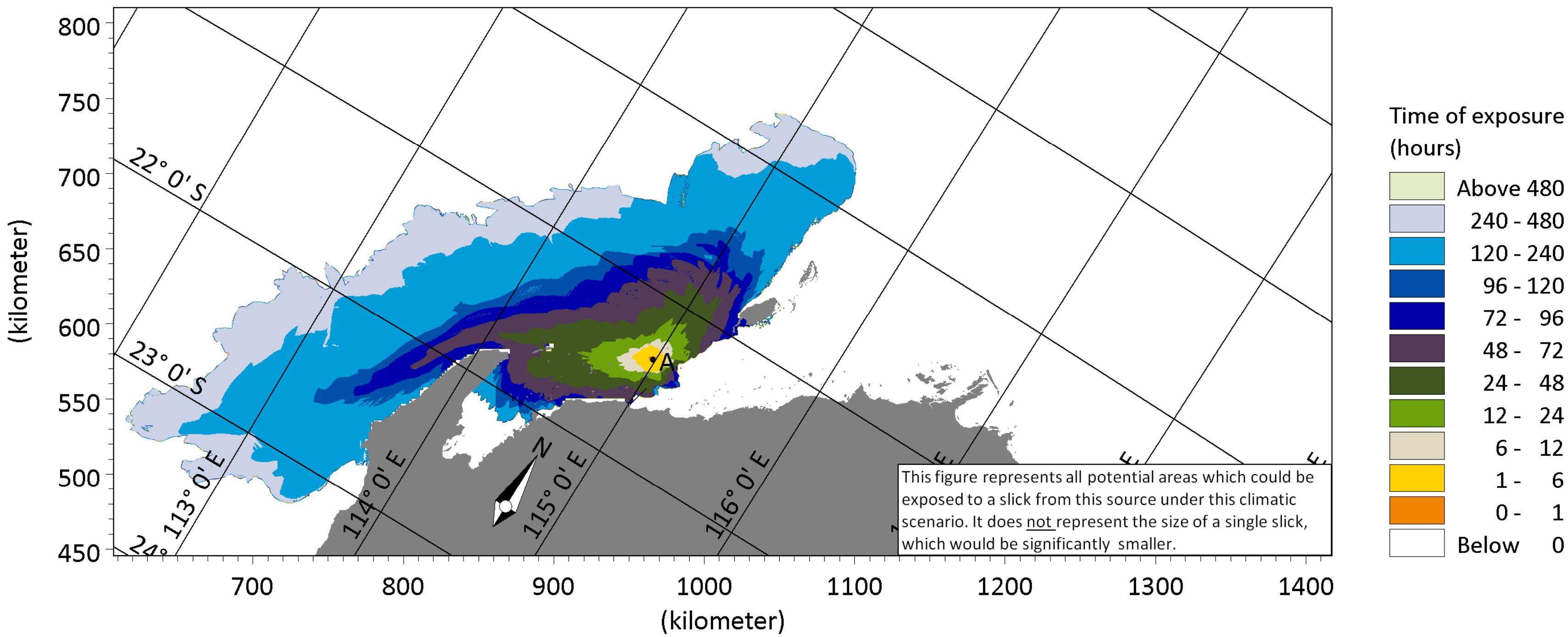

Figure E.8 Minimum time of exposure for spill near entrance of northern approach channel (winter).

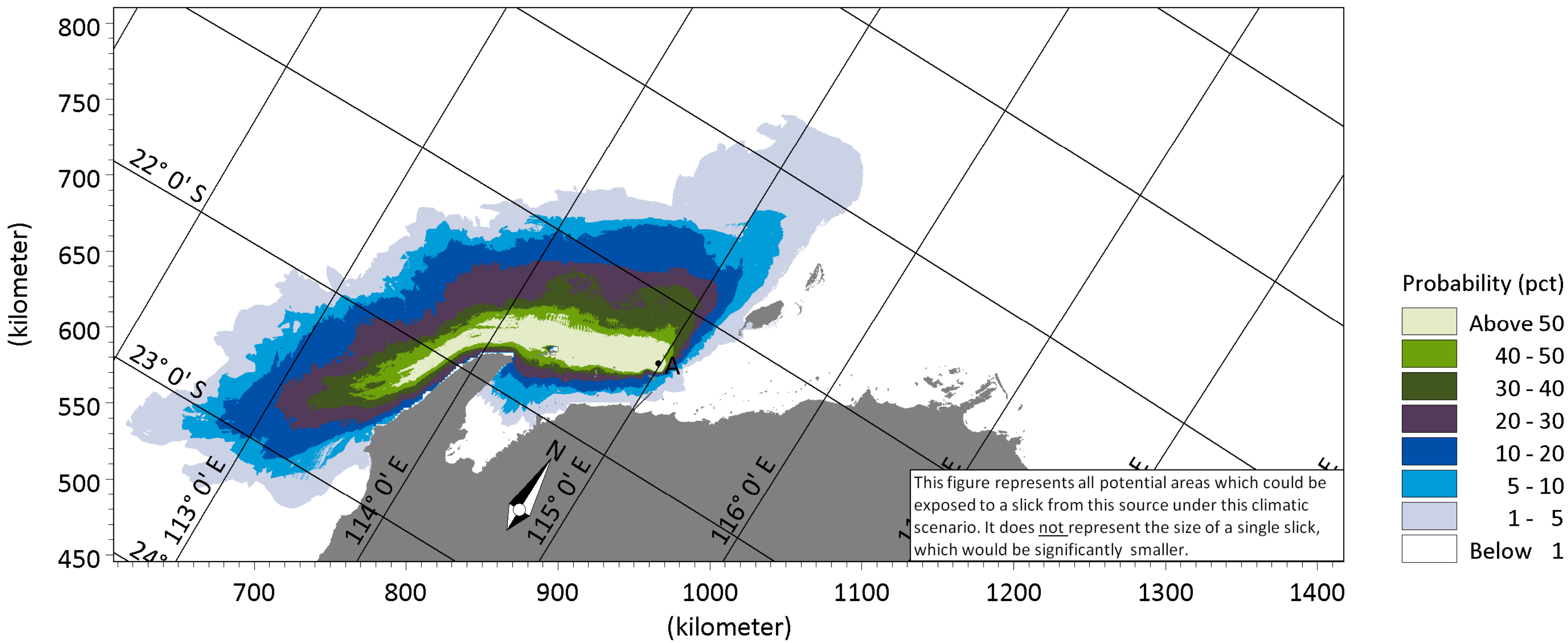

Figure E.9 Probability of exposure for spill near entrance of northern approach channel (winter)

A D D E N D U M   F

Scenario 7b – Tanker Grounding

Key Results

F SCENARIO 7B

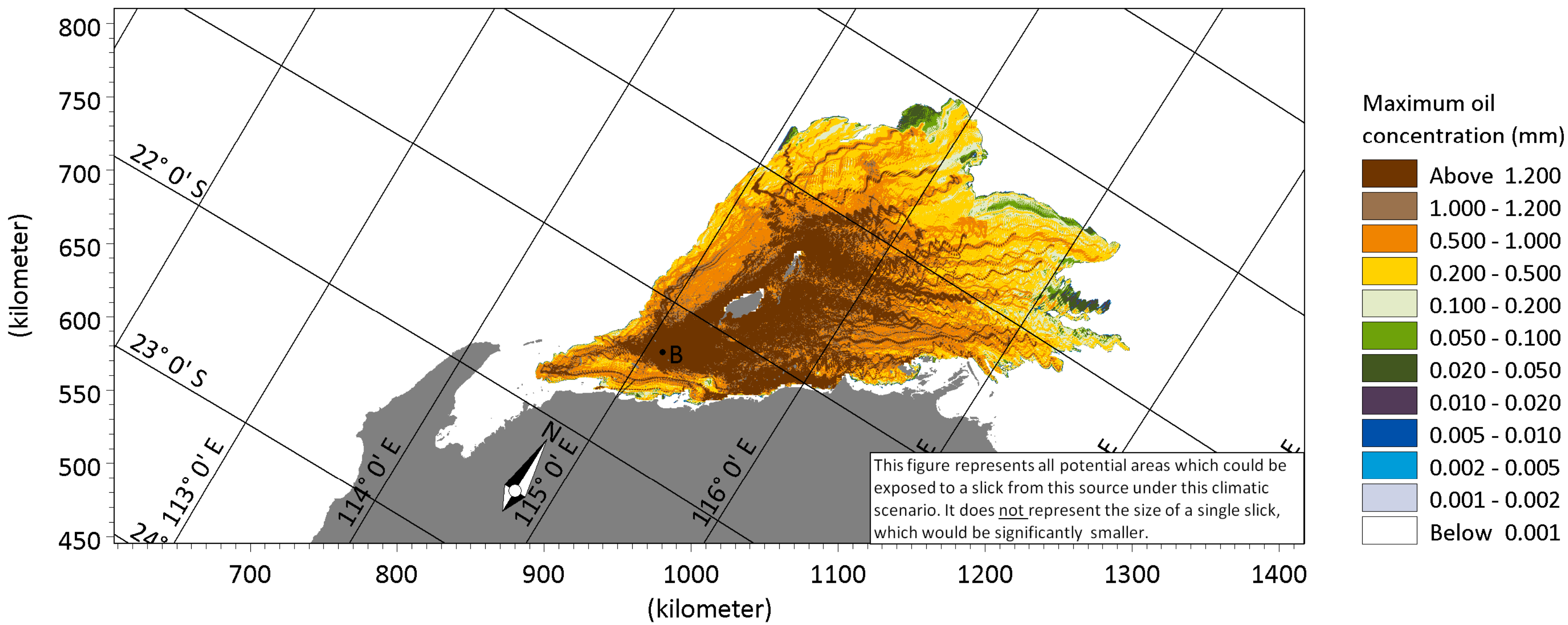

Figure F.1 Maximum oil thickness for spill near entrance of northern approach channel (summer).

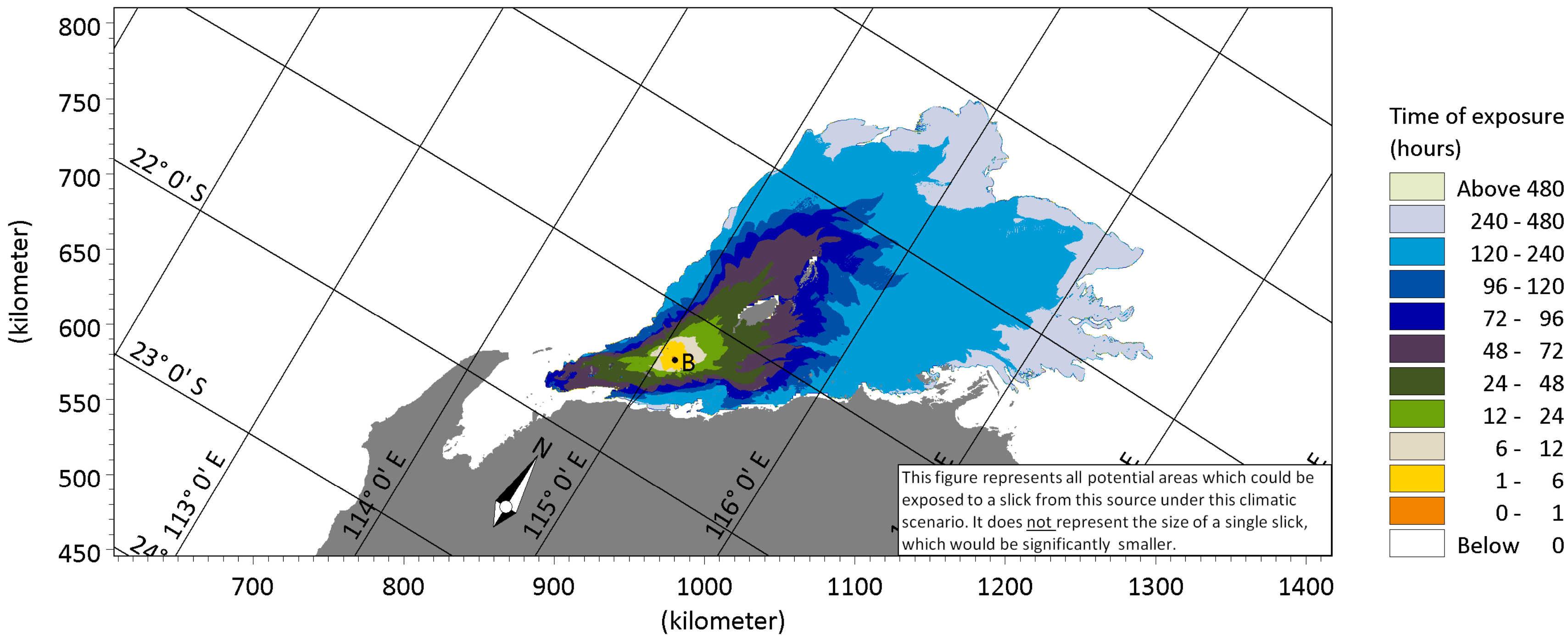

Figure F.2 Time of exposure for spill near entrance of northern approach channel (summer).

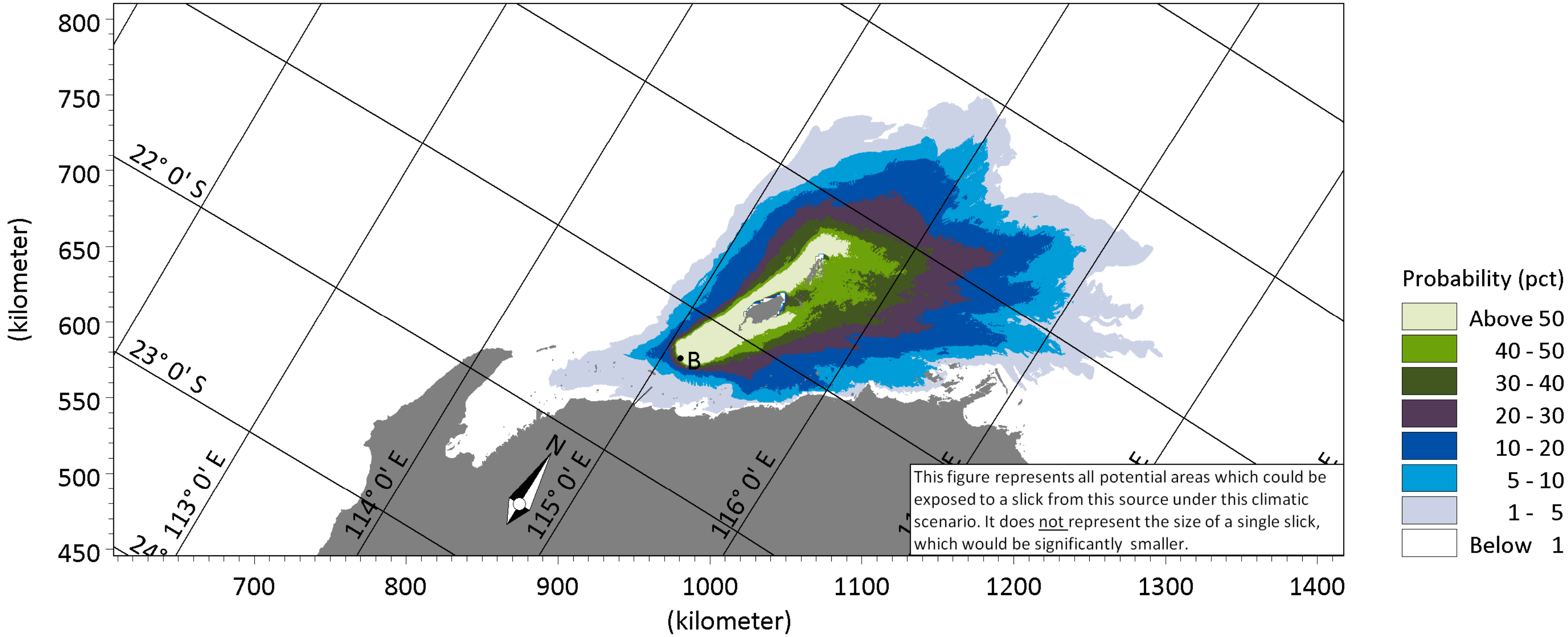

Figure F.3 Probability of exposure for spill near entrance of northern approach channel (summer).

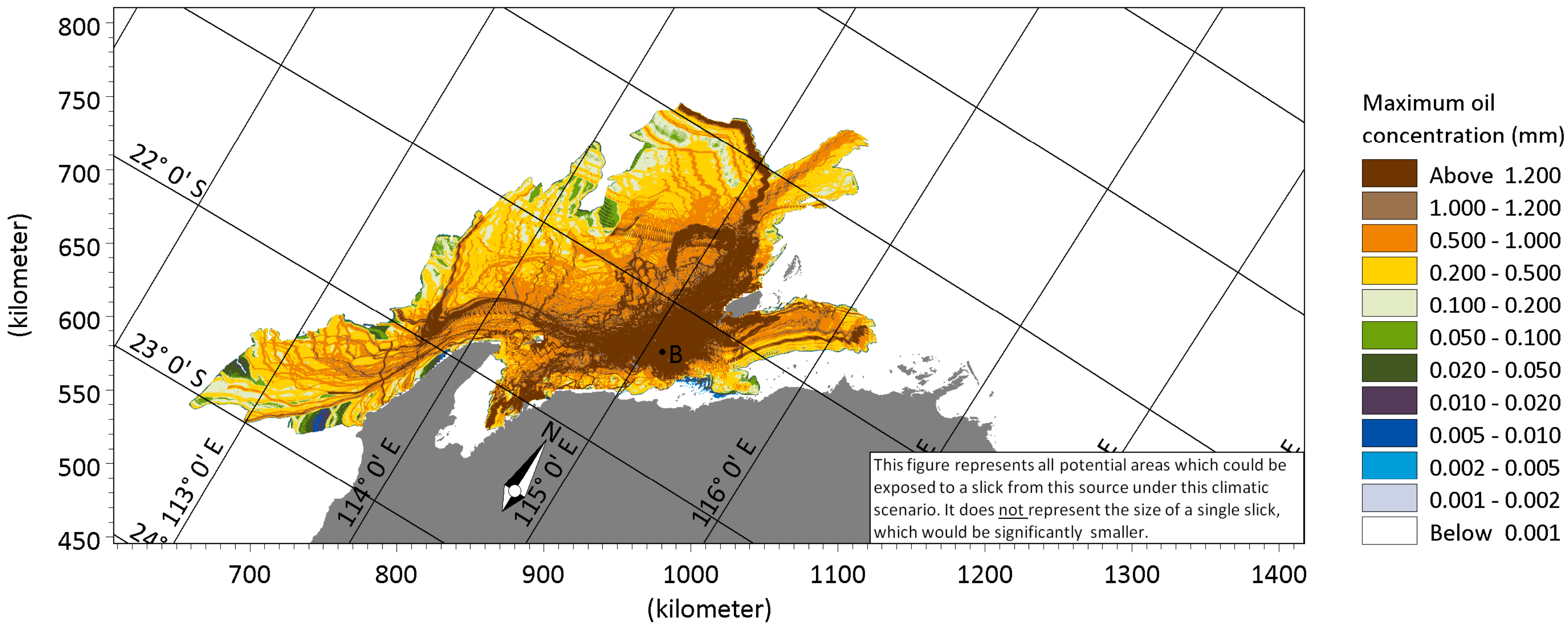

Figure F.4 Maximum oil thickness for spill near entrance of northern approach channel (transitional).

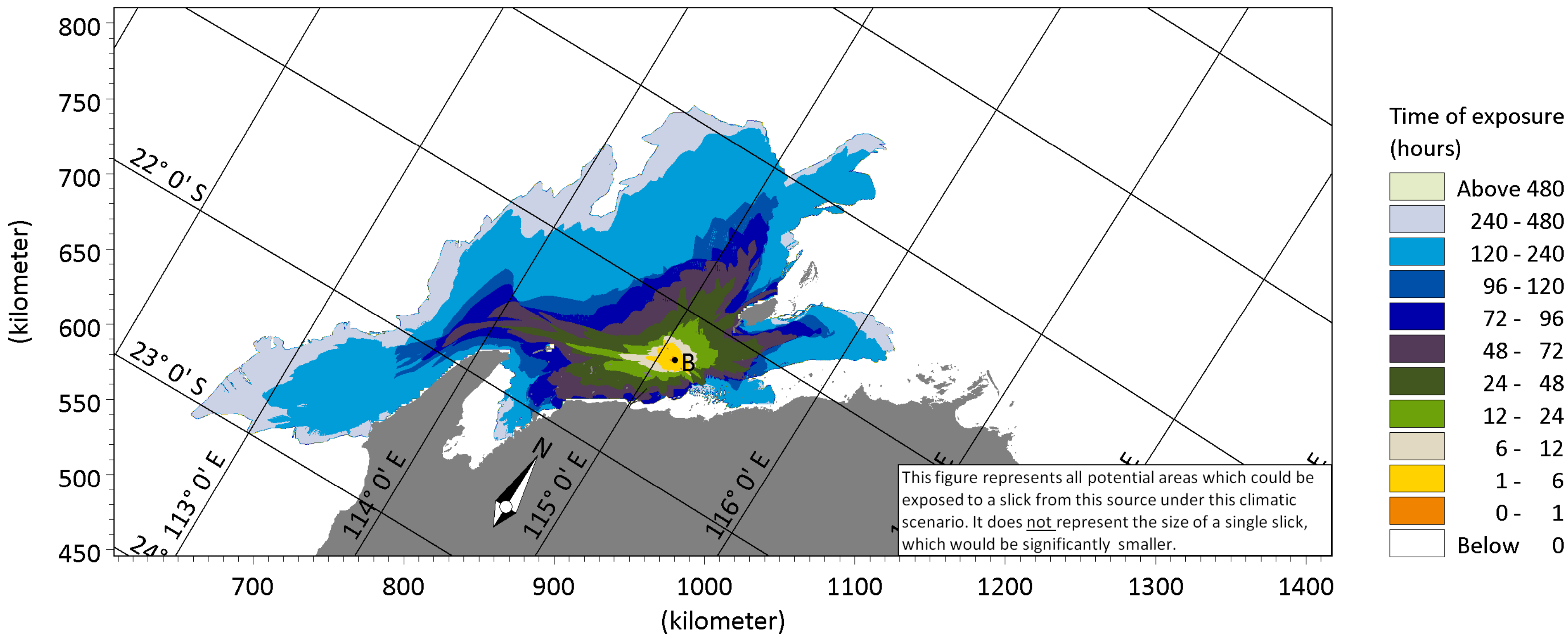

Figure F.5 Time of exposure for spill near entrance of North approach channel (transitional).

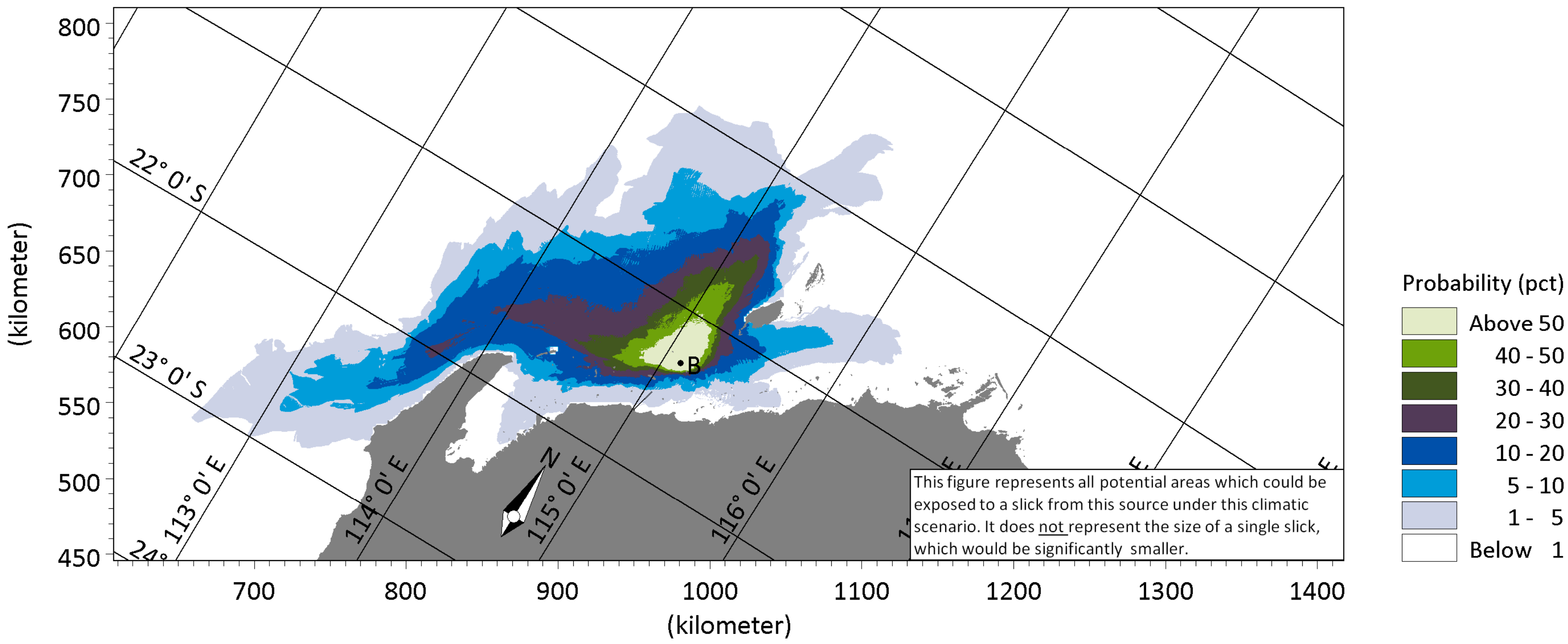

Figure F.6 Probability of exposure for spill near entrance of North approach channel (transitional).

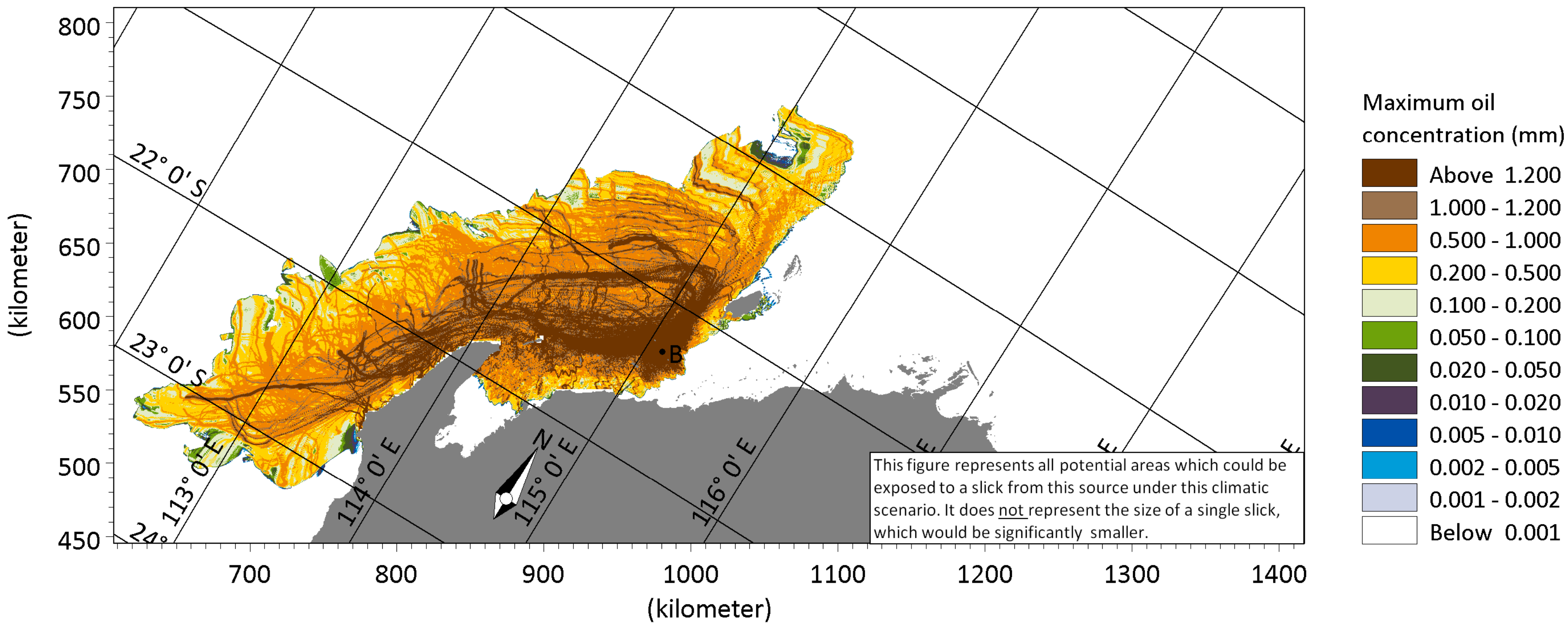

Figure F.7 Maximum oil thickness for spill near entrance of northern approach channel (winter).

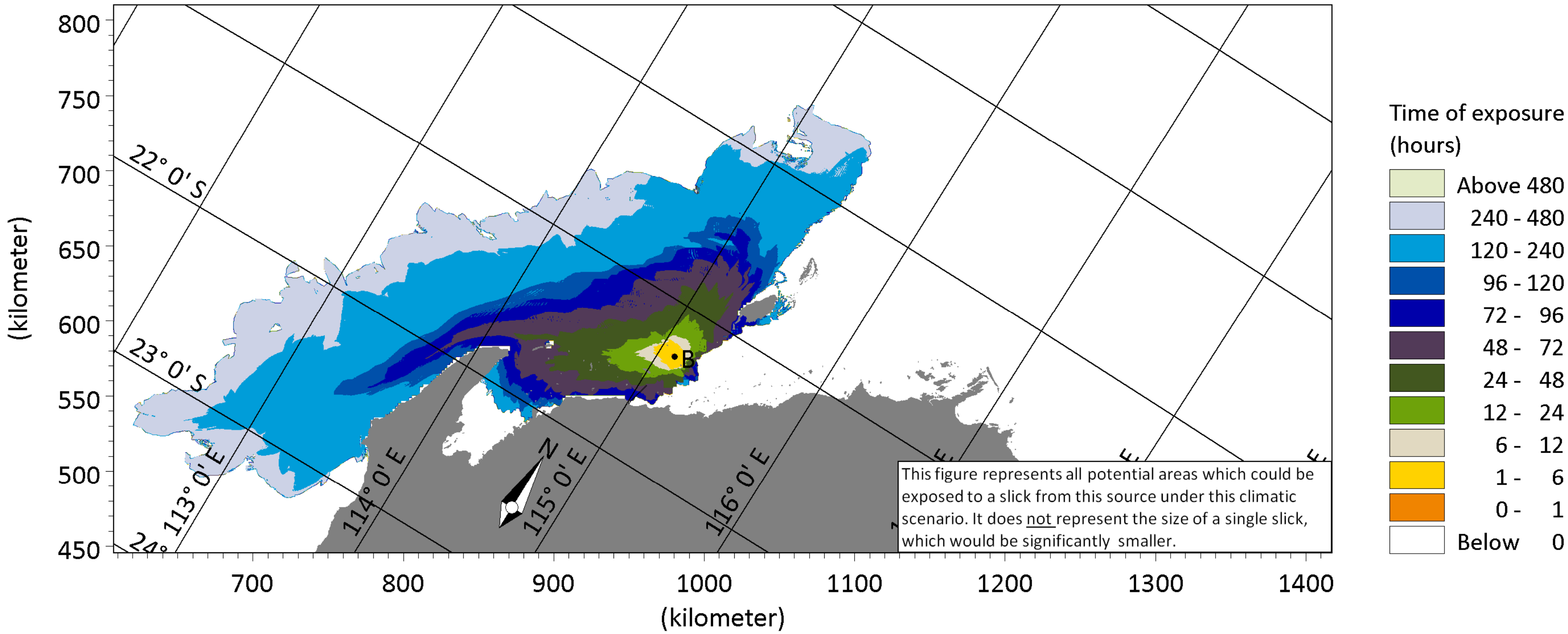

Figure F.8 Time of exposure for spill near entrance of northern approach channel (winter).

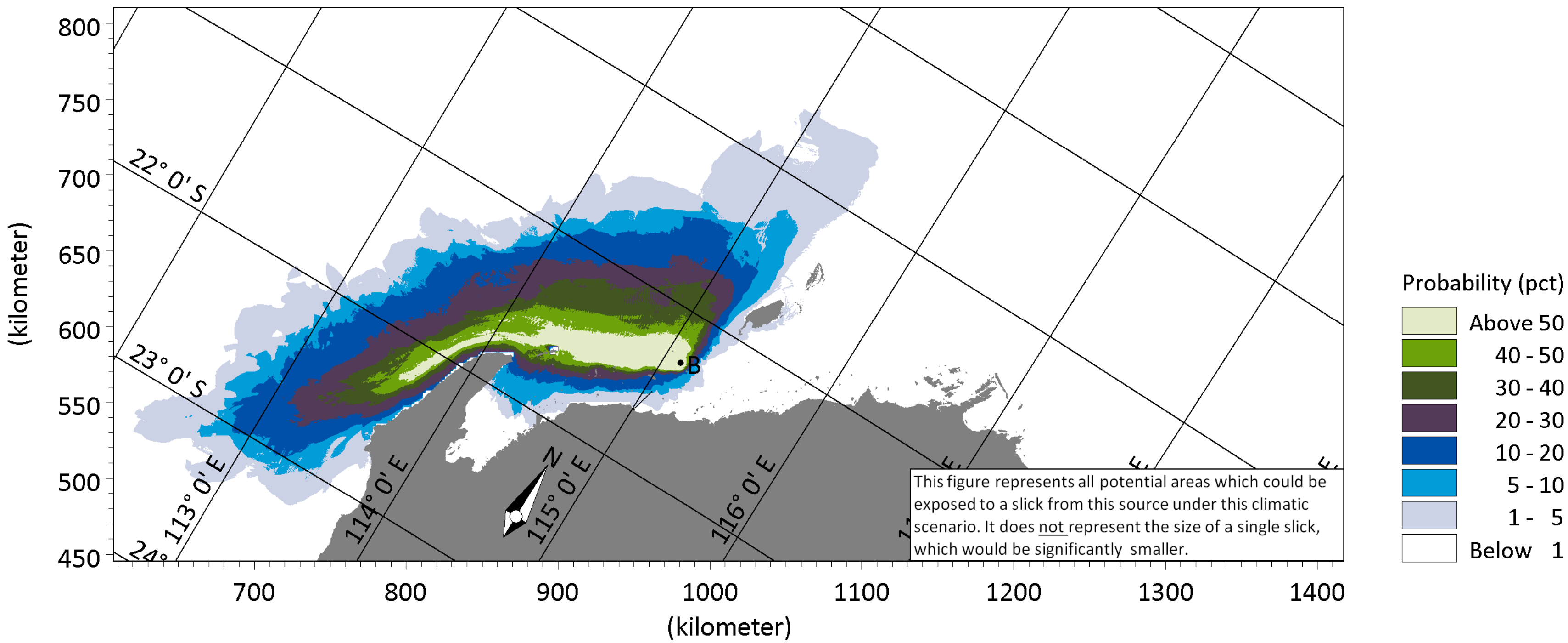

Figure F.9 *Time of exposure for spill near entrance of northern approach channel (winter).*

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Appendix FP

Dredge Spoil Modelling Additional Documentation
and Response to Independent Peer Review
Closeout Report of 28th July, 2010

This report provides the DHI responses to Dr. Des Mills final review of the Dredge Plume Modelling Report. Dr. Des Mills identified a number of recommendations in relation to this Study. DHI's responses to his key final recommendations were:

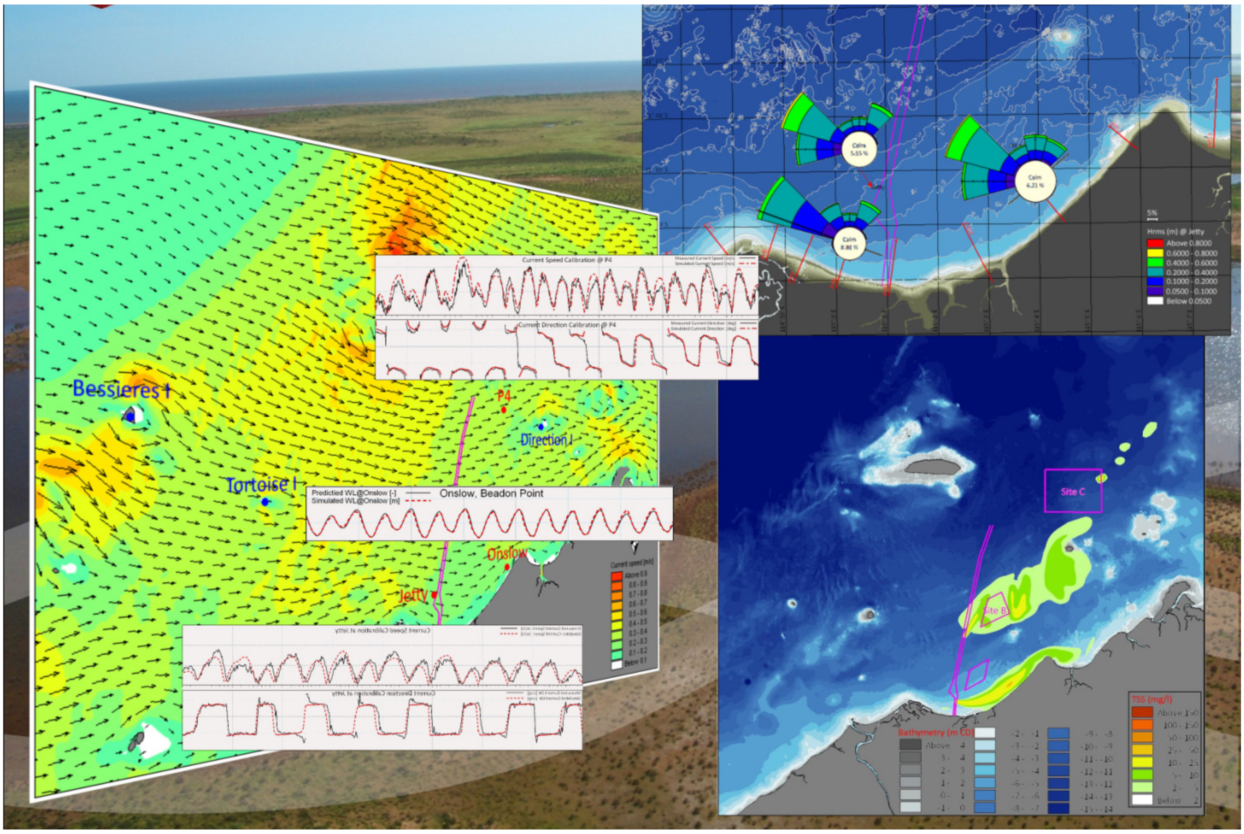
Issue	Status
3D current structures: DMMER recommends comparison to cover all climatic scenarios.	Comparisons have been extended as recommended by DMMER. 3D scenarios have further been carried out for spoil ground D.
Wind fields: Request for explanation of merging of two sets of results.	Explanation of the merging will be provided in EIS supplement.
Concern whether climatic scenarios can adequately represent the plume impacts.	Extension of data comparison for the wind driven net currents has been carried out.
Recommendation to include 1999-2000 for assessment of interannual variability.	1999-2000 as well as 2002-04 assessed for interannual variability.
Resuspension: Can the short term scenarios adequately cover effects of resuspension? Additional analysis recommended.	Additional analysis per DMMER recommendations has been carried out and will be reported in the EIS supplement.

DHI
Water & Environment (M) Sdn Bhd (535484 - V)

Wheatstone Project - Dredge Spoil Modelling

Additional Documentation and Response to Independent Peer Review Closeout Report of 28th July, 2010.

Chevron Australia P/L



November 2010

Technical Note

DHI Water & Environment (M) Sdn Bhd (535484 - V)

Wheatstone Project - Dredge Spoil Modelling

Additional Documentation and Response to Independent Peer Review Closeout Report of 28th July, 2010.

November 2010

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Project Title Wheatstone Project - Dredge Spoil Modelling Additional Documentation and Response to Independent Peer Review Closeout Report of 28th July, 2010.		Project / Report No My43800137-0 – Response to IPR closeout report dated 28th July 2010			
Authors Amy Ling Cesar Rocha Dr. Claus Pedersen		Date 15 November 2010 Approved by Dr. Claus Pedersen			
0	Responses to IPR Closeout Note	CLP	CLP	CLP	24.06.2010
Revision	Description	By	Checked	Approved	Date

Key words	Classification
Response to Independent Peer Review	☐ Open ☐ Internal ☒ Proprietary

Distribution	No of copies
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CONTENTS

1 INTRODUCTION

A report, Mills (June 2010), dated 8 June 2010 was submitted by Dr. Mills of Des Mills Marine Environmental Reviews (DMMER) outlining the findings of the independent peer review (IPR) of the DHI report "Dredge Spoil Modelling" of 10th May, 2010.

Responses to the issues raised in the IPR report of June were included as Appendix JJ to Appendix Q of the Draft Wheatstone EIS/ERMP.

Subsequently, Dr. Des Mills issued a report, Mills (July 2010) with follow up comments to DHI's responses. This report is considered a closeout report in terms of the independent review process, and is hereafter referred to as "IPR closeout report". The IPR closeout report is attached to this document as Appendix A for easy reference.

The present technical note constitutes DHI's responses to the comments and recommendations in the IPR closeout report and documents further work undertaken to address those issues and recommendations.

The present report is structured with Section 2 providing a brief overview of issues and recommendations derived from the IPR closeout report together with outline responses by DHI. Sections 3 to 6 together with Appendix FF contain additional information in response to the issues and recommendations raised in the IPR closeout report.

2 SUMMARY OF REVIEWER ISSUES AND RESPONSES

DHI's interpretation of the IPR closeout report has identified 5 main outstanding issues and recommendations. These are briefly outlined below together with a high-level response. Detailed responses are provided in following sections and are referenced in the present section.

2.1 3D Effects

2.1.1 Issue per IPR closeout report

MER Recommendation:

A comparison of the plumes (and the resultant zones of effect) derived from the 2D and the 3D simulation results should be conducted for the Winter A, Summer A and Transitional A scenarios. These comparisons and the previously reported comparisons for the "B" scenarios should be considered together to determine whether the 2D modelling provides more conservative results overall compared to the 3D modelling approach.

DHI Response:

The 2D-3D comparison has been extended as requested – see Section 3.1.

Overall, the assessment of the climatic "A" conditions confirm the expected overall conservatism of the 2D modelling trend with similar or mostly slightly larger predicted potential impact zones from the 2D modelling compared to the 3D modelling.

The differences between the 2D and the 3D derived impact zones are insignificant compared to the differences due to, for instance, different dredge, climatic or release scenarios.

The conclusion previously drawn and reported in the Draft EIS/ERMP is maintained. It is DHI's opinion that the 2D scenario approach provides a conservative assessment for the majority of the release sources. 3D current effects are present, but small, at the deeper areas located at the outer part of the channel and the primary dredge material placement Site C. Potential effects of 3D currents on the derived impact zones at these areas are insignificant compared to the effects of other modelling input variables.

2.1.2 3D Scenario for Dredge Placement Site D

DHI has previously indicated that an additional scenario covering the offshore Dredge material placement Site D would be modelled in 3D. This has been carried out and is reported in Section 3.2 of the present report.

The assessment concluded that the only habitat potentially impacted by the placement of dredge material at Site D for the simulated scenario is a small area of benthic filter feeder community along the shelf break which may suffer partial mortalities, while a larger area of the filter feeder community, within 6km of Site D, may fall within the Zone of Influence.

2.2 Merging of Results for Different Wind Fields

A request for further explanation of the merging of modelling results from the simulations with Onslow Met Station (OMS) and MesoLAPS winds is included twice in the IPR closeout report.

MER Recommendation

The numerical procedure for the merging of plumes should be explained in more detail, both for SSC and net sedimentation rates.

DHI Response

The plumes and sedimentation fields from the two different wind sources are simulated separately. For each set of simulations, predicted potential impact zones are produced. The total resultant envelope of potential impact zones is derived by always taking the worst of the predicted impact zones at all locations from the two sets of simulations with different wind fields.

This is described in further detail in Section 4 and in Appendix N2: "Dredge Plume Impact Assessment" of the Draft EIS/ERMP, which describes the derivation and merging of the predicted potential impact zones.

2.3 Climatic Scenario Documentation

Two aspects are mentioned in the IPR closeout report:

1. The representation of the full range of climatic conditions by a limited number of climatic scenarios
2. The representation of inter-annual variability.

Issue per MER

The sequence, persistence and frequency of occurrence of modelled net current speeds and directions used for the various climatic scenario periods do not fully represent the variability inherent in other periods of the measured net currents. This creates some uncertainty as to whether the plume and its impacts can be adequately represented in terms of six short term climatic scenarios.

MER Recommendation:

DHI proposes to model the period 2002-2003 corresponding to an El Nino period (predominantly negative values of the Southern Oscillation Index (SOI)). This period is expected to have a greater frequency of occurrence of westerly winds compared to long-term averages. The aim is to assess whether the simulated net currents from this period can reasonably be characterized by the set of six climatic scenarios already selected.

The period 1999-2000 should also be modelled as these years had clear positive SOI values, corresponding to a La Nina period, which may be expected to have a smaller frequency of occurrence of westerly winds compared to the long-term average. The aim is to assess whether the simulated net currents from this period can reasonably be characterized by the set of six climatic scenarios already selected.

DHI Responses

DHI responses are covered in Section 5 of the present report, supported by comprehensive documentation in revised Appendix FF to Appendix Q1 of the Draft EIS/ERMP. Revised Appendix FF is attached to the present document.

A comprehensive assessment of both winds and net current fields has been carried out to assess whether the adopted climatic scenarios can be considered reasonably conservative. The assessment showed that the chosen "strong" winter and summer conditions comprise the strongest monthly averages of net wind and current fields. The transitional periods include weak and variable winds and net currents to cover the potential local build-up of sediments during periods of neap tide.

Whereas it is agreed that the limited number of climatic scenarios may not cover all possible variations of winds and resulting net current conditions that may be experienced during the dredging period, it is concluded that the range of selected summer, winter and transitional (calmer) conditions provide good coverage of the range of potential conditions and provide a reasonably conservative estimate of the predicted potential impact zones when applied through the scenario modelling approach.

2.4 Sediment Resuspension

Two recommendations for changes to plots to provide better clarity have been provided in relation to the presentation of long-term modelling.

MER Recommendation 1:

Replot Figure F.13 as net sedimentation change for each 14 day period to determine whether the spatial distribution is stationary or migrating over time.

DHI Response to MER Recommendation 1.

DHI agrees that the proposed changes improve the interpretation of the results, and Figure F.13 has been replotted as recommended, see Section 6.2. The changes to the figure do not lead to changes in the assessment.

MER Recommendation 2:

The comparison of dredge plume footprints using the short term and long term scenario approaches (Figure F.22) should be reworked. For this purpose only outputs from the short term scenarios involving MesoLAPS winds should be merged.

2.5 DHI Response – Issue 2.

Figure F.22 (from Appendix F of Appendix Q1 of the EIS) has been reworked as recommended by Dr. Mills, see Section 6.4.

The changes add clarity to the interpretation. The conclusions previously drawn are unchanged, see Section 6.4

3 3D EFFECTS

Two components have been included for additional documentation in relation to 3D modelling:

1. Comparison of 2D and 3D modelling for climatic scenarios “A” per recommendation in IPR closeout report.
2. Additional 3D scenario carried out for placement of dredge material at Site D, which has not previously been covered by the dredge scenarios.

These two components are addressed below.

3.1 Response to IPR Closeout Report

3.1.1 Issue per Mills (2010):

Note from Figures E15, E17, E19, E21 and E23 (Appendix E) that the sequence and frequency distributions of speed and directional data for the simulated net currents corresponding to the “A” climatic scenarios differ significantly from those of their “B” scenario counterparts. Hence, simulated plumes may differ significantly between the Summer A and Summer B climatic scenarios, for example, and likewise for the transitional and winter scenarios.

MER Recommendation: A comparison of the plumes (and the resultant zones of effect) derived from the 2D and the 3D simulation results should be conducted for the Winter A, Summer A and Transitional A scenarios. These comparisons and the previously reported comparisons for the “B” scenarios should be considered together to determine whether the 2D modelling provides more conservative results overall compared to the 3D modelling approach.

3.1.2 DHI Response:

The comparisons of plumes and resulting zones of potential impacts for corals (the most sensitive habitats) have been extended to include for the “A” climatic conditions as recommended, see Figure 3.1 to Figure 3.18.

The observations made for the climatic “B” conditions are also found to be valid for the “A” conditions. The predicted indicative zones of impact (IZI) for partial mortality derived based on Suspended Sediment Concentration (SSC) is generally similar or extend further away from the release sources for the 2D modelling. Some of the IZIs derived based on sedimentation are slightly larger from the 3D modelling results, but overall the predicted potential impact zones are dominated by the SSC assessment. The 3D derived impact zones are contained within the total envelope derived from the 2D results.

Overall, the assessment of the climatic “A” conditions are deemed to confirm the expected tendency with similar or mostly slightly larger impact zones from 2D modelling.

The differences between the 2D and the 3D derived impact zones are insignificant compared to the differences due to, for instance, different dredge, climatic or release scenarios.

Conclusion

The conclusion previously drawn in the Draft EIS/ERMP is maintained. It is DHI’s opinion that the 2D scenario approach provides a conservative assessment for the majority of the release sources of dredge material. 3D current effects are present, but small, at the outer part of the channel and the primary Placement Site C, and potential effects of 3D currents on the derived impact zones at these areas are insignificant compared to the effects of other modelling input variables.

The comparisons of 2D and 3D model results have illustrated that in general the 2D model predicts the sediment plume to travel further from the source at higher concentration, increasing the predicted potential impacts on coral reefs and seagrass habitats. The differences between 2D and 3D results are insignificant compared to the uncertainties related to the dredge programme and other parameters such as release rates, and the 2D model has been adopted as the preferred tool for the assessment as it maintains a slightly more conservative approach when applied in conjunction with the scenario modelling approach. This approach also enables efficient assessment of a much larger array of variables governing plume dispersion than the more computationally demanding 3D approach.

Scenario 6 - Summer A

2D **3D (vertically integrated)**

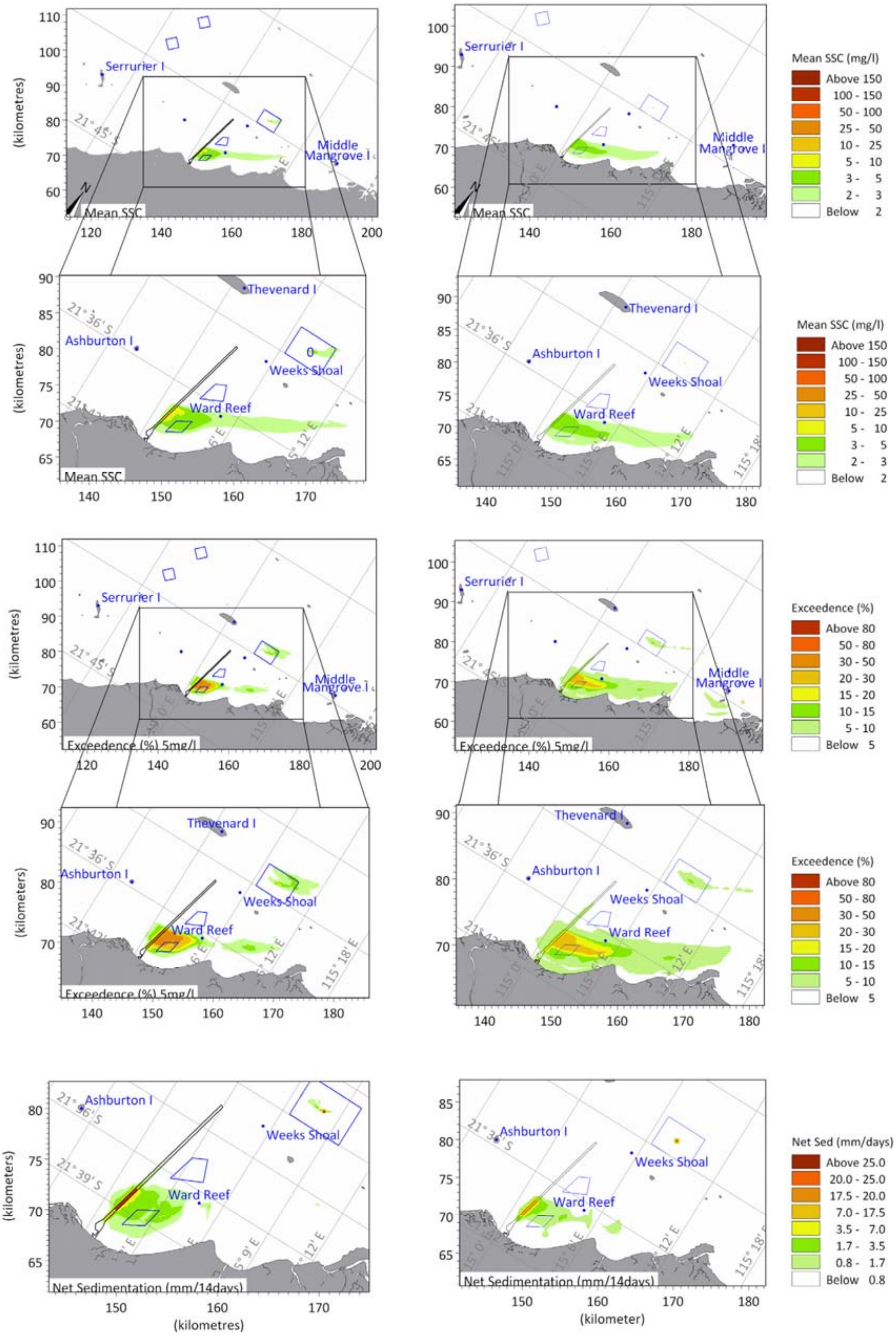


Figure 3.1 *Scenario 6, Summer A, with realistic release rates. Comparison of 2D (left) and 3D (right) results.*

Scenario 6 - Transitional A

2D **3D (vertically integrated)**

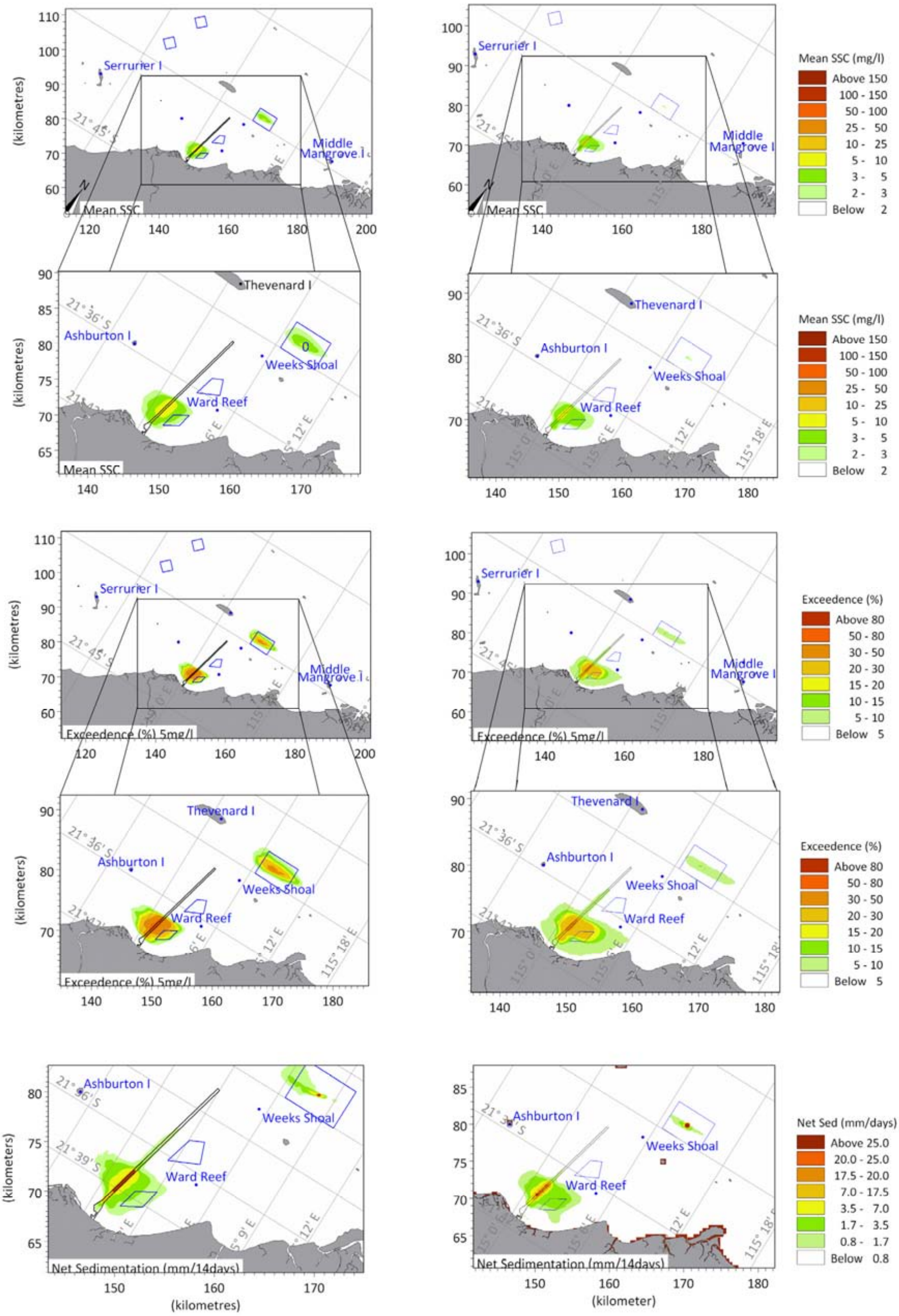


Figure 3.2 Scenario 6, Transitional A, with realistic release rates. Comparison of 2D (left) and 3D (right) results.

Scenario 6 - Winter A

2D　　　　　　3D (vertically integrated)

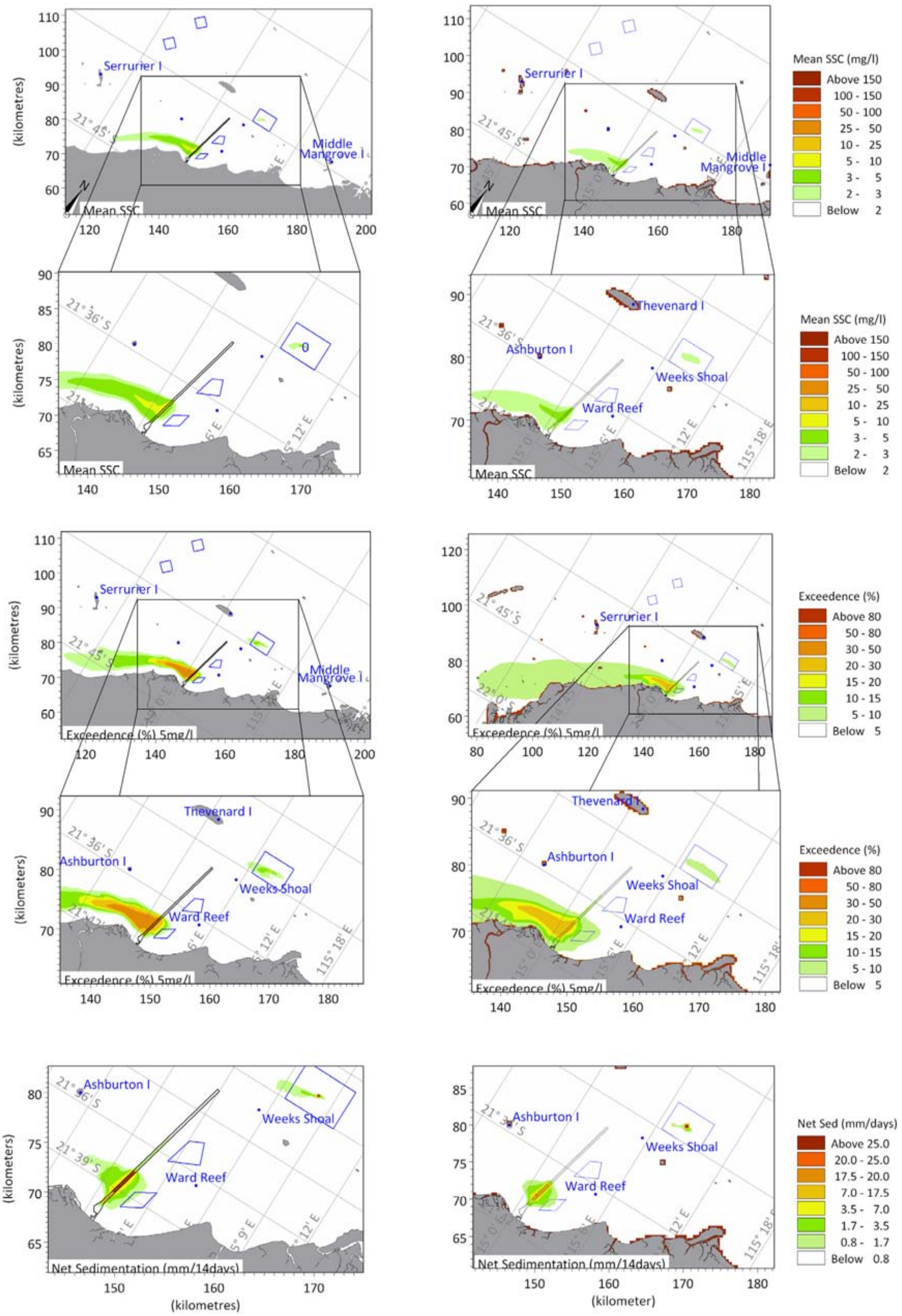


Figure 3.3　Scenario 6, Winter A, with realistic release rates. Comparison of 2D (left) and 3D (right) results.

Scenario 7 - Summer A

2D **3D (vertically integrated)**

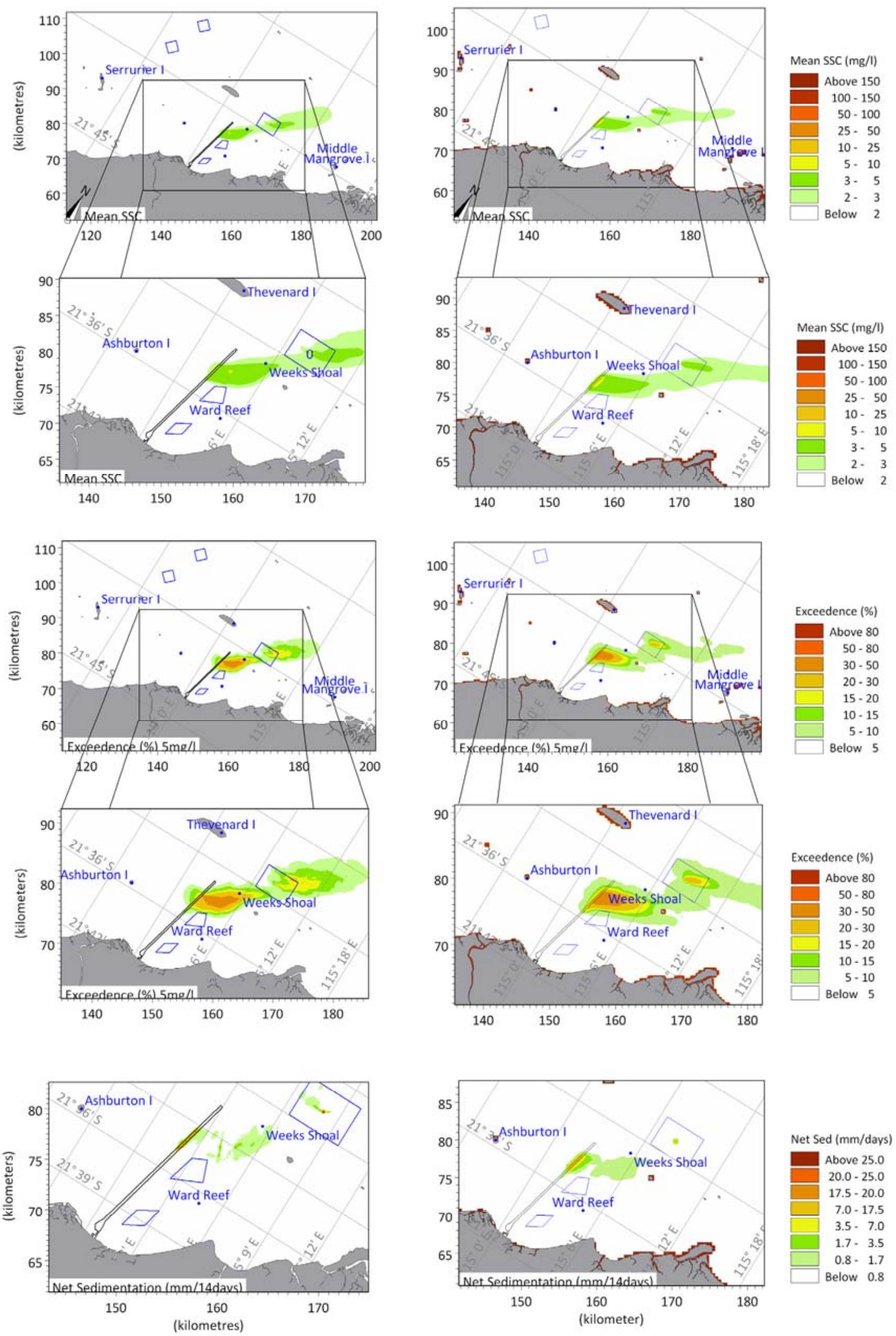


Figure 3.4 Scenario 7, Summer A, with realistic release rates. Comparison of 2D (left) and 3D (right) results.

Scenario 7 - Transitional A

2D   3D (vertically integrated)

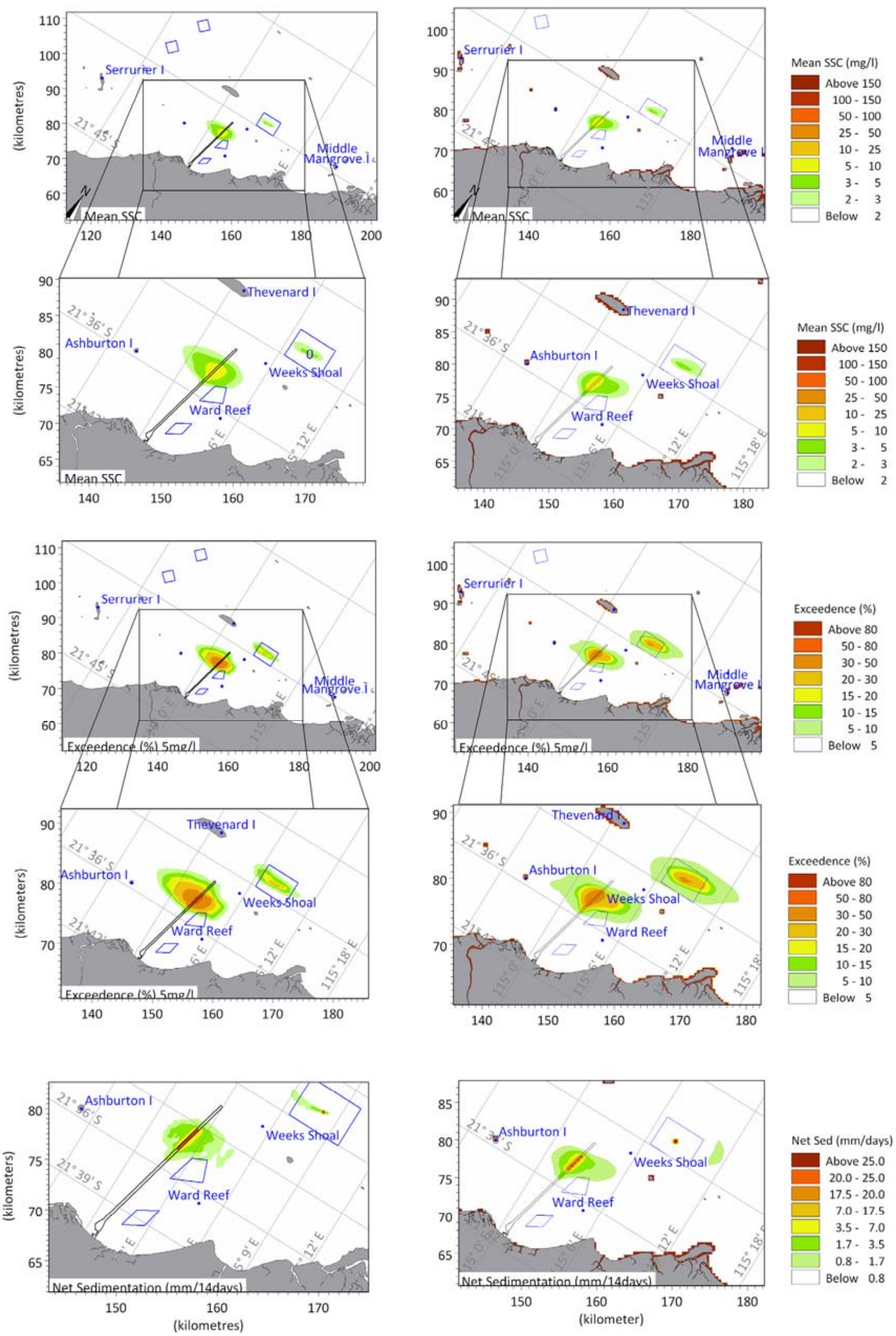


Figure 3.5 *Scenario 7, Transitional A, with realistic release rates. Comparison of 2D (left) and 3D (right) results.*

Scenario 7 - Winter A

2D   3D (vertically integrated)

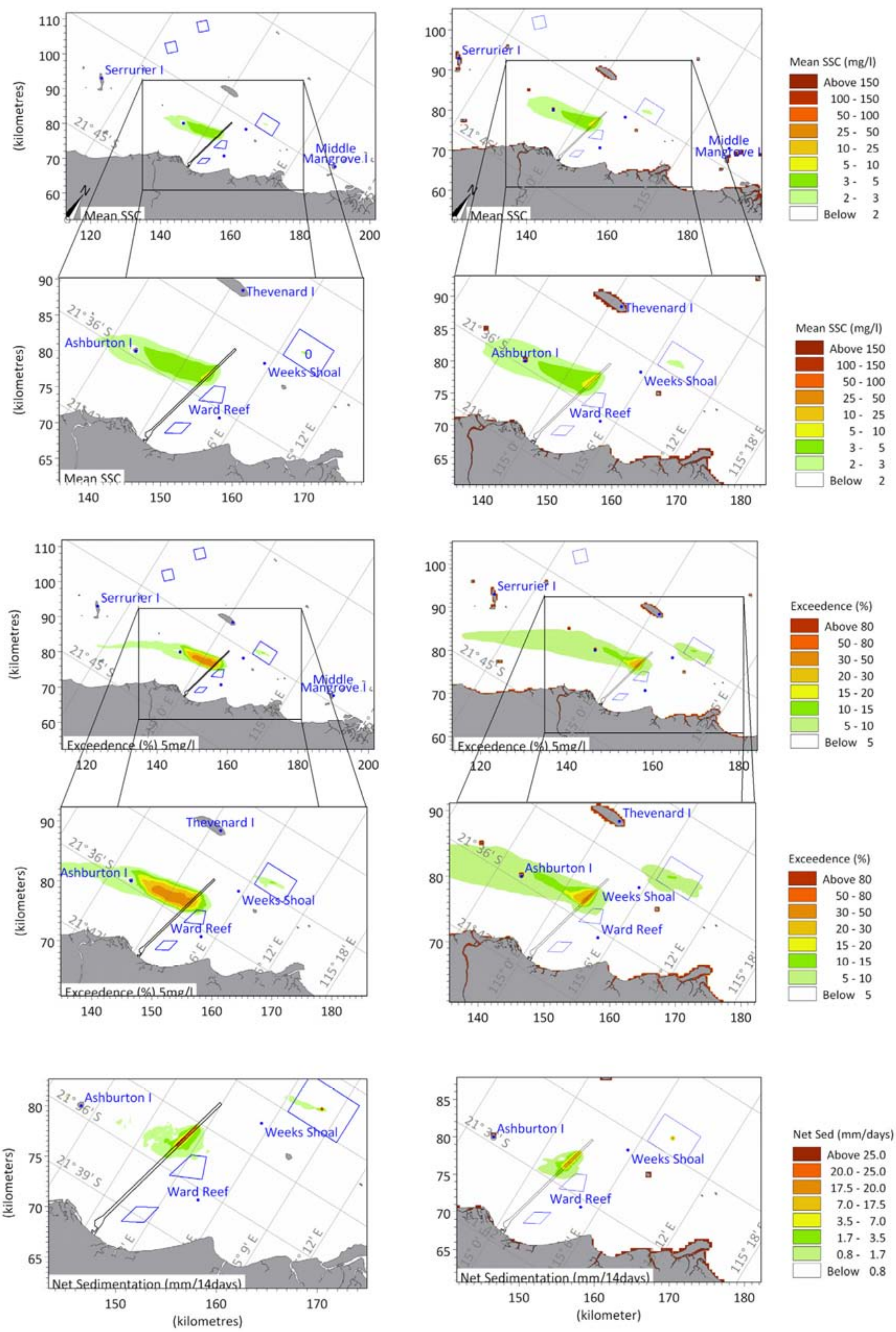
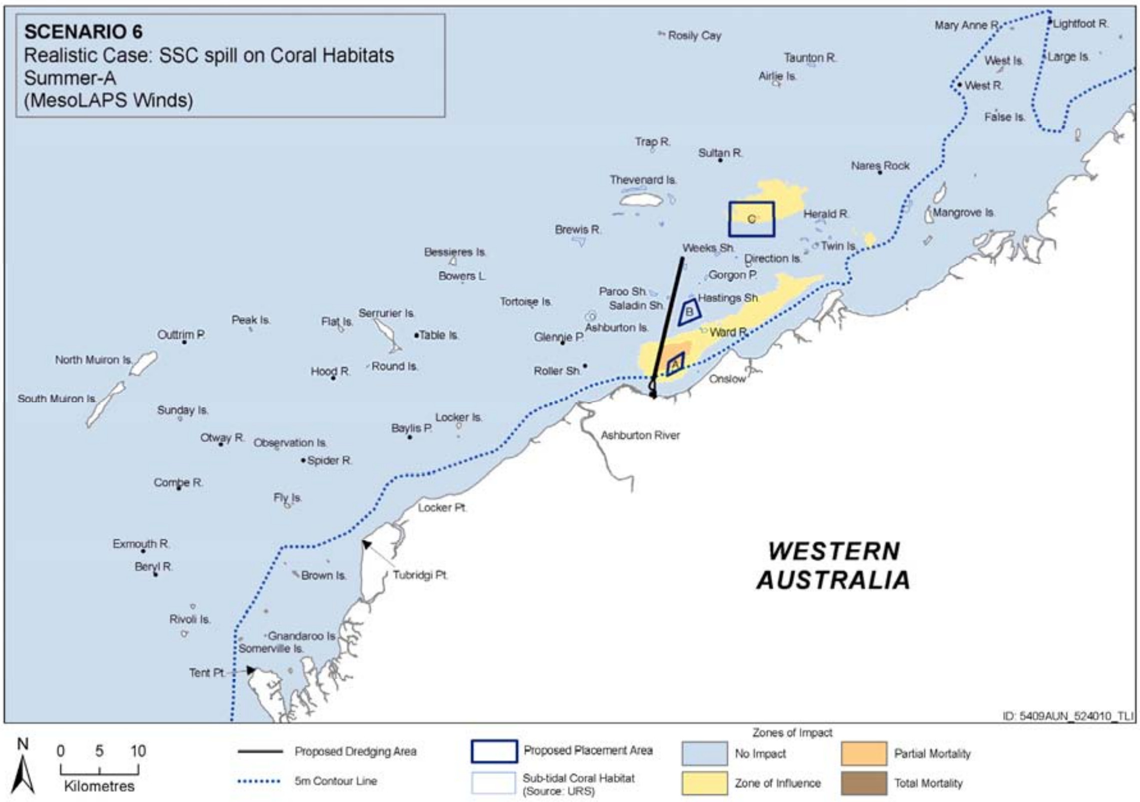


Figure 3.6 Scenario 7, Winter A, with realistic release rates. Comparison of 2D (left) and 3D (right) results.



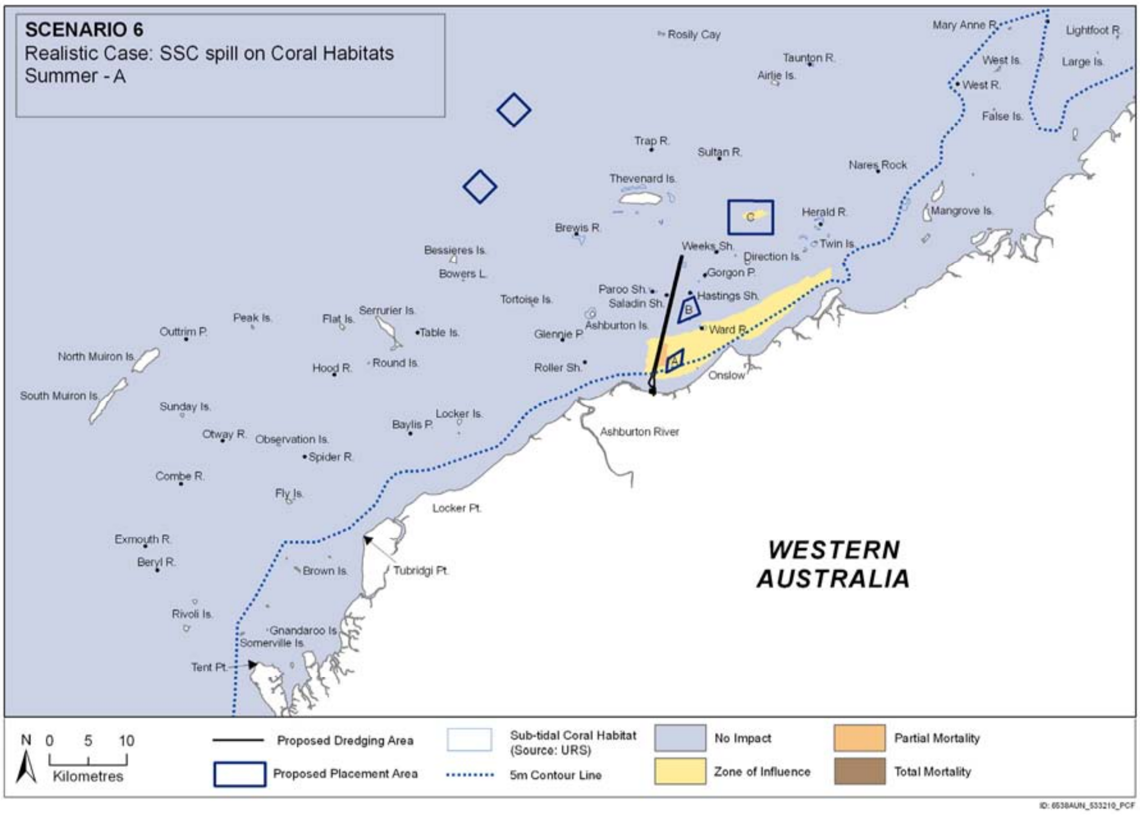


Figure 3.7 Scenario 6 summer A, IZI derived for SSC on coral habitats. Top 2D model and bottom 3D model.

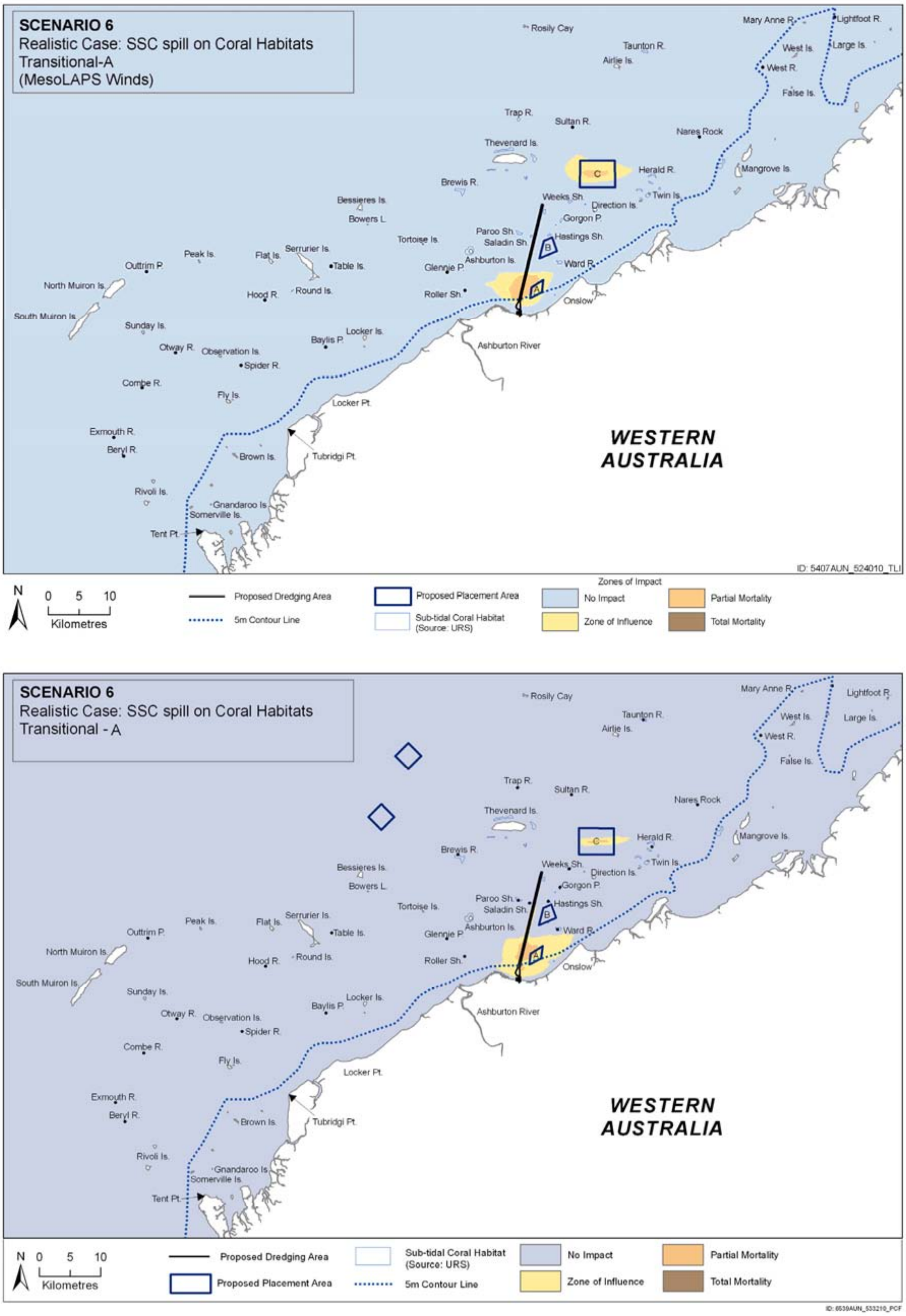


Figure 3.8 Scenario 6 transitional A, IZI derived for SSC on coral habitats. Top 2D model and bottom 3D model.

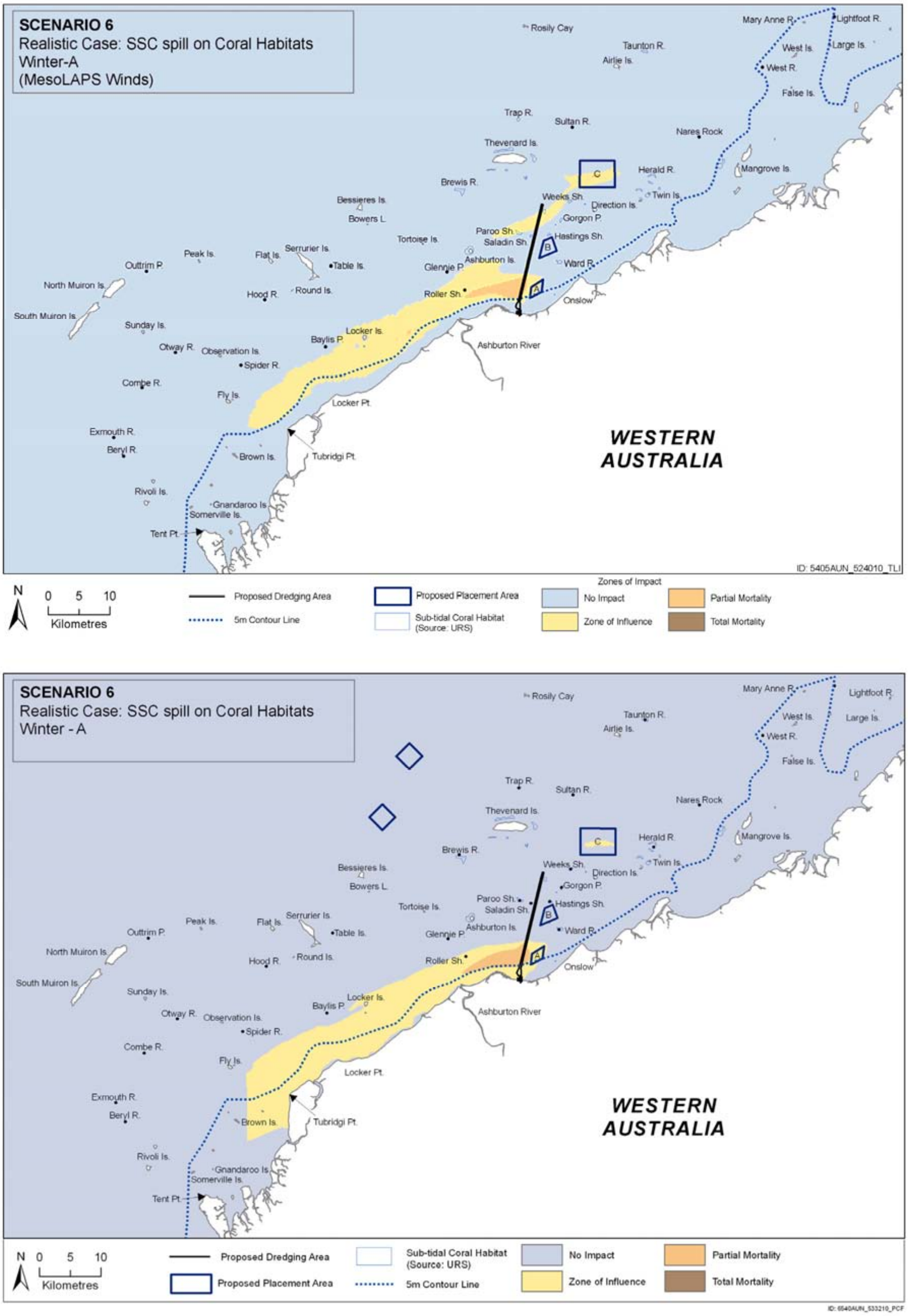


Figure 3.9 Scenario 6 winter A, IZI derived for SSC on coral habitats. Top 2D model and bottom 3D model.

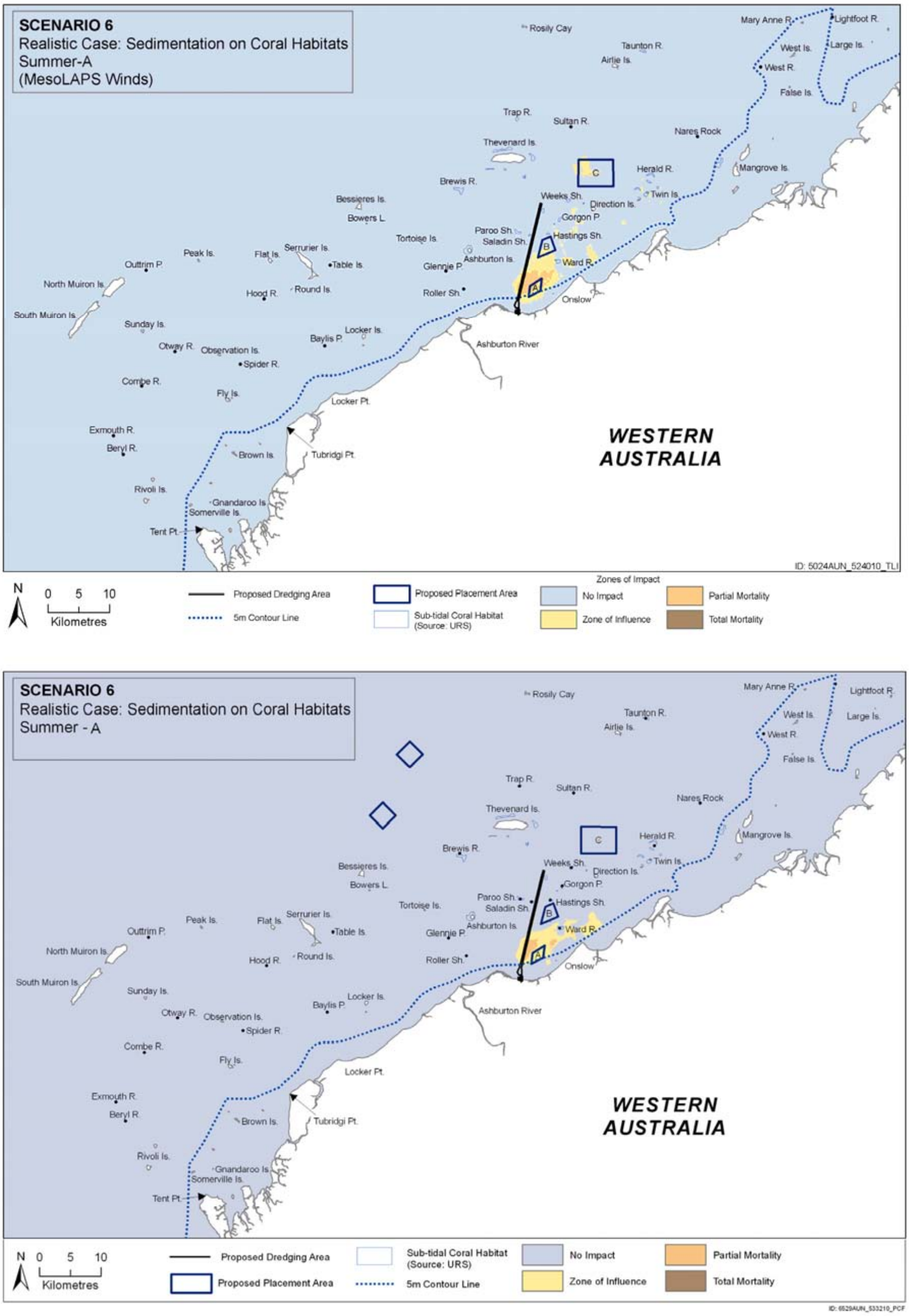
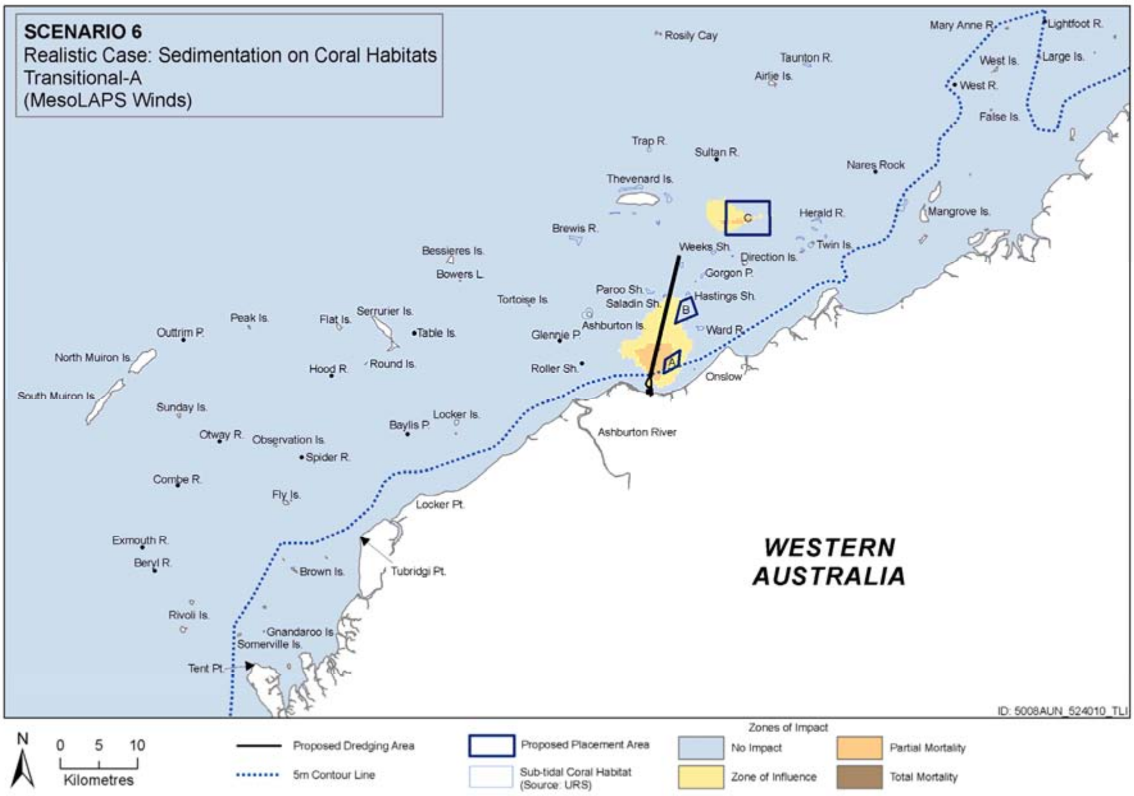


Figure 3.10 Scenario 6 Summer A, IZI derived for sedimentation on coral habitats. Top 2D model and bottom 3D model.



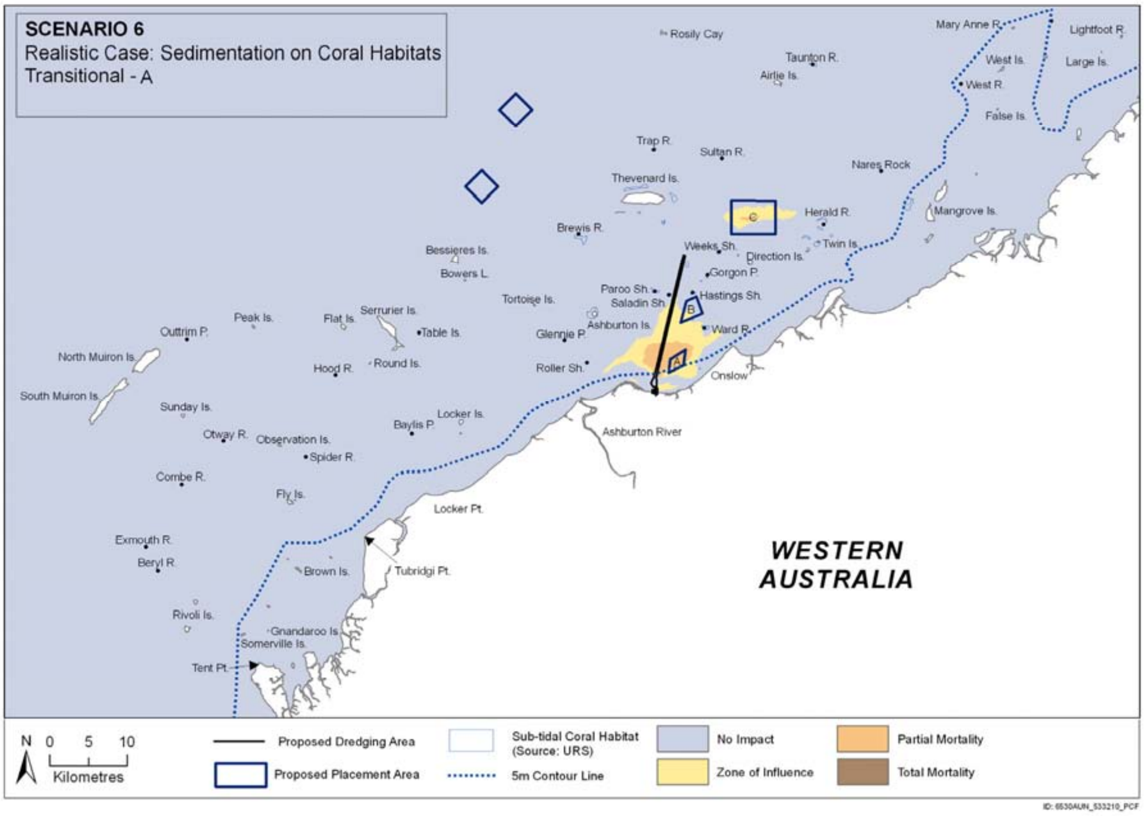
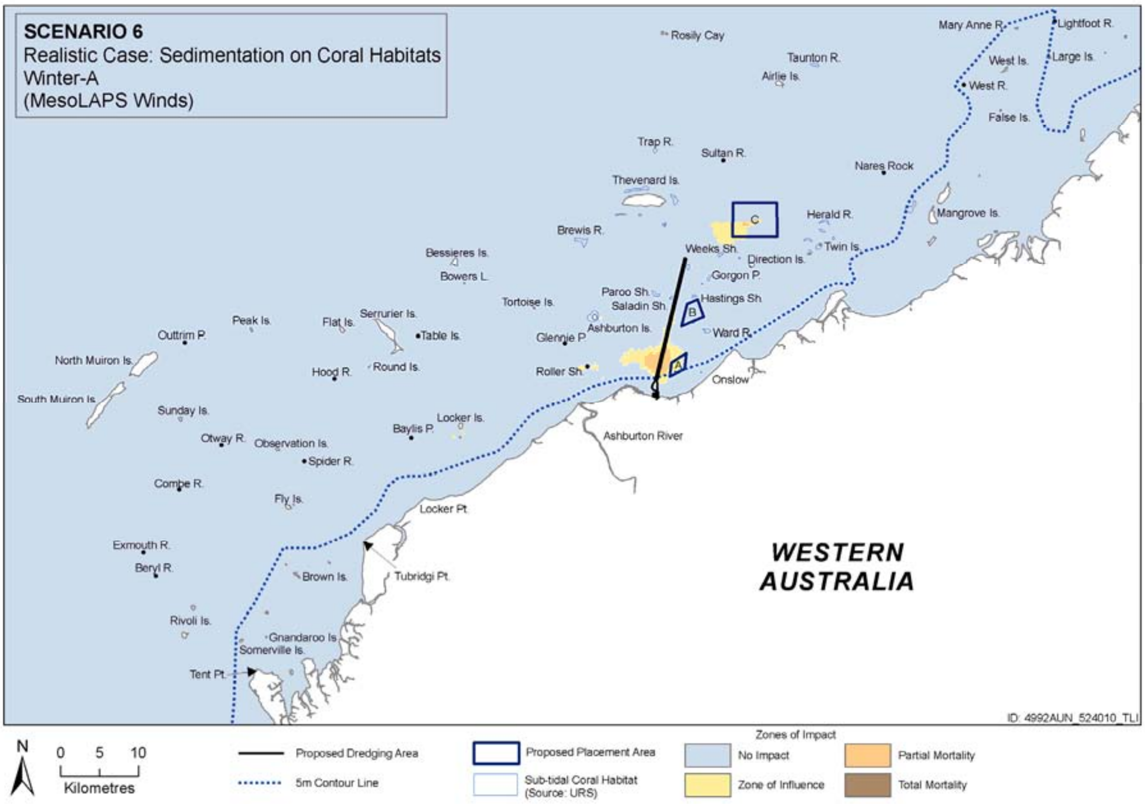


Figure 3.11 Scenario 6 Transitional A, IZI derived for sedimentation on coral habitats. Top 2D model and bottom 3D model.



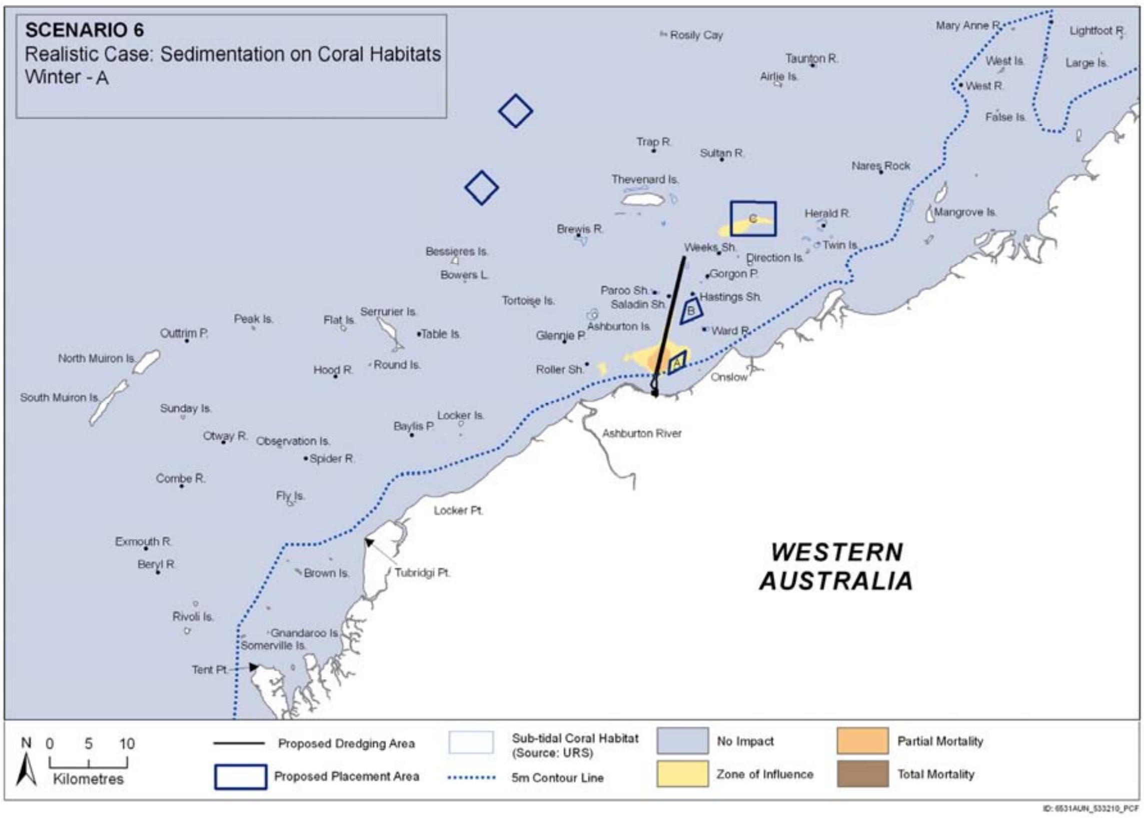


Figure 3.12 Scenario 6 Winter A, IZI derived for sedimentation on coral habitats. Top 2D model and bottom 3D model.

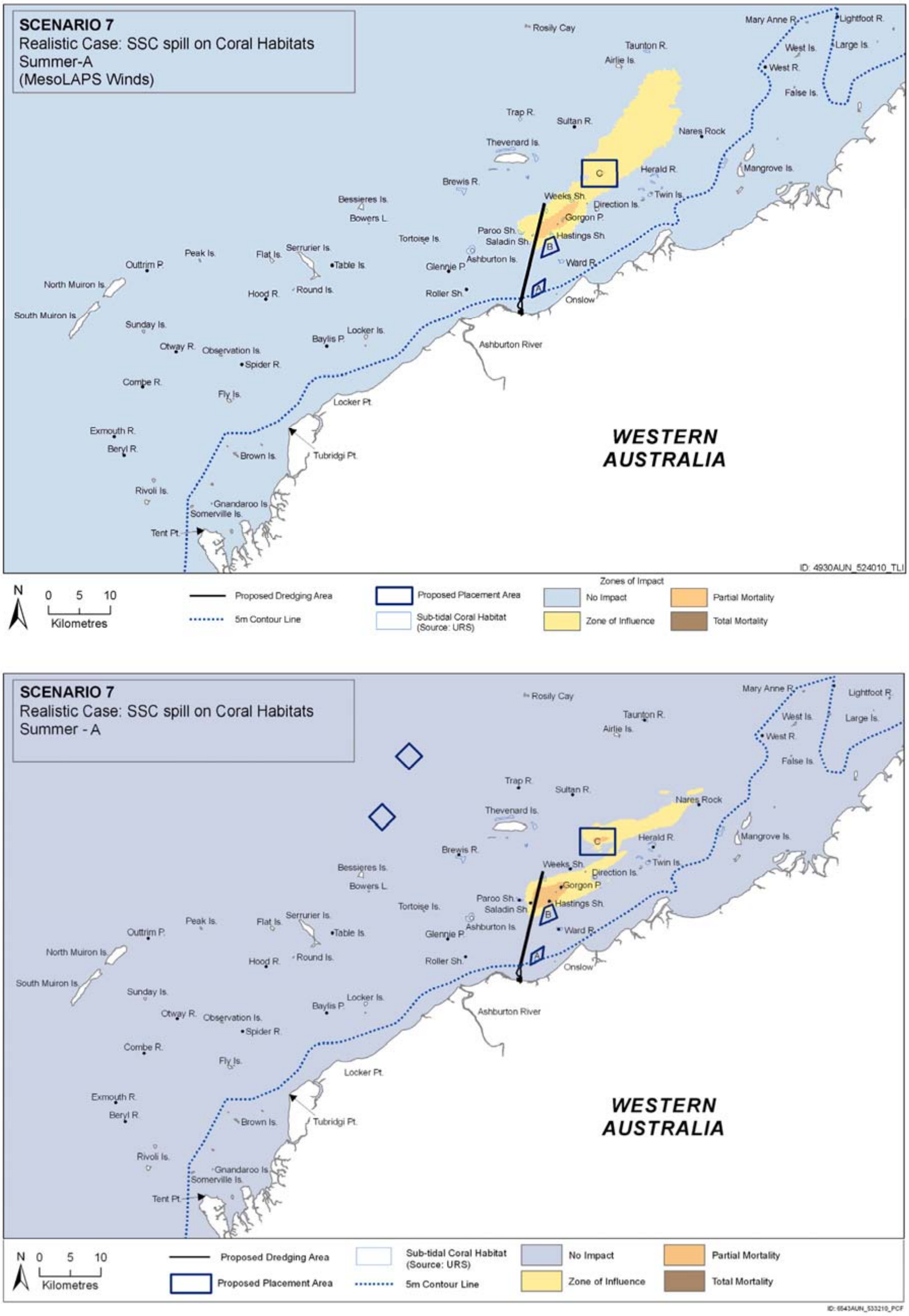
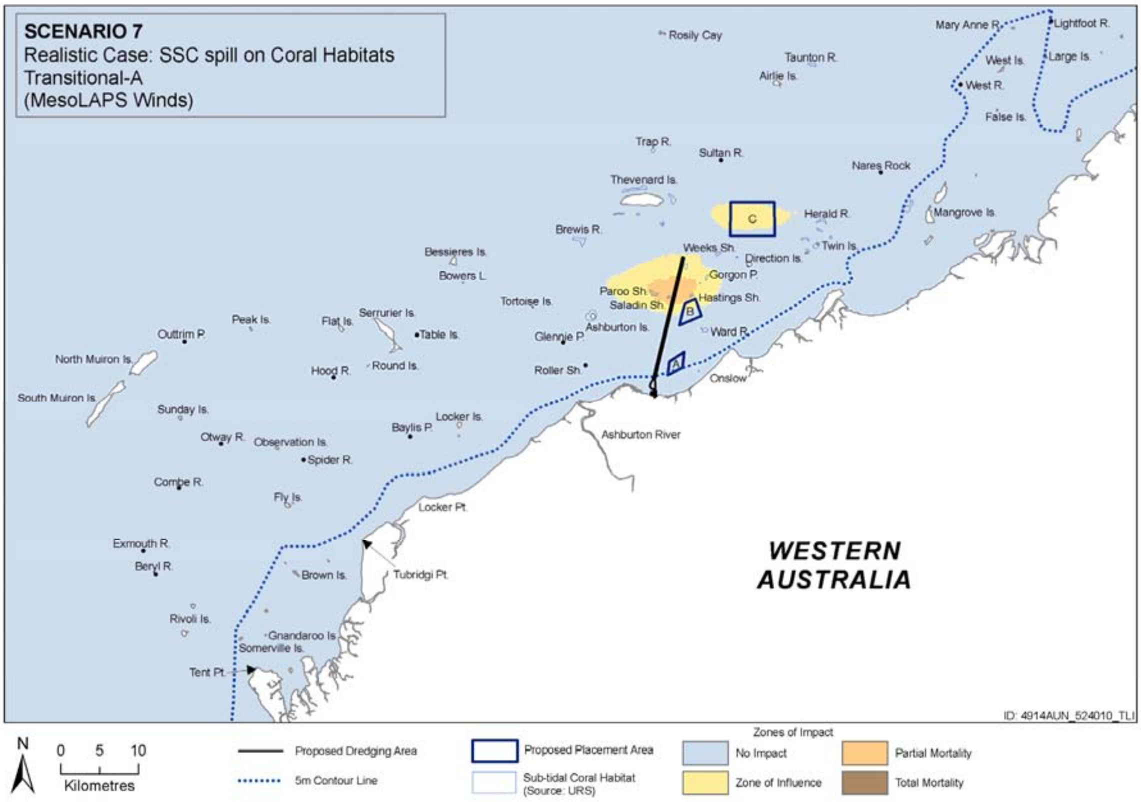


Figure 3.13 Scenario 7 Summer A, IZI derived for SSC on coral habitats. Top 2D model and bottom 3D model.



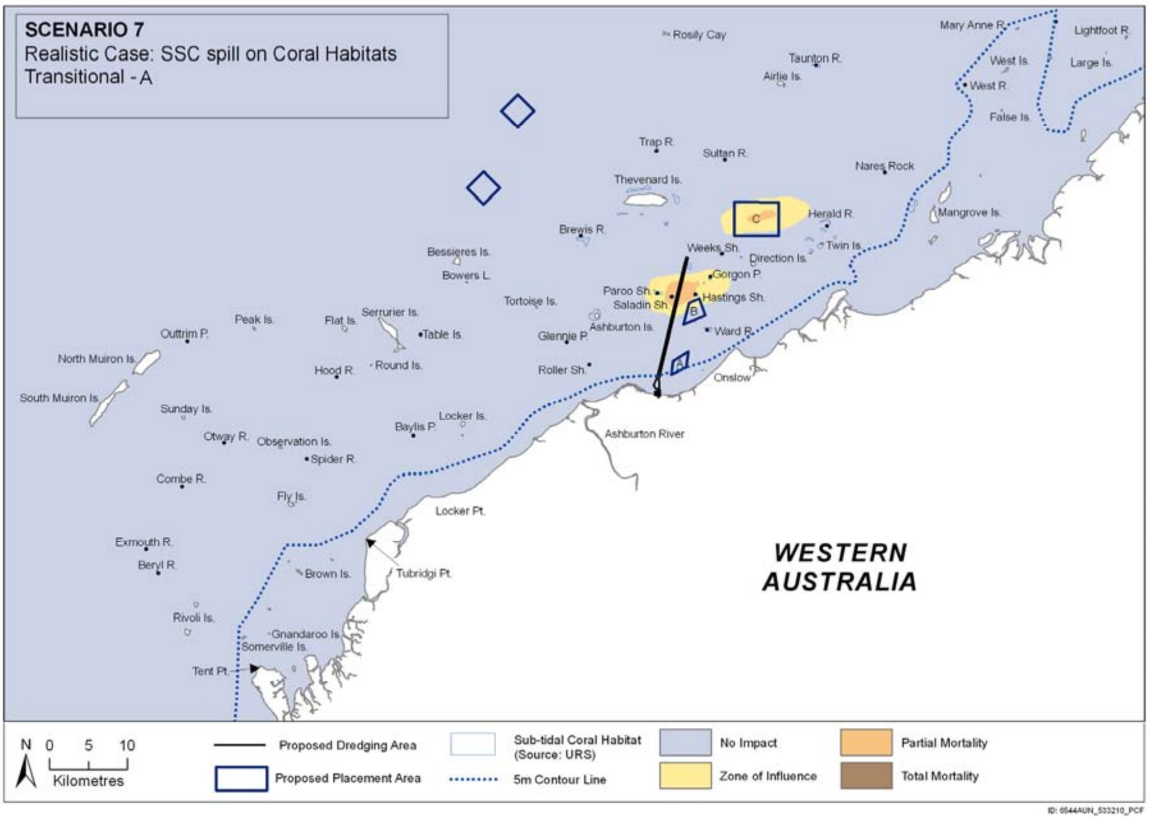
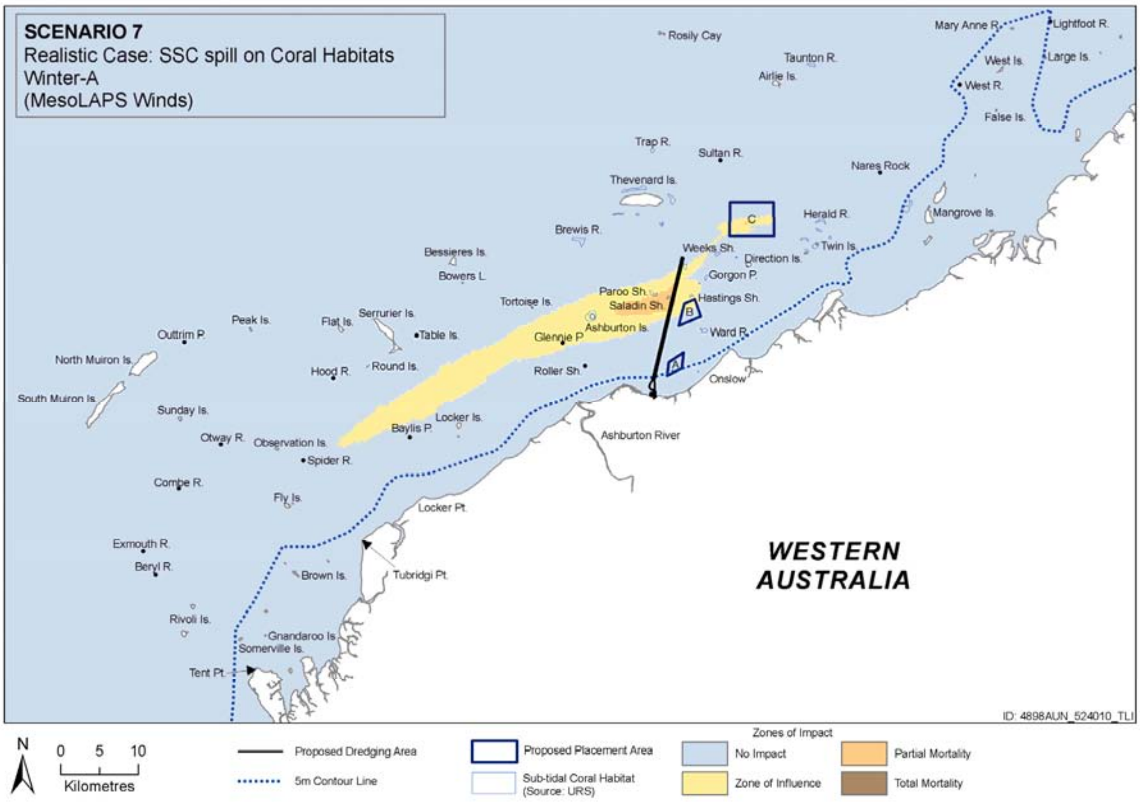


Figure 3.14 Scenario 7 Transitional A, IZI derived for SSC on coral habitats. Top 2D model and bottom 3D model.



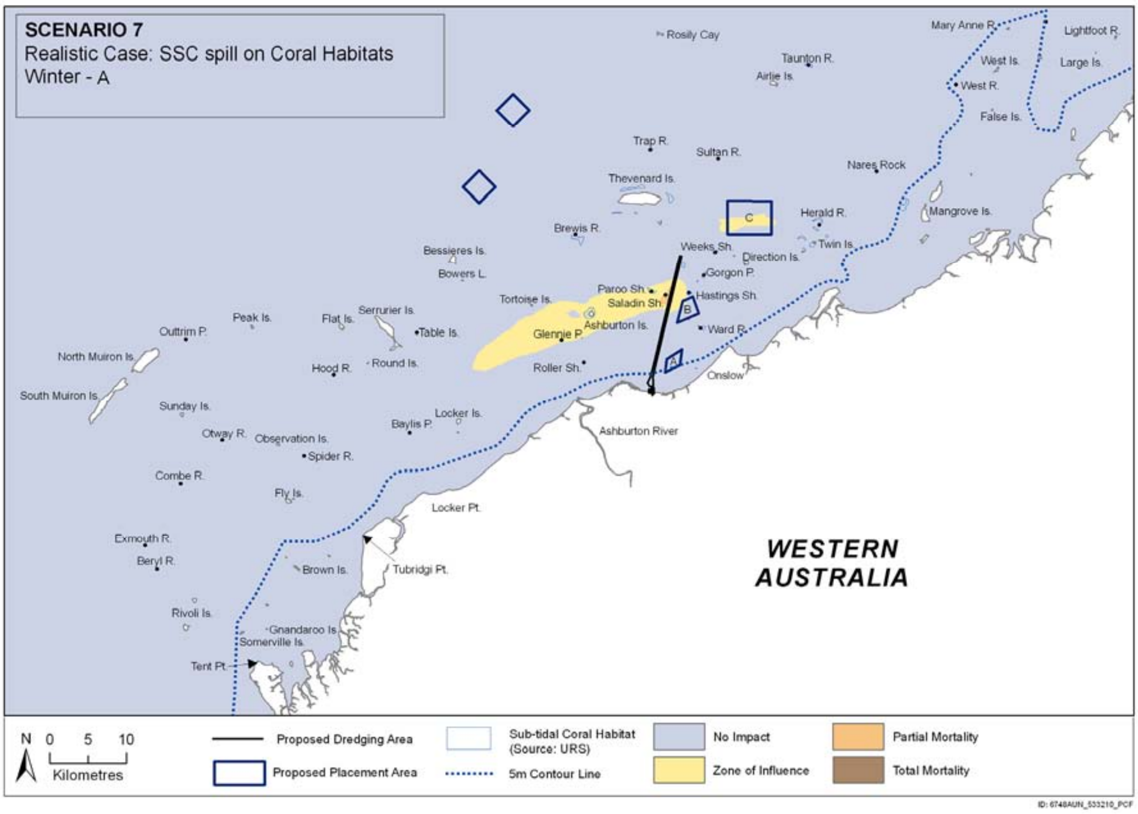
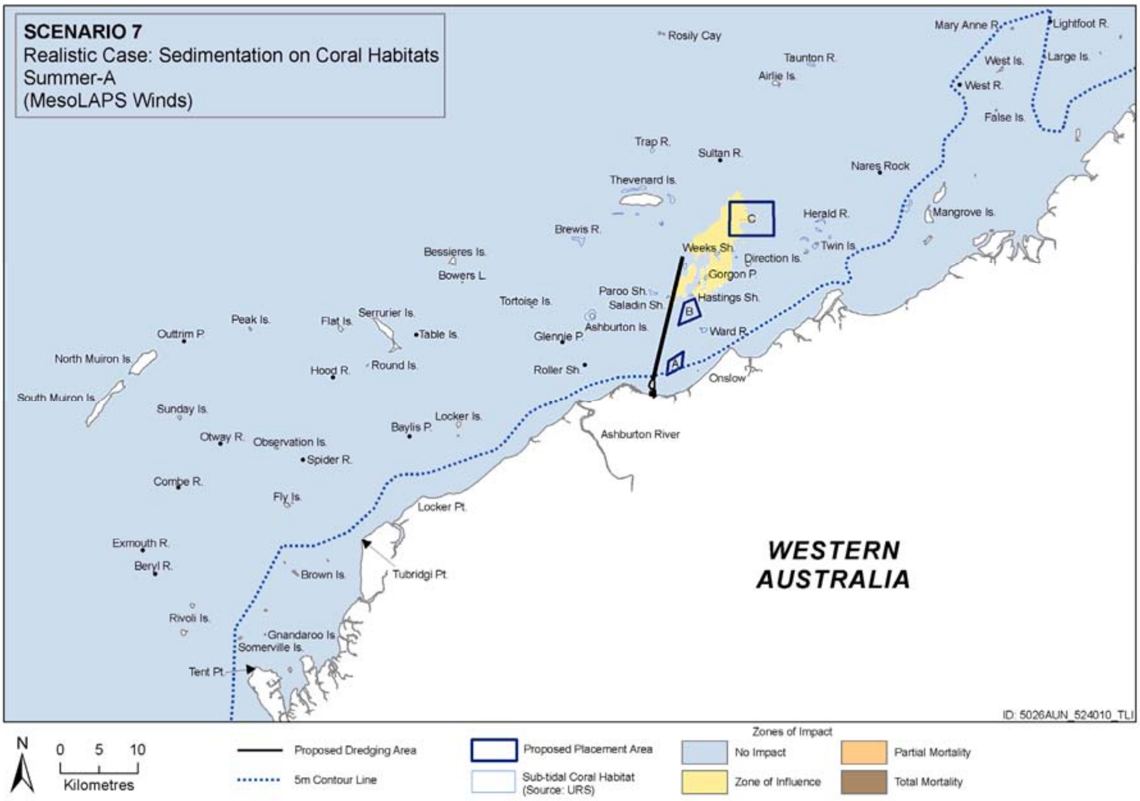


Figure 3.15 Scenario 7 Winter A, IZI derived for SSC on coral habitats. Top 2D model and bottom 3D model.



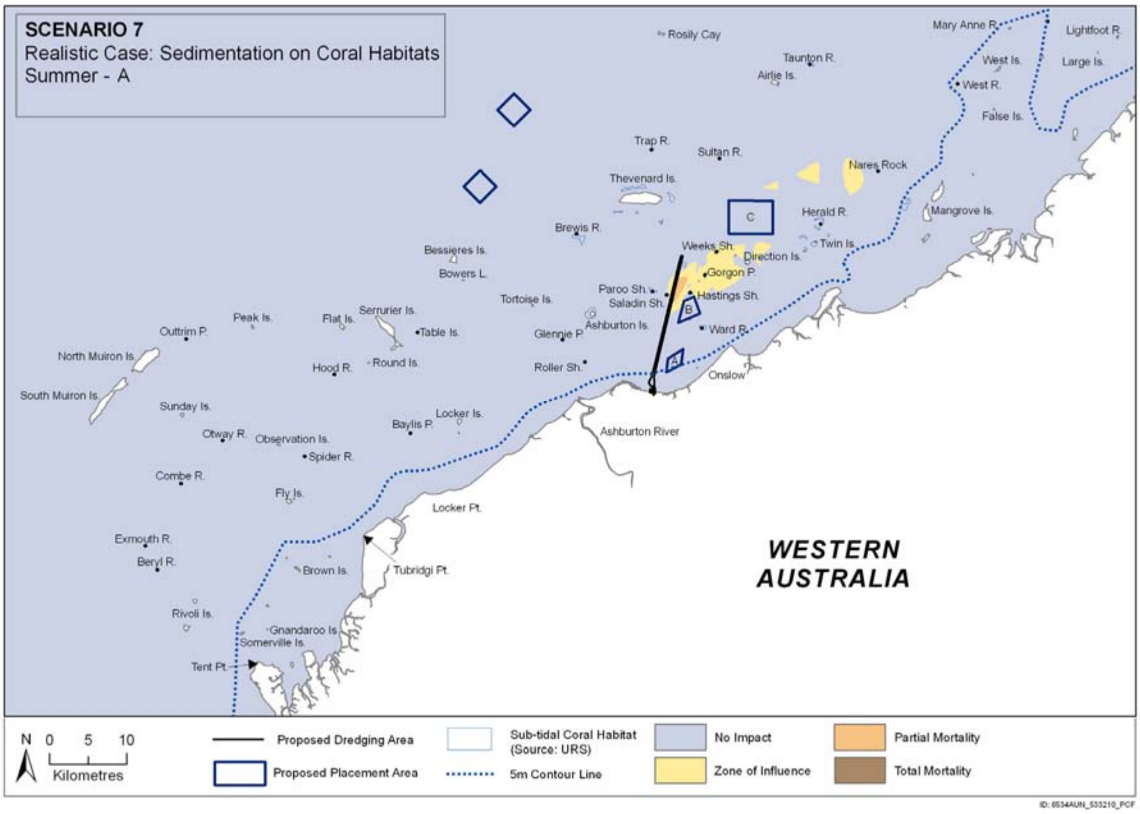
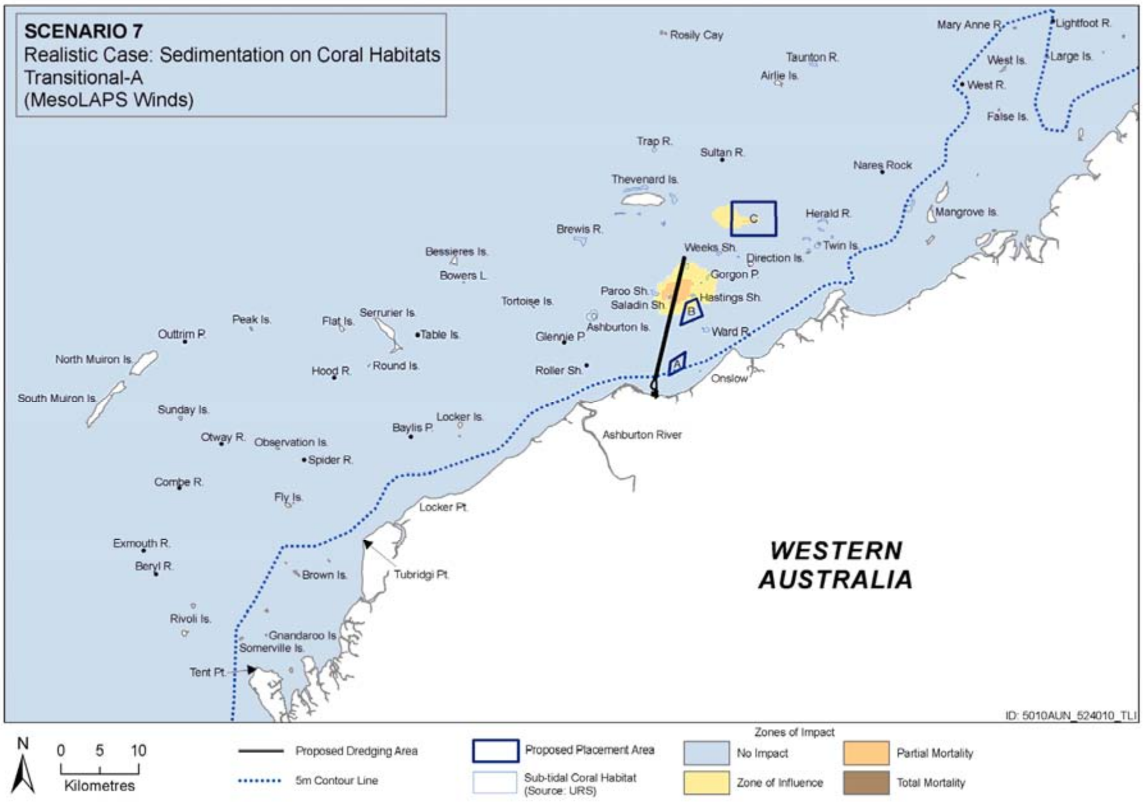


Figure 3.16 Scenario 7 Summer A, IZI derived for sedimentation on coral habitats. Top 2D model and bottom 3D model.



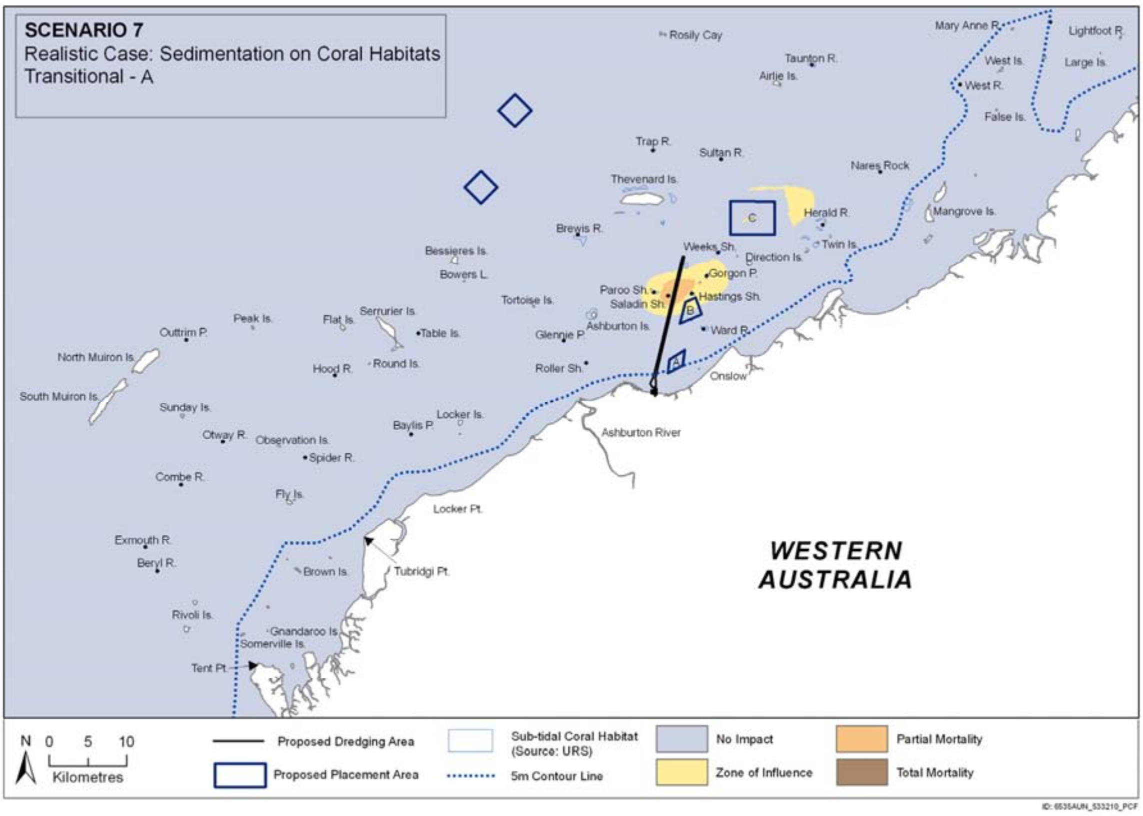
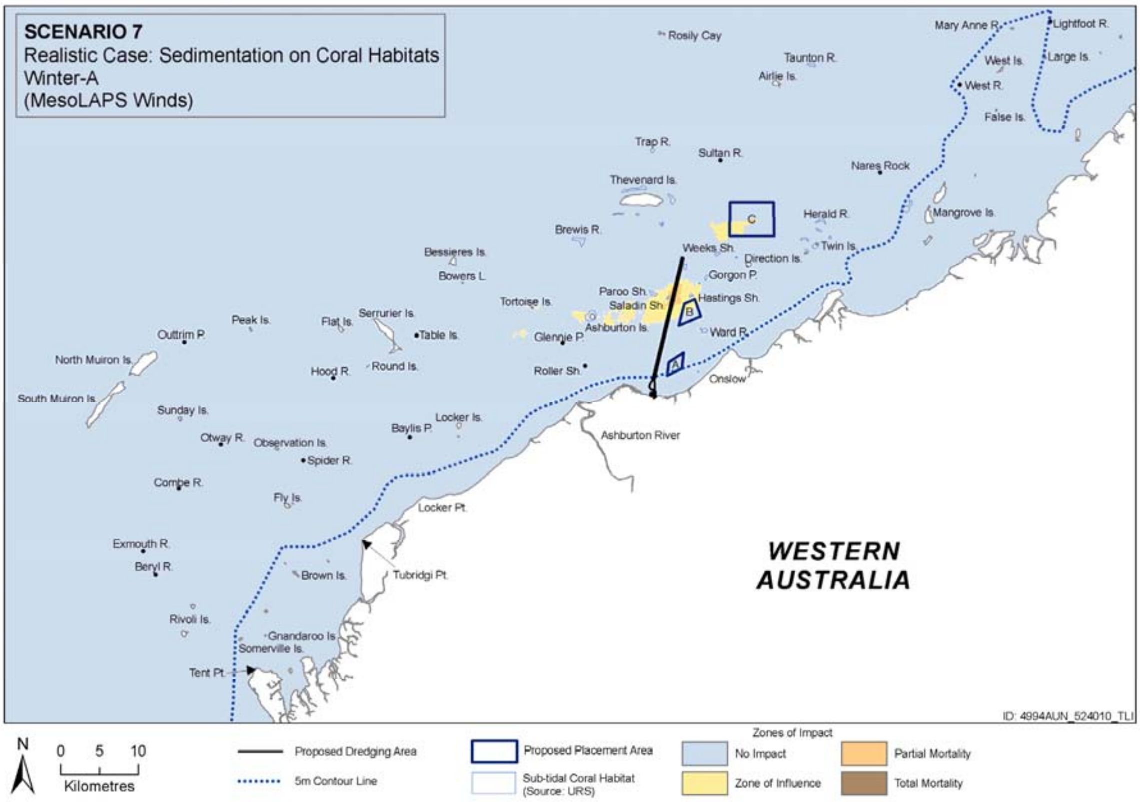


Figure 3.17 Scenario 7 Transitional A, IZI derived for sedimentation on coral habitats. Top 2D model and bottom 3D model.



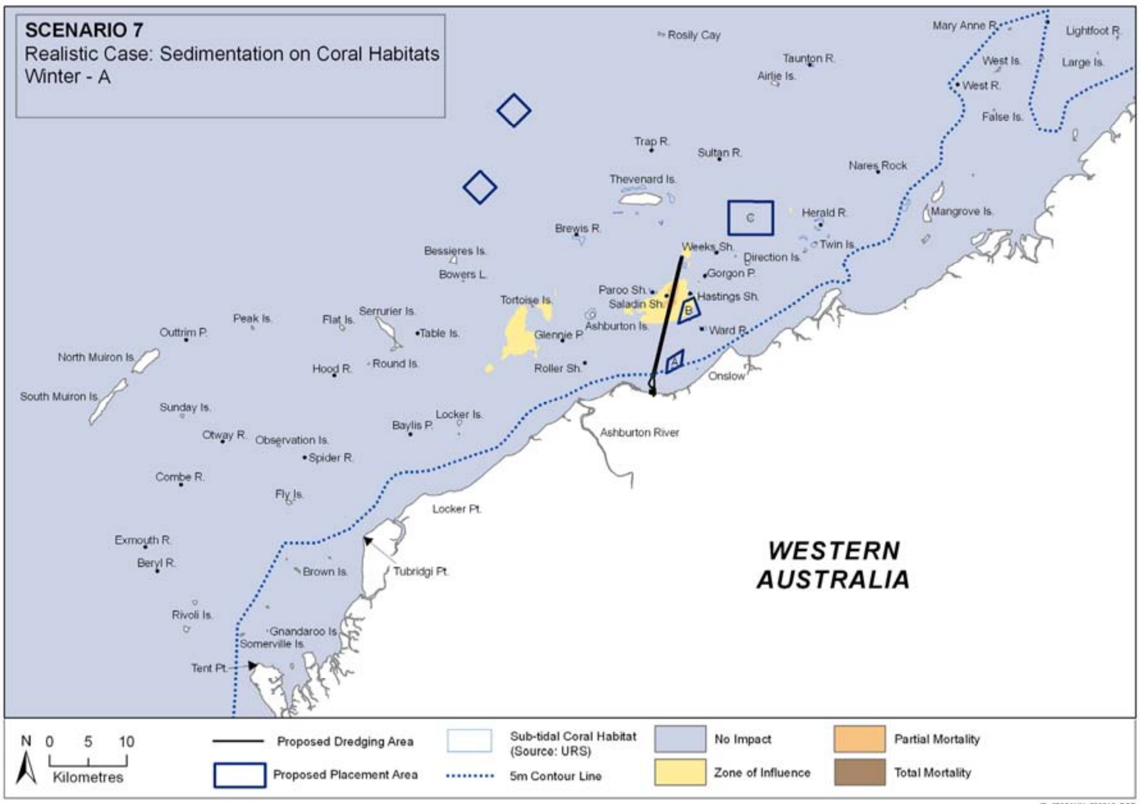


Figure 3.18 Scenario 7 Winter A, IZI derived for sedimentation on coral habitats. Top 2D model and bottom 3D model.

3.2 Scenario for Dredge Material Placement Site D

In the present Dredge and Disposal Plan (DDP), Site D is used for "clean-up" dredge of the channels only. 3D current effects at the comparatively deeper Placement Sites D and E (in the order of 50m depth) are significant, and although the limited placement planned for these sites combined with the large distance to sensitive receptors make significant potential impacts unlikely, a full release scenario for Site D has been simulated in a 3D model.

3.2.1 Modelling Approach

The clean-up dredging as specified in the DDP is to be carried out applying an environmentally sensitive dredging method with limited or no overflow, which will mean a comparatively very low release rate during the dredging. This combined with the fact that the dredge plumes from previous simulations of dredging along the channel do not spread off-shore to Site D indicates that there will be no mixing of the plumes from dredging and material placement. The plume from Site D has therefore been assessed in isolation.

During dredge material placement, density currents will carry much of the sediment toward the bottom, and fine sediments will be entrained into the water column from the surface to the bottom. It has thus been assumed that the initial sediment source is evenly distributed over the depth. The daily schedule of material placement activities was derived from the DDP. The placement was modelled for the same 6 climatic scenarios applied for the modelling of the channel dredging. MesoLAPS winds, which are considered the best wind source for the off-shore area, were applied in the modelling.

The modelling was carried out in the 3D flexible mesh model Mike 3 FM. The basic model setup and validation was documented in Appendix H of Appendix Q1 to the EIS. The model mesh resolution at Site D was refined for the present application, see Figure 3.19.

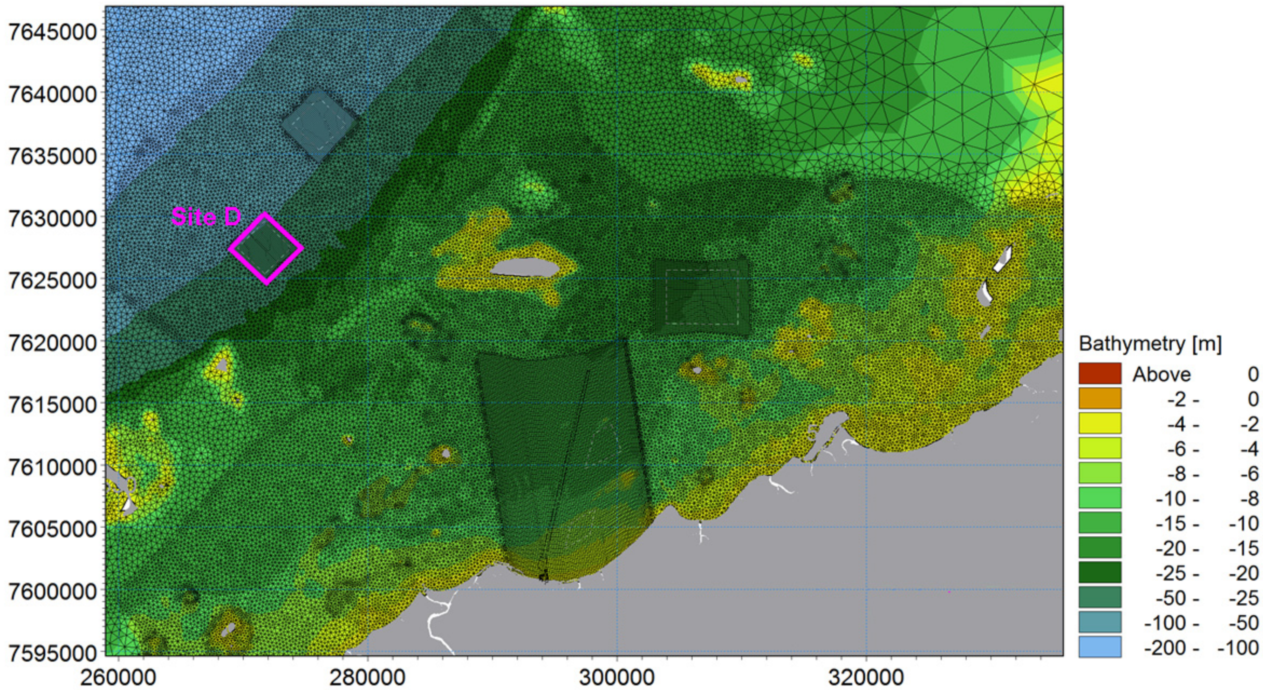


Figure 3.19: New refined mesh for the simulation of the offshore placement at Placement Site D.

3.2.2 Result Presentation and Impact Criteria

For the channel dredging in shallower water depths, the plume statistics and impact criteria were developed for depth-averaged plume concentrations. This approach is not directly transferable to greater water depths such as found at Site D. For the assessment of the impact zones at Site D, the following is considered:

- Depth-averaged concentrations will be reduced due to the large water depths.
- Sedimentation rates are derived directly from the 3D modelling for the fines suspended in the water column.
- The benthic species found in water depths such as at Site D have different sediment tolerance sensitivities than the key species in shallower waters for which the impact criteria have been developed in the Draft EIS/ERMP.

The approach taken to address these issues, in order to ensure a conservative (but realistic) assessment of potential impacts from dredge material placement at Site D, is described in detail in the following sections.

3.2.2.1 Plume Statistics

To counter the “dilution” of the plume through depth-averaging over larger water depths, DHI has utilised an alternative statistical methodology, based on derivation of depth-averaged concentrations over depth bins approximately 10m thick, and production of maps based on the depth bin with the highest concentration at any given location. A sample comparison between means derived over a 14 day period based on depth-averaging over the full water depths and based on the 10m depth bin with the highest concentration is illustrated in Figure 3.20. This illustrates a significant difference in the two sets of results. The depth-averaged bins with the highest concentrations have therefore been used to illustrate the plumes.

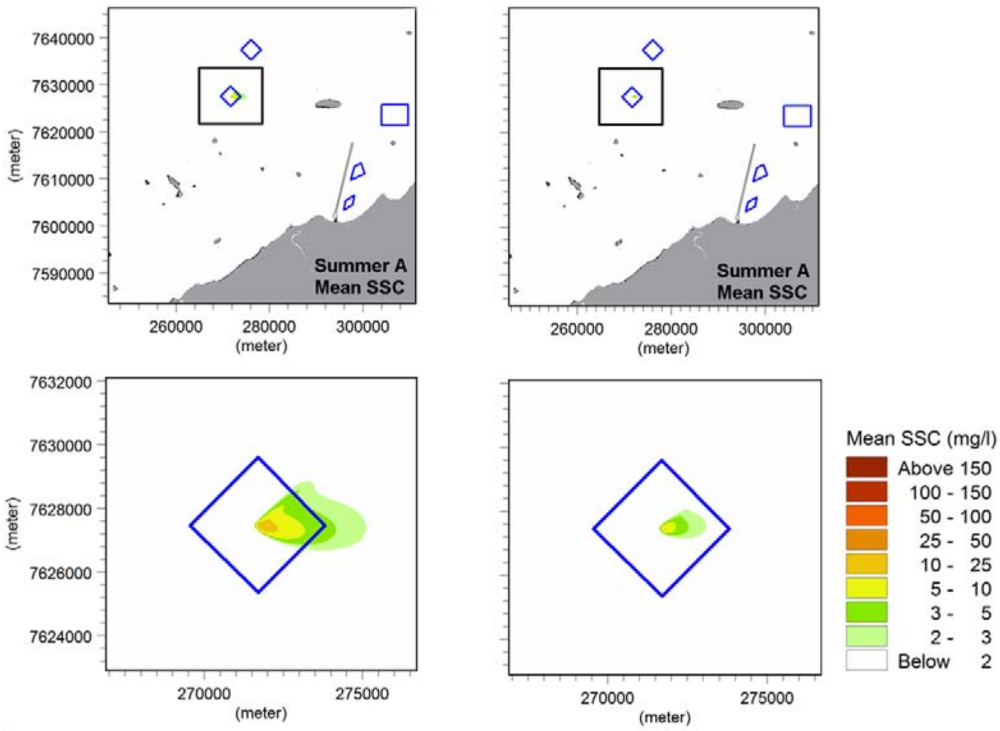


Figure 3.20 Example of mean SSC at Site D derived over a 14 day period derived from depth-averaging over entire water depth (right) and based on the depth-averaged 10m depth bins with the highest concentration (left).

Mean concentrations over 14 day periods based on the highest concentration bins are shown for the plumes originating from placement at Site D for the 6 climatic scenarios in Figure 3.21 to Figure 3.23. This shows low average SSC concentrations of 2 mg/l reaching up to about 3-4 km from the placement location (in the centre of the site in these simulations). The plumes travel predominantly easterly during summer conditions, and predominantly westerly during the winter scenarios, although there is also significant easterly progression during winter.

To further investigate the maximum extent of the plume from the placement site, a map of maximum concentrations reached at any point in time during the 14 day processing period has been produced and is presented in Figure 3.24. It is important to note that this plot does not represent an instantaneous plume, but shows an envelope of all plume concentrations reached at any time throughout the 14 day simulation period. The maximum plot demonstrates that the simulated plume generally has very low SSC concentrations. Predicted maximum SSC concentrations (depth-averaged over 10m depth bins) of 2mg/l reach up to about 30 km from the source, while maximum concentrations of 5 mg/l only reach about 10 km from the source. The plumes predominantly spread in south-westerly and north-easterly directions along the depth contours.

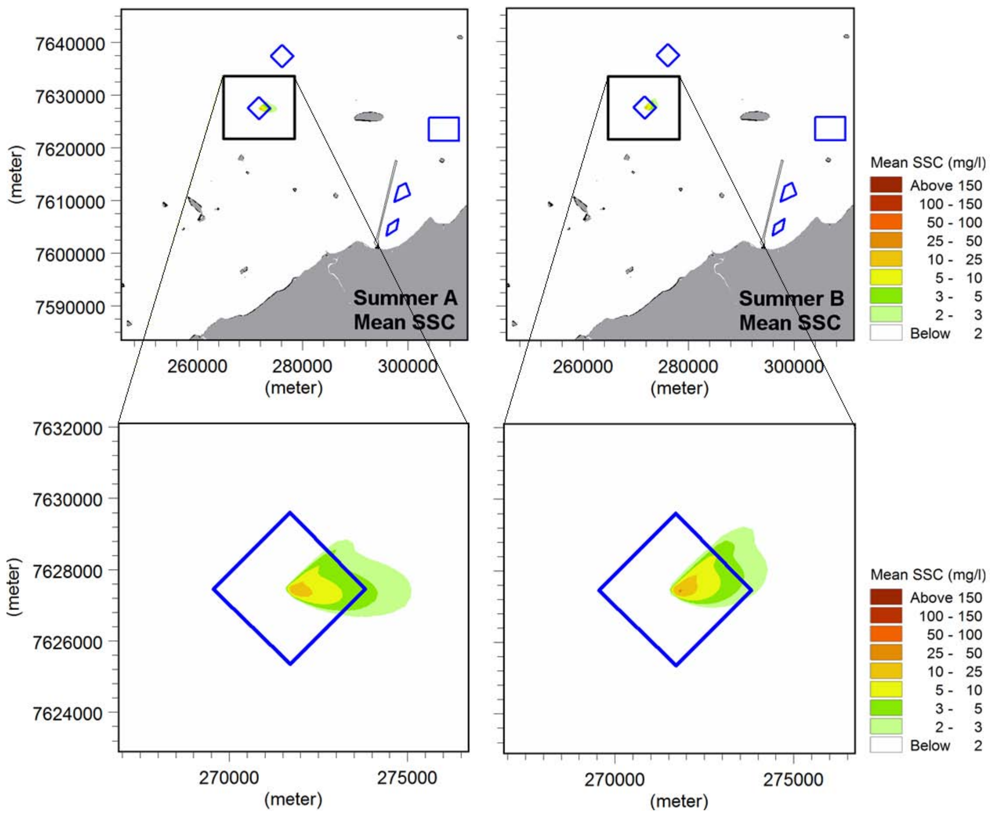


Figure 3.21 Simulated mean concentrations (over 14 day periods) for summer. SSC are derived from the app. 10m depth bins with the highest concentrations at each location across the model area.

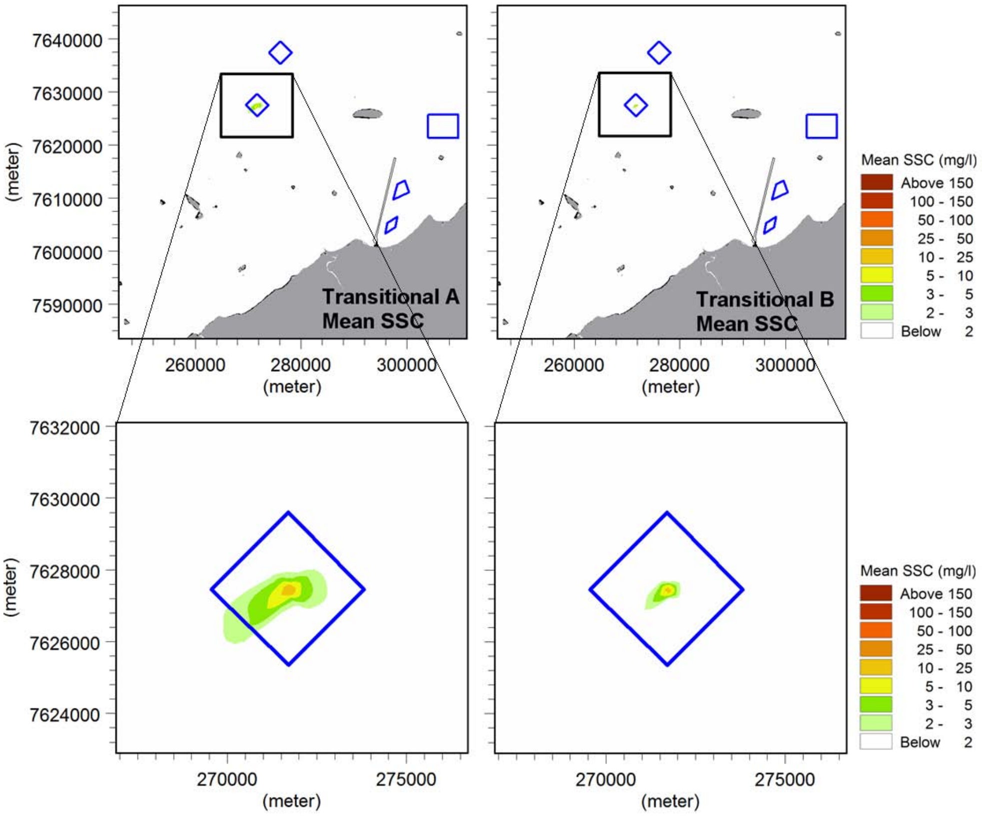


Figure 3.22 Simulated mean concentrations (over 14 day periods) for transitional conditions. SSC are derived from the app. 10m depth bins with the highest concentrations at each location across the model area.

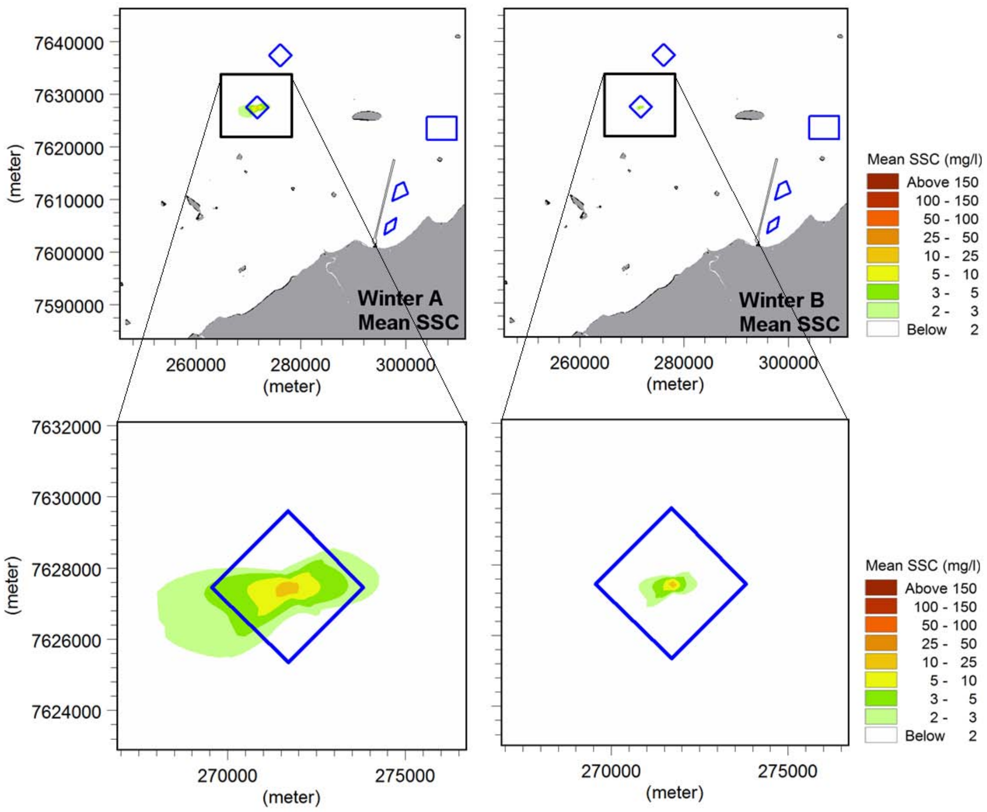


Figure 3.23 Simulated mean concentrations (over 14 day periods) for winter conditions. SSC are derived from the app. 10m depth bins with the highest concentrations at each location across the model area.

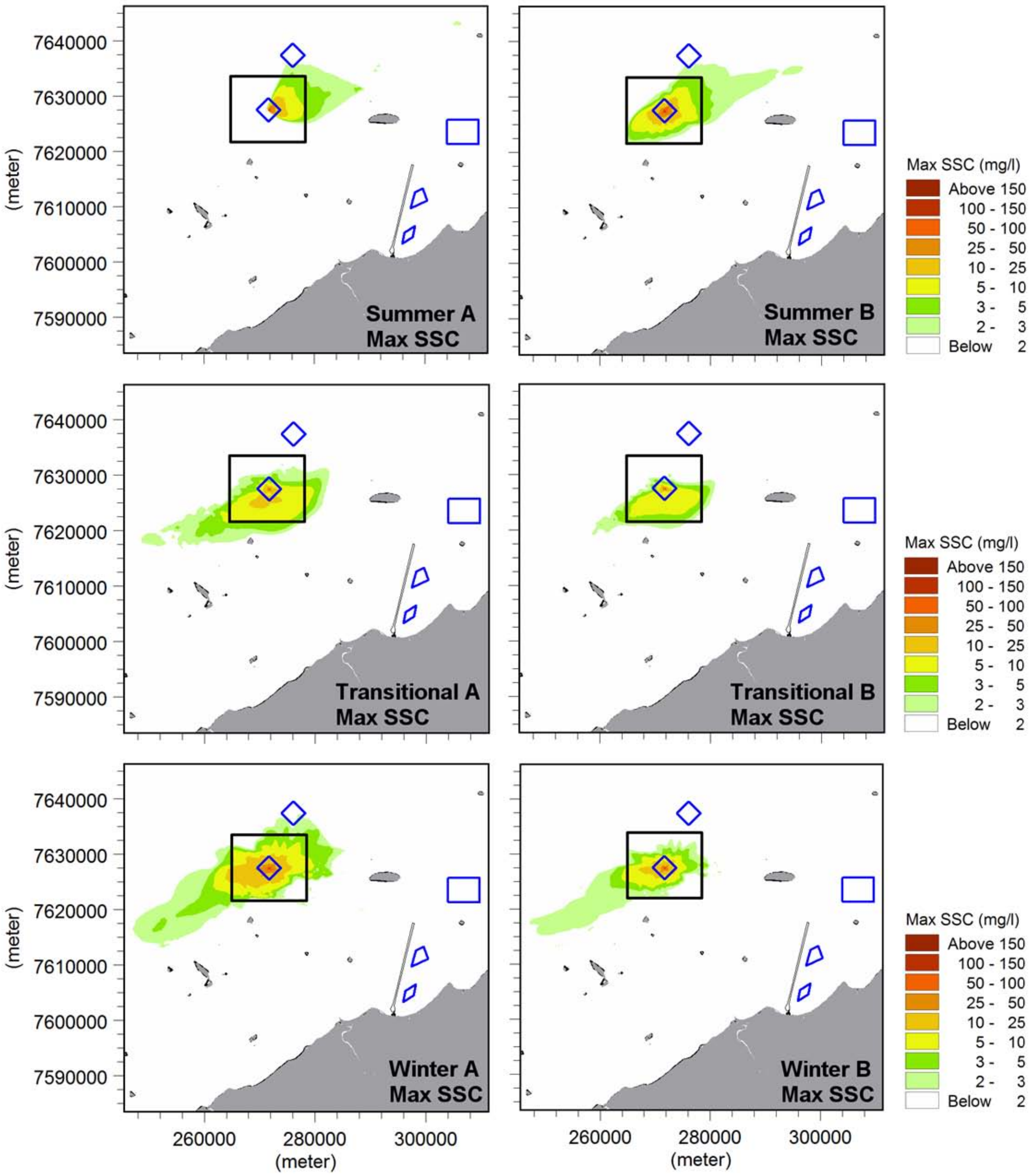


Figure 3.24 Simulated maximum concentrations in time and over depth (over 14 day period) for summer, transitional and winter conditions. SSC are derived from the 10m depth bins with the highest concentrations at each location across the model area.

3.2.2.2 Impact Criteria

In deriving the potential impacts, the following is noted:

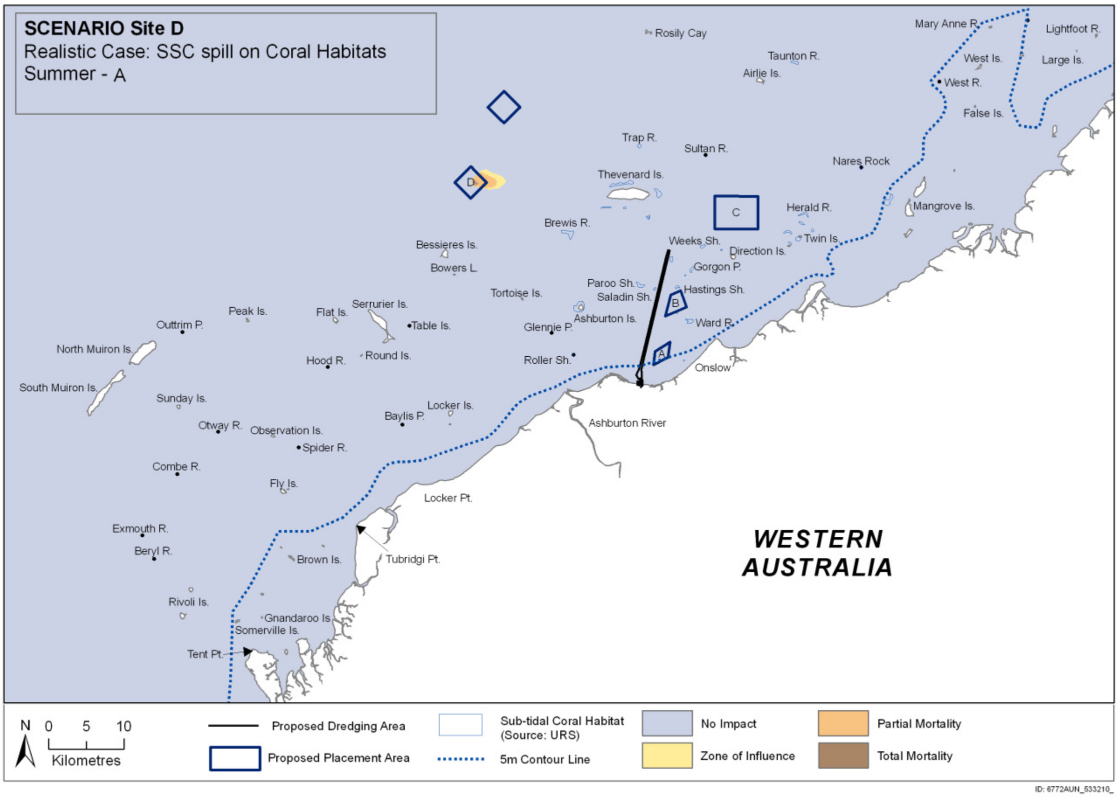
- The key benthic species found in the deeper water at Site D are filter feeders which are not sensitive to light deprivation, and likely less sensitive to sedimentation than corals. The literature review used to derive the coral tolerance limits (Appendix N2 of the Draft EIS/ERMP) also addressed filter feeder tolerance limits, and concluded that they were not likely to be more sensitive than corals to suspended sediment or sedimentation impacts.
- To maintain conservatism, the tolerance limits for SSC and sedimentation derived for coral habitats in shallower water have therefore been applied for Site D.
- The sedimentation rates simulated do not include the smothering by the total volume of dredge material placed at Site D. Total smothering and loss of the benthic dwelling species within Site D has to be assumed.
- However, with the large spatial extent of Site D and the limited volumes proposed for placement at the site, it is assumed that the direct smothering is confined within the boundaries of Site D.

3.2.2.3 Indicative Zones of Impact (IZI)

Indicative zones of impact (IZIs) derived for the various climatic scenarios are shown in Figure 3.25 to Figure 3.27 based on SSC and in Figure 3.28 to Figure 3.30 based on the sedimentation impact criteria. Figure 3.31 illustrates the combined IZI for all climatic scenarios based on SSC and sedimentation. The IZI for SSC are derived based on the depth bins with the highest concentrations at each location across the model area, as described in Section 3.2.2.1.

The figures show that the IZI (particularly the zones of partial and total mortality) are confined to the immediate vicinity of Site D. None of the coral reefs identified in the EIS are impacted either by SSC or sedimentation resulting from placement operations at Site D.

However, Site D does occur adjacent to the shelf break, which was reported in the EIS to have an average cover of approximately 5% of sessile filter feeders (predominantly sponges) from the 20-40m isobath (Appendix N8 of Draft EIS/ERMP). A small area of the filter feeder community, within approximately 1km of Site D, may fall within the zone of partial mortality, while a larger area of the filter feeder community, within 6km of Site D, may fall within the Zone of Influence (Figure 3.32).



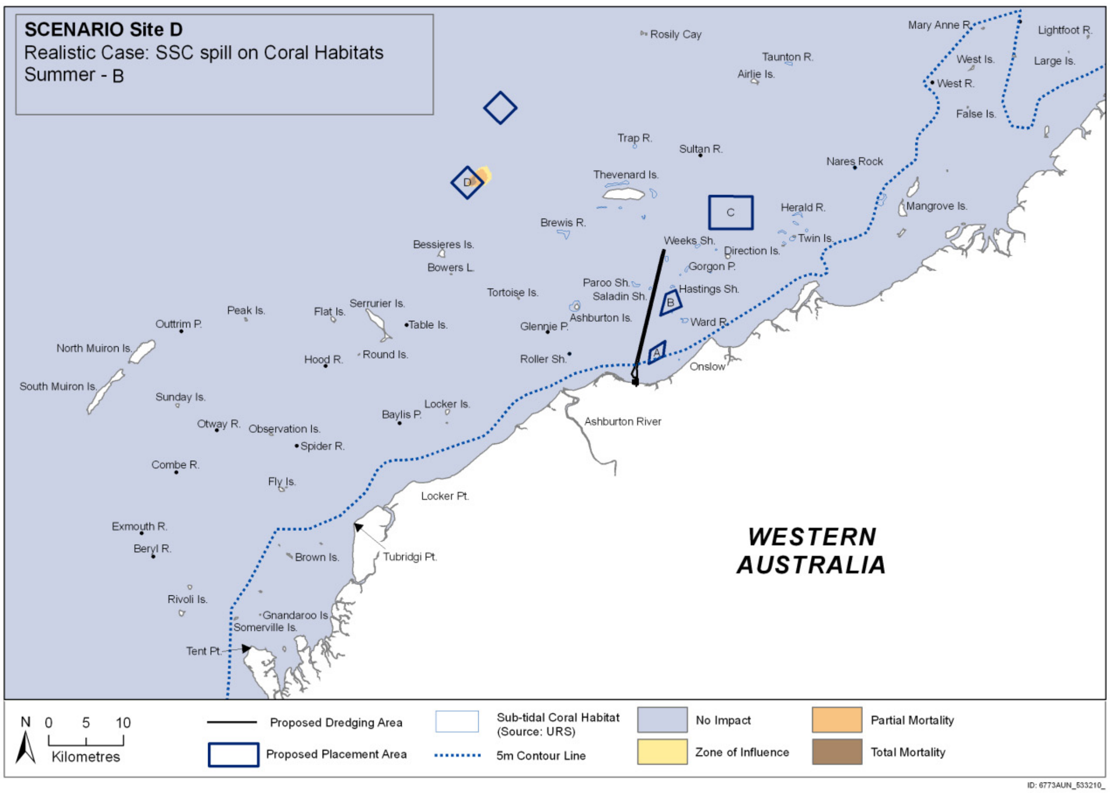
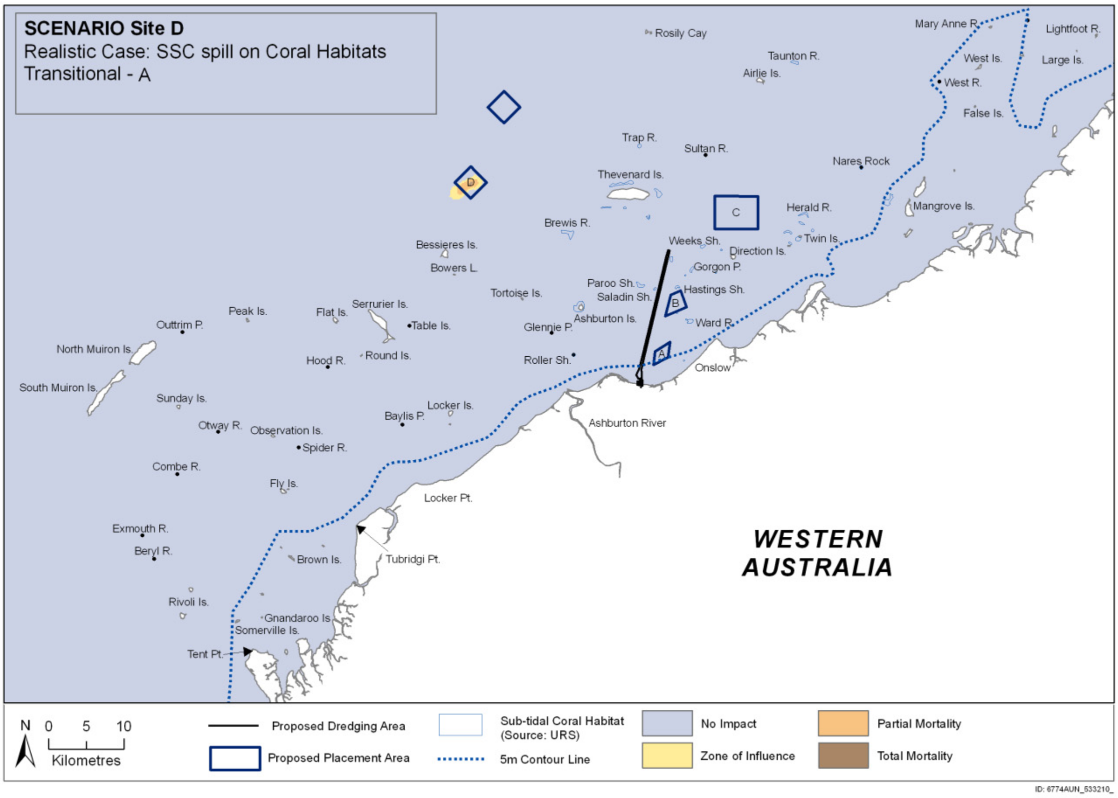


Figure 3.25 IZI derived for Site D for SSC on corals for summer conditions. Top: Summer A; Bottom: Summer B.



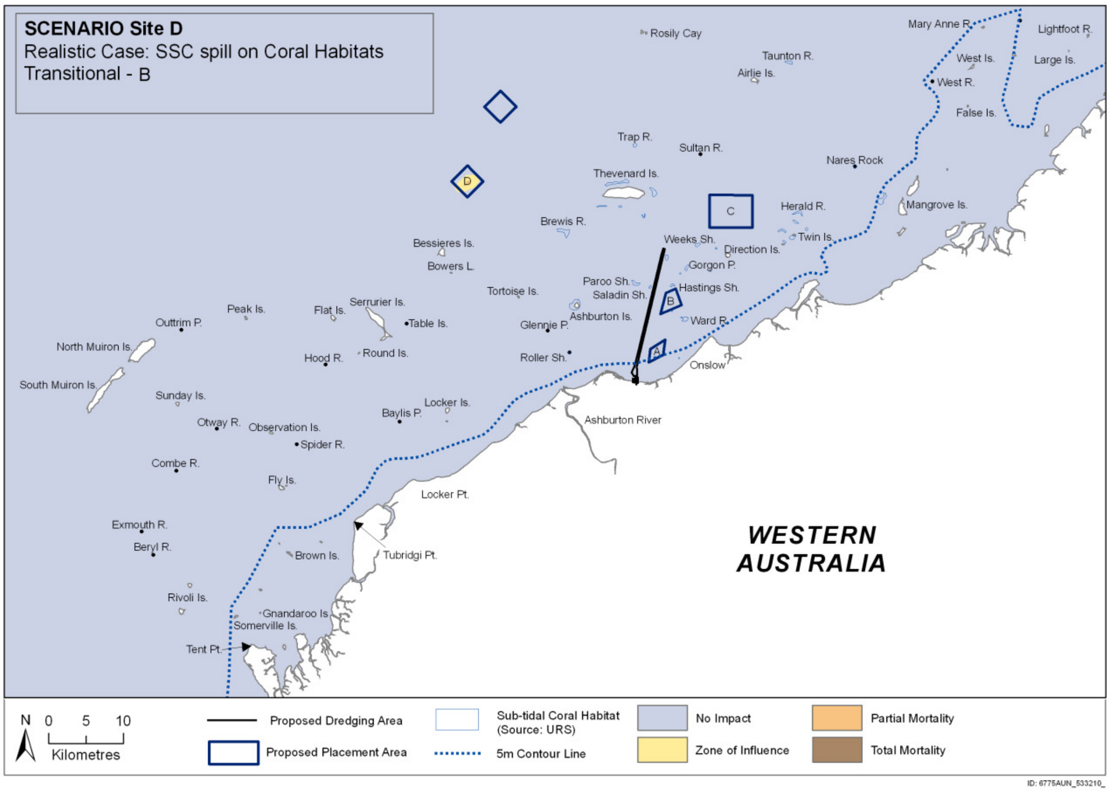
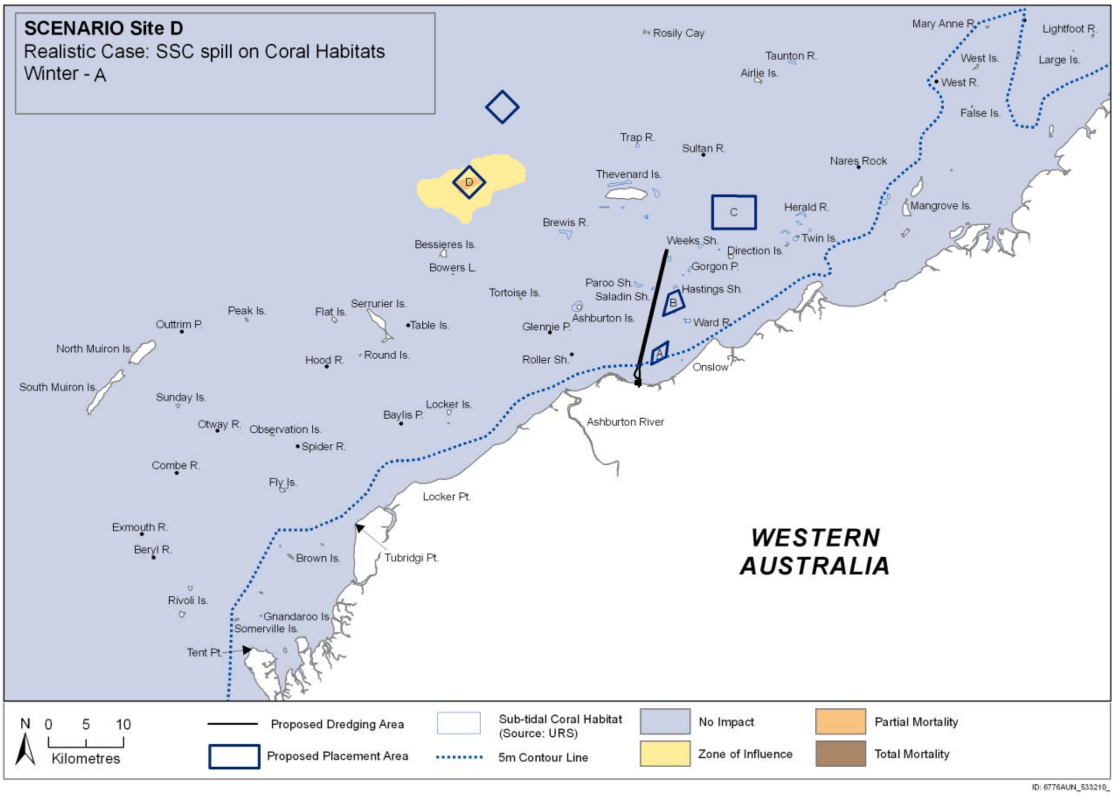


Figure 3.26 IZI derived for Site D for SSC on corals for transitional conditions. Top: Transitional A; Bottom: Transitional B.



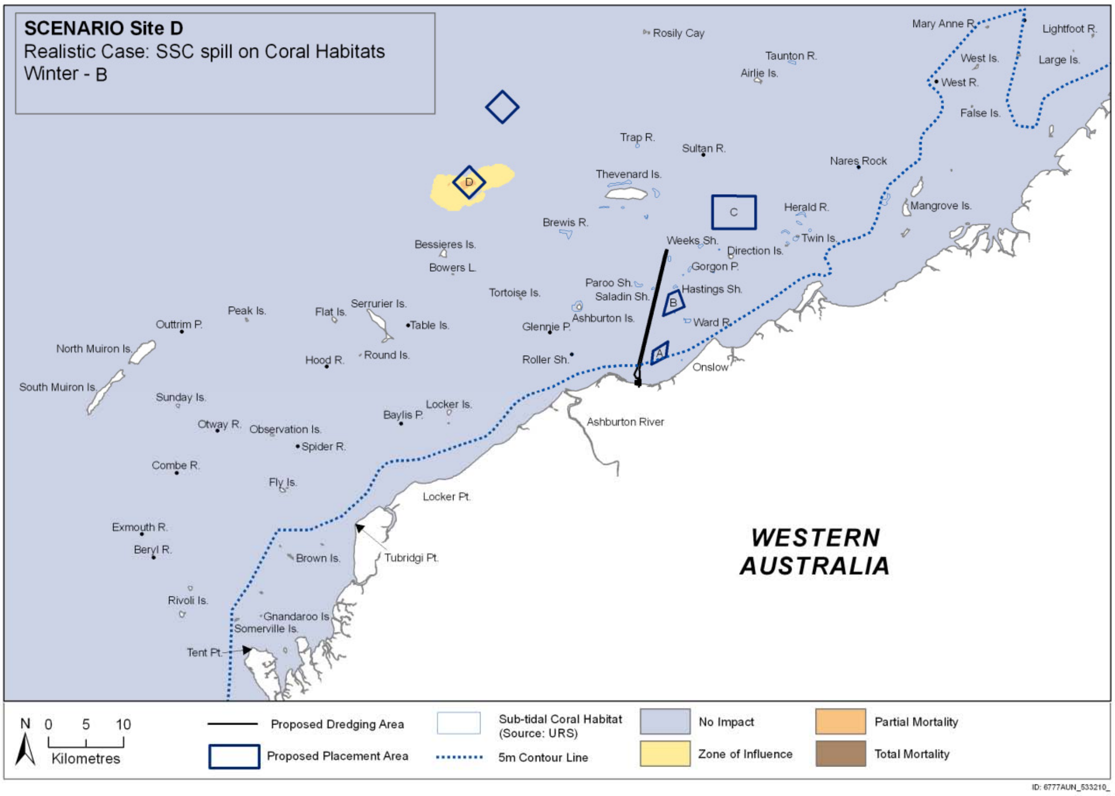
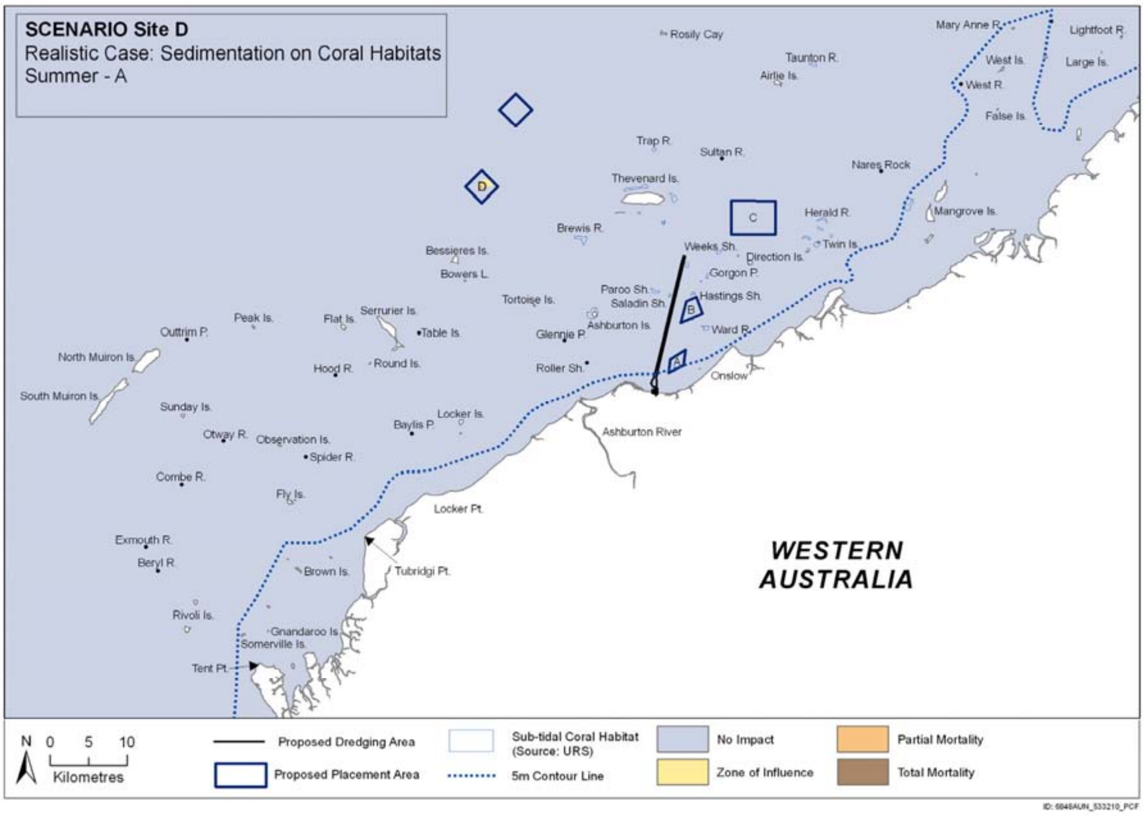


Figure 3.27 IZI derived for Site D for SSC on corals for winter conditions. Top: Winter A; Bottom: Winter B.



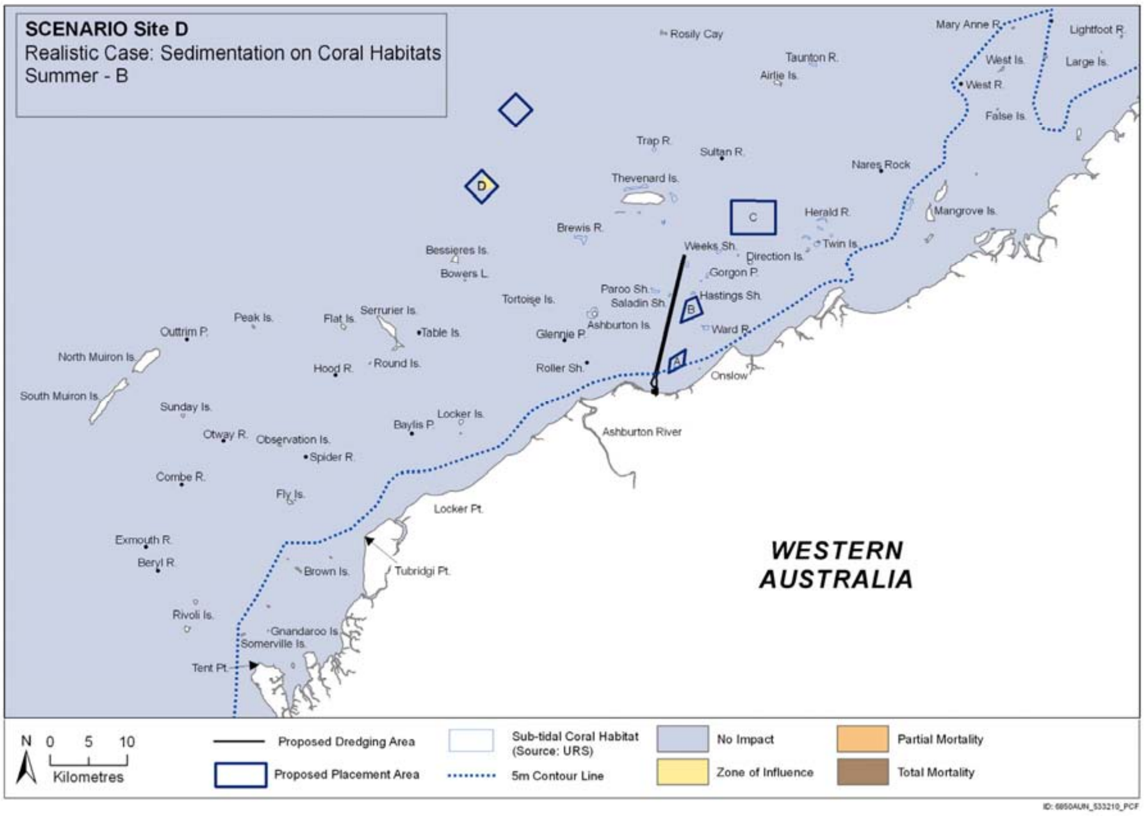
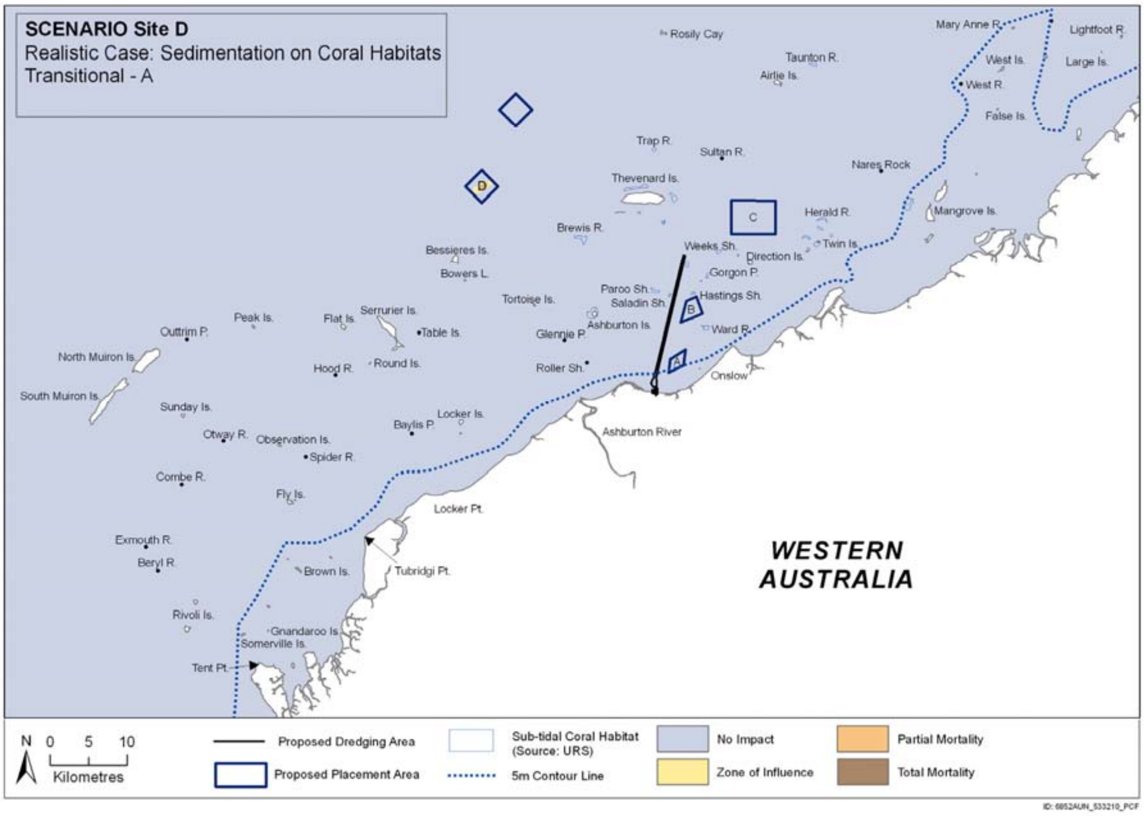


Figure 3.28 IZI derived for Site D for sedimentation on corals for summer conditions. Top: Summer A; Bottom: Summer B.



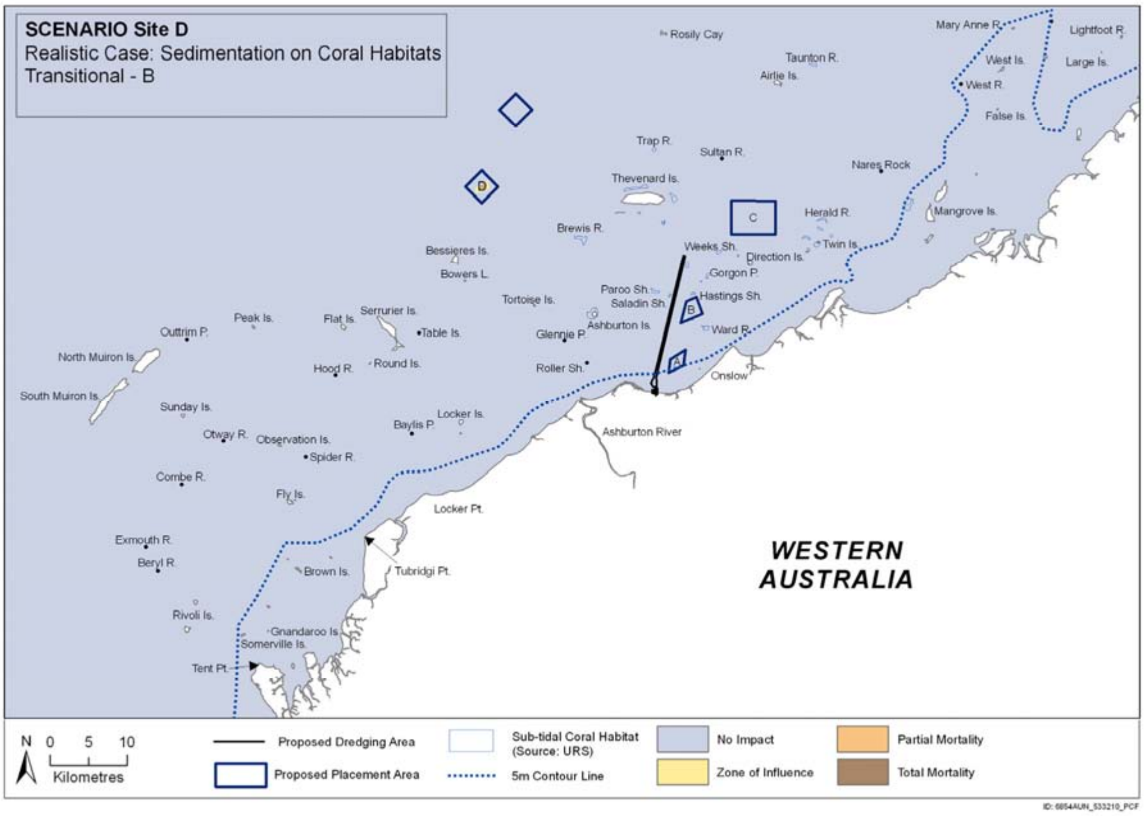
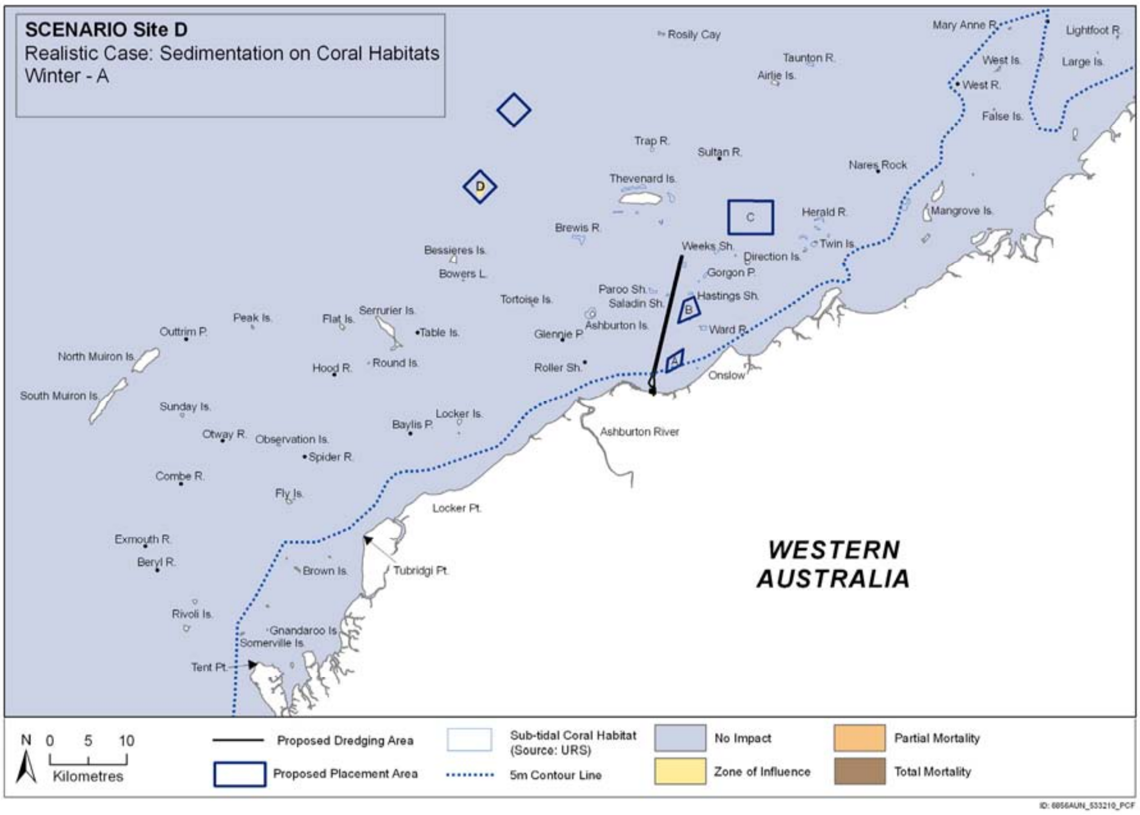


Figure 3.29 IZI derived for Site D for sedimentation on corals for transitional conditions. Top: Transitional A; Bottom: Transitional B.



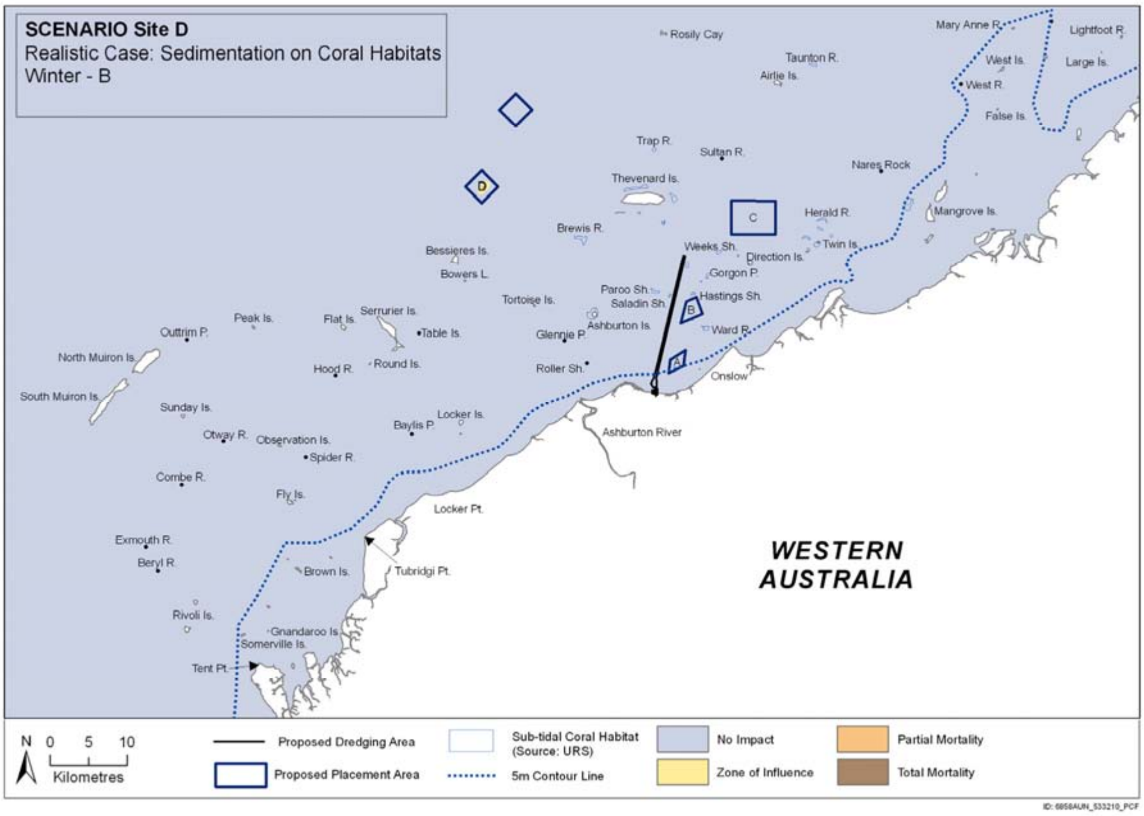
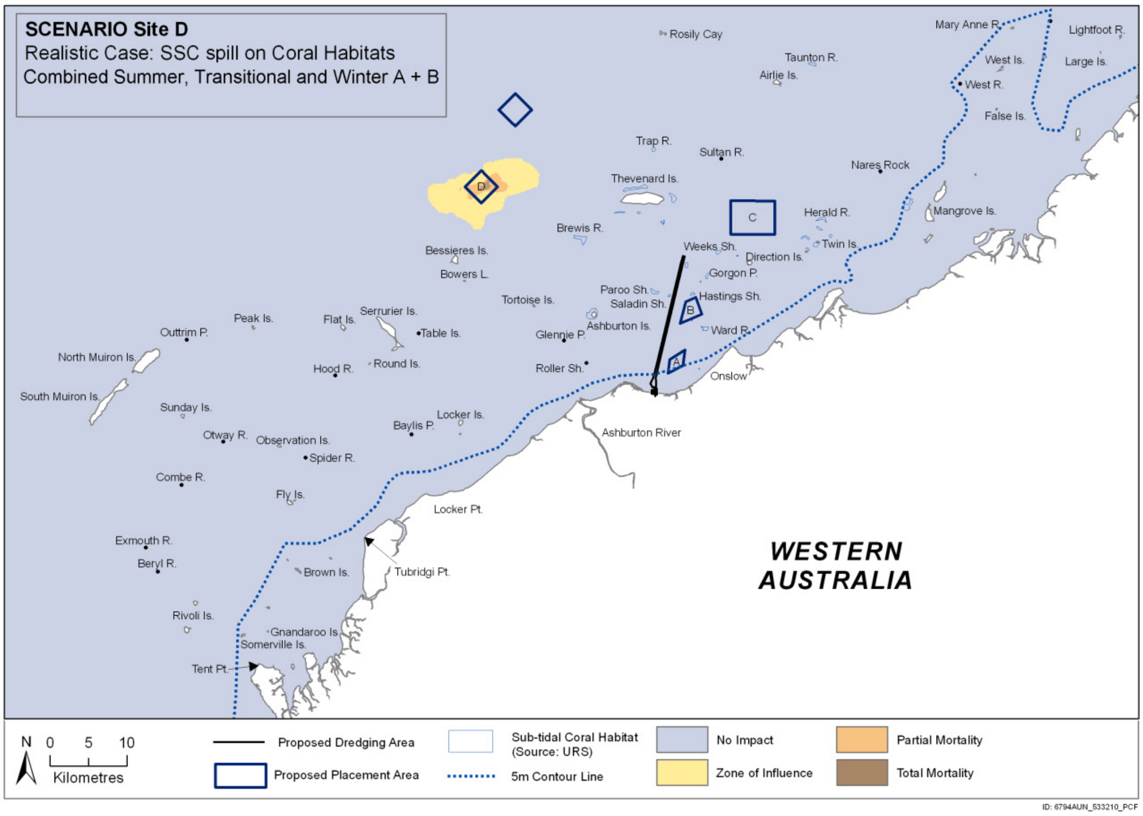


Figure 3.30 IZI derived for Site D for sedimentation on corals for winter conditions. Top: Winter A; Bottom: Winter B.



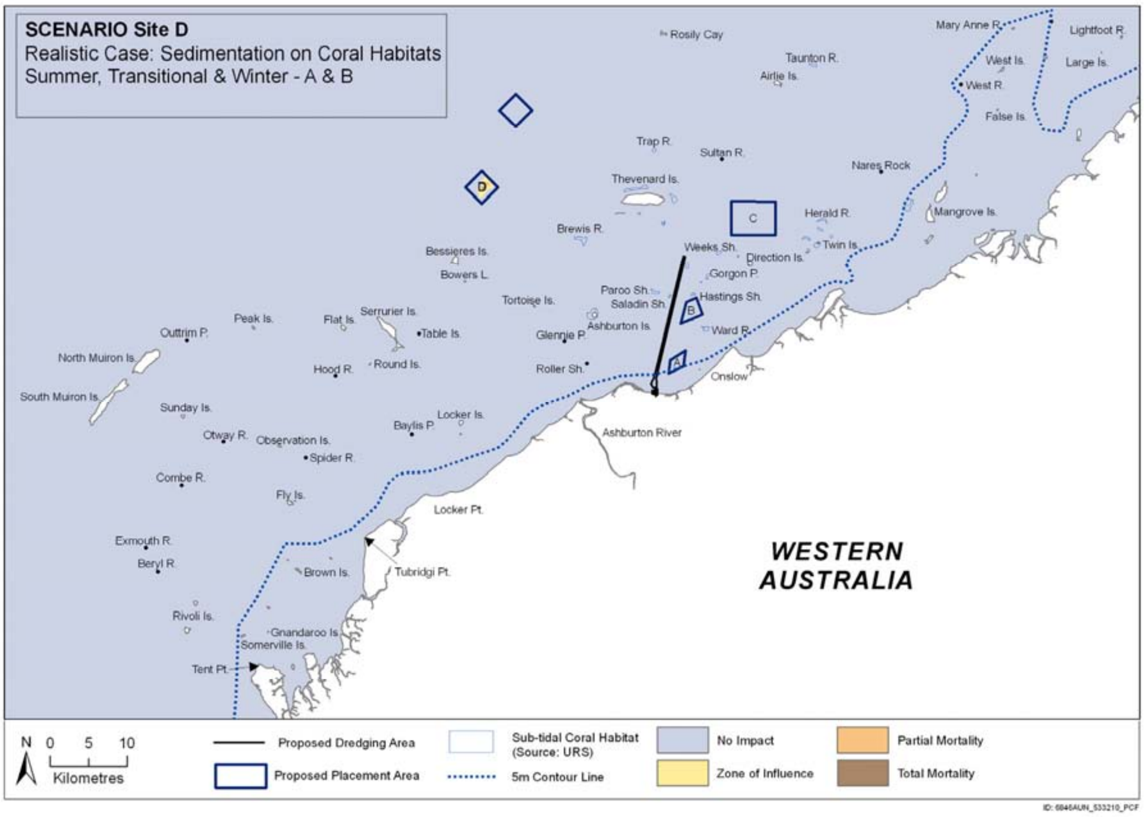
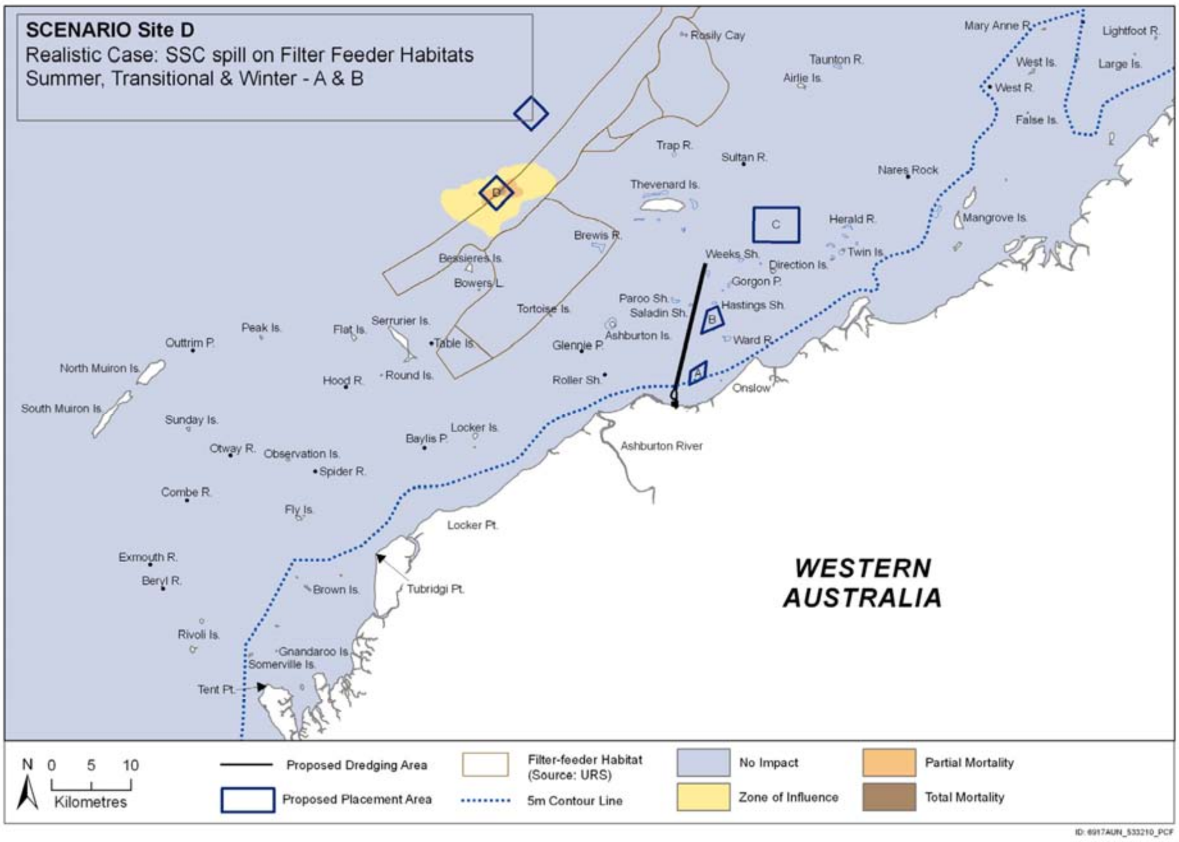


Figure 3.31 Combined IZI derived for Site D for SSC (top) and sedimentation (bottom) on corals for all climatic scenarios.



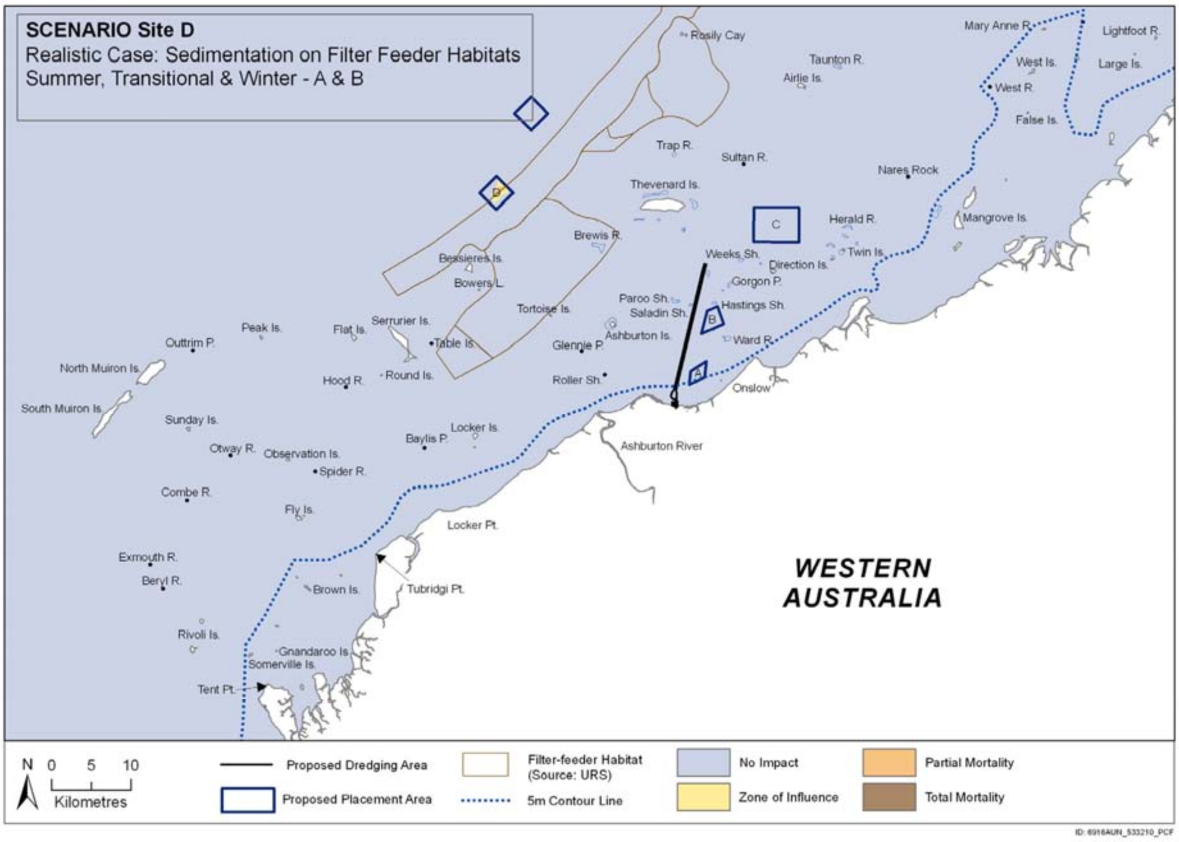


Figure 3.32 Combined IZI derived for Site D for SSC (top) and sedimentation (bottom) on filter feeders for all climatic scenarios.

4 MERGING OF RESULTS FOR DIFFERENT WIND FIELDS

A request for further explanation of the merging of results from the simulations with Onslow Met Station (OMS) and MesoLAPS winds is included twice in the review – please see below.

4.1 IPR Issue

8th June 2010

Both the 2D and 3D hydrodynamic models applied to this study have difficulties in accurately simulating wind-driven net current flows which drive large-scale plume excursions. For both models this is largely because of the lack of an entirely satisfactory and representative source of wind forcing data for the project area and surrounding region.

For the purposes of environmental impact assessment this uncertainty has been mitigated by merging dredge plume simulation results derived separately from the two-dimensional hydrodynamic model flows driven by OMS and MesoLAPS winds. This produces a broader spatial representation of the plume, since use of the OMS winds leads to higher simulated net currents and plume excursions when movement is to the east (mainly in summer), whereas use of the MesoLAPS winds leads to higher simulated net currents and plume excursions when movement is to the west (mainly in winter).

IPR Comment on DHI Response

MER agrees that merging two sets of dredge plume simulation results, one forced by OMS and the other by MesoLAPS winds, leads to a more conservative outcome than would have been the case for plume simulations forced by one of these wind sources only.

MER Recommendation

The numerical procedure for the merging of plumes should be explained in more detail, both for SSC and net sedimentation rates.

Supplementary Issue

The report refers to the merging of the outputs derived from different dredge plume scenario simulations. However the exact numerical procedure used to effect this merging has not been detailed in the report.

The outputs for each dredge plume scenario simulation are given as spatial distributions of pre-selected statistics of the suspended sediment concentrations and as net sedimentation rates for each 14 day scenario period. The pre-selected statistical measures are those required by the ecological tolerance limits of selected benthic habitat receptors within the Project area.

It is assumed that the merging of simulated dredge plume statistical outputs from the various short term scenarios is performed on a cell-by-cell basis across the model grid. For example, for each model cell, the maximum “percent exceedance of 25 mg/L SSC” from the various scenarios under consideration can be determined and then compared with the ecological tolerance limits to determine the level of ecological impact intensity for that model cell. In this way it is possible to build up the spatial distribution (or zones) of different levels of ecological impact intensity.

MER Recommendation:

DHI should explain the numerical procedure for merging plume scenario simulation results.

4.2 DHI Response

The plumes and sedimentation fields from the two different wind sources are not merged as part of the plume modelling. The statistical output from each individual simulation is used to derive indicative zones of impact (IZI) related to both Suspended Sediment Concentrations (SSC) and sedimentation for both corals and sea grasses. The use of different wind fields in effect add another parameter to the scenario approach, leading to twice the number of total scenarios. The "merging" of the results is carried out when "impact envelopes" are produced from the total number of impact zones. This is described in detail in Appendix N2: "Dredge Plume Impact Assessment" of the Draft EIS/ERMP. The derivation of the impact envelopes is done on a cell-by-cell basis as mentioned by Dr. Mills. For each cell, the impact classification from all the different scenarios are compared, and the highest (worst) impact attribute amongst all scenarios assigned to that cell. In addition, the total impact envelopes derived from the combination of all scenarios is "extended" to take into account the limitations in spatial coverage of the dredge scenarios. Please refer to Appendix N2 of the Draft EIS/ERMP for further details.

5 CLIMATIC SCENARIOS

5.1 IPR Issue

8th June 2010

It is important to understand whether the wind forcing data applied to the model for each of the seasonal climatic scenarios produces “strong”, “weak” or “typical” net currents compared to long-term averages for these seasonal climatic types. This will have a bearing on the spatial extent and concentration/sedimentation of the simulated plume and is relevant to the provision of conservative estimates of the plume. Some discussion of this aspect was provided in draft versions of this report but has not been included in the final report.

IPR Comment on DHI Response

For five locations where current meter data are available, Figures 15-24 (of Appendix FF to Appendix Q1) present:

- net currents (24 hour averages) simulated by the 2D hydrodynamic model driven by wind and tide conditions for the six selected 14-day time periods chosen to represent the climatic scenarios, and
- net currents derived from measured current data.

From Figures 15-24 DHI argues that the range of net current speeds and the dominant net current direction from any period of the measurements are able to be represented by one or other of the six periods of modelled net currents used for the various climatic scenarios. However, the measurements shown are confined to a couple of calendar years only, so that it is not possible to generalize this argument to fully include longer term inter-annual variability.

Furthermore, the sequence, persistence and frequency of occurrence of modelled net current speeds and directions used for the various climatic scenario periods do not fully represent the variability inherent in other periods of the measured net currents. This creates some uncertainty as to whether the plume and its impacts can be adequately represented in terms of six short term climatic scenarios.

DHI proposes to model the period 2002-2003 corresponding to an El Nino period (predominantly negative values of the Southern Oscillation Index (SOI)). This period is expected to have a greater frequency of occurrence of westerly winds compared to long-term averages. The aim is to assess whether the simulated net currents from this period can reasonably be characterized by the set of six climatic scenarios already selected.

MER Recommendation:

The period 1999-2000 should also be modeled as these years had clear positive SOI values, corresponding to a La Nina period, which may be expected to have a smaller frequency of occurrence of westerly winds compared to the long-term average. The aim is to assess whether the simulated net currents from this period can reasonably be characterized by the set of six climatic scenarios already selected.

5.2 DHI Response

Two issues are raised:

1. "Uncertainty as to whether the plume and its impacts can be adequately represented in terms of six short term climatic scenarios".
2. Inter-annual variability as captured in MER Recommendations.

DHI agrees that the climatic scenarios do not cover all possible combinations of sequence, persistence and frequency of net currents. However, periods with relatively persistent and strong easterly (during summer) and westerly (during winter) net currents as well as relatively calm periods have been targeted for the climatic scenarios. For the present dredging programme which has a long channel running basically perpendicular to the main currents dominant in the Project area, the various selected dredge scenarios cover the distribution of potential impacts along the channel, while the extent of potential impacts away from the channel to a large degree are determined by the maximum distance that higher SSC concentrations are persistently carried. DHI therefore believes that as long as the selected climatic scenarios encompass sufficiently strong and persistent net currents to cover what can reasonably be expected to occur (under non-cyclonic conditions) in the Project area, they should ensure a sufficient level of conservatism in their combined output of predicted impact domains. The exact composition in terms of variability is then of less concern.

It is further noted that:

- The combination of two wind fields and 6 climatic periods can to some extent be viewed as 12 climatic scenarios.
- As documented in Appendix F and Appendix JJ of Appendix Q, the 14 day assessment periods with 14 day warm-up are considered sufficiently long to represent "quasi-stationary" conditions.

Further documentation of the net currents has been carried out as recommended by MER to investigate whether the climatic scenarios can adequately cover the inter-annual variability. This is comprehensively documented in revised Appendix FF: Climatic Scenario Selection, Revision 1, November 2010. The summary and conclusions are included below:

The selection of climatic scenarios is one of the key components for dredge plume modelling. For Wheatstone, where the transport away from the site is dominated by variable wind driven currents, the climatic scenarios are of particular importance. The climatic scenarios must target a range of conditions to provide "realistic" worst case conditions throughout the potential impact area. This includes both mild weather conditions which will cause lower dispersion with resulting higher concentrations and sedimentation rates in the near field area and stronger winds which will tend to disperse the plume more rapidly and reduce near-field impacts, but drive the plume further away from the dredge area and thereby extend the zone of impact and define the zone of influence.

Waves, which are important for the settling and resuspension of sediments, are included in the models based on the same winds that drive the net currents.

Significant intra- and inter-annual variability exists in the climatic conditions at the site. To represent this, three seasons have been defined, and two climatic periods defined for each season. With the use of two different wind fields to drive the model, this in effect leads to six periods with two different wind fields, i.e. a total of twelve different climatic drivers.

A comprehensive assessment of both winds and net current fields has been carried out to assess whether the adopted climatic scenarios can be considered reasonably conservative. The assessment showed that the chosen "strong" winter and summer conditions comprise the strongest monthly averages of net wind and current fields. The transitional periods include weak and variable winds and net currents to cover the potential local build-up of sediments during periods of neap tide.

A particular strength of the scenario modelling approach adopted for the Wheatstone EIA is the independence of the timing of the climatic conditions as all climatic scenarios are combined with all defined dredge scenarios to develop total envelopes of the impact zones. Whereas the inter-annual variability may shift the seasonal currents, it was found that the overall ranges of net current speeds and consistency were well covered by the periods adopted for the climatic scenarios.

Whereas the limited number of climatic scenarios do not cover all variations of winds and resulting net currents that will be experienced during the dredging period, it is concluded that the range of both summer, winter and transitional (calmer) conditions are well covered and provide a reasonably conservative estimate of the impact zones when applied through the scenario modelling approach.

For further details, please refer to revised Appendix FF.

6 SEDIMENT RESUSPENSION

6.1 IPR Issue 1

8th June 2010

The report identifies "significant and repeated resuspension of [dredged] material" by currents and waves which can regenerate plumes far from the dredge location. This has the potential to redistribute dredged sediment material (e.g. migration of areas of net sedimentation) over time-scales considerably greater than 14 days, which cannot be represented by the short-term scenario simulations.

DHI has tested the model for this effect and found that, with the present settings for the sediment fractions, there is negligible migration of the SSC footprint or net sedimentation areas over an extended simulation period. This may be because the sediment fractions specified in the model are expected to remain in full suspension for most of the time under the range of current and wave conditions encountered in the Wheatstone area.

By contrast, coarser silts fractions with settling velocities of 3 or 4 mm/s are likely to experience greater deposition rates when bed stress levels are sub-critical. The transport of these intermittently suspended coarser silt fractions is likely to differ (in rate and possibly direction) from the transport of the finer fractions represented in the model, and may not be fully represented within a fourteen day simulation period.

IPR Comment on DHI Response

DHI (May 2010), in Appendix F, considered the issue of repeated dredged sediment resuspension by currents and waves over extended time periods. In particular, the influence of repeated resuspension on the spatial extent of predicted zones of impact and influence was examined.

The dredge plume model was run for a two month summer period with (a) no sediment resuspension, (b) resuspension by currents only, and (c) resuspension by currents and waves combined. The model results suggest that "resuspension can significantly increase the area [that is occasionally] affected by low concentration plumes." In the model simulation, much of the resuspension occurs "in short bursts during spring tides" so that "the duration of the resulting plumes is low". The model also suggests that "the areas covered by higher concentration plumes are largely unchanged" by the effects of resuspension.

In another test the model was run for an extended period of 224 days, using 16 repetitions of a 14 day summer climatic (wind forcing) scenario. The history of the dredged sediment distributions was maintained throughout the course of this simulation. The model results (Figures F.5 to F.12) demonstrated that, after the second repetition, the summary statistics for the suspended sediment concentration fields remain virtually unchanged for the rest of the simulation, suggesting that "the changes due to additional resuspension not captured through a one month period" are only very low concentration changes which would not be expected to have a significant influence on the extent of predicted zones of potential impact or influence. In terms of net sedimentation, the model results (Figure F.13) show an accumulation throughout the simulation period. As the simulation progresses net sedimentation is indicated further away from the source. Whether this represents a migration of areas of net sedimentation, or an accumulation pattern that is essentially spatially invariant over time, can be better illustrated by plotting net sedimentation rates per 14 days throughout the simulation (i.e. the difference between net sedimentation at the end of successive 14 day periods).

MER Recommendation:

Replot Figure F.13 as net sedimentation change for each 14 day period to determine whether the spatial distribution is stationary or migrating over time.

6.2 DHI Response – Issue 1.

Figure F.13 has been replotted as recommended, see Figure 6.1 below. In addition, the scale has been changed to capture very low sedimentation rates to better capture the spatial distribution. The replotting shows that the sedimentation patterns are largely identical after the first 14day period. This shows that the sedimentation further away from the site due to re-suspension beyond the 14 day "warm up" and 14 day processing period is small compared to the sedimentation arising from the continuous sources.

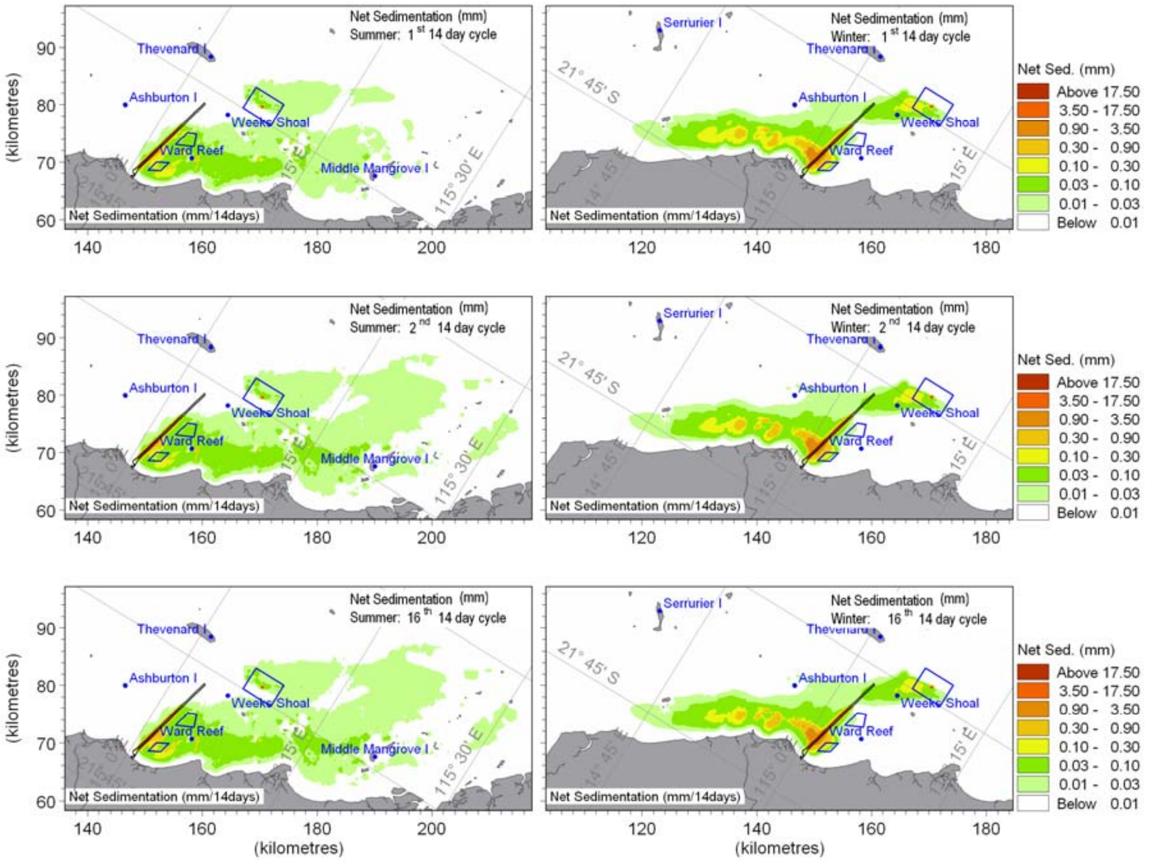


Figure 6.1 Revised Figure F.13 from Appendix F of Appendix Q1 to the EIS. Net sedimentation rates over 14 day periods for the 1st, 2nd and 16th 14 day assessment periods for summer (left column) and winter (right column) conditions.

6.3 IPR Issue 2

Section F4.2 presents the statistical outputs for SSC for each 14 day period from a full dredge program simulation of two years duration, driven by MESOLAPS winds. The history of the dredged sediment distribution (including the effects of resuspension) is retained and allowed to evolve throughout this period. The statistical outputs for each 14 day period are merged to produce a cumulative footprint of these outputs for the entire dredge campaign (Figure F.22 - top). This is compared to the results of merging of the statistical outputs from the short term scenario method (Figure F.22 – bottom). These are not strictly comparable, since the short term results account for the variability of both the Onslow and the MesoLAPS winds, whereas the longer term simulation results are driven by MesoLAPS winds only. This accounts in no small way for the difference in the plume footprint to the east of the project area. A more valid comparison would be provided by the merging of outputs from the short term scenarios involving MesoLAPS winds only.

MER Recommendation: The comparison of dredge plume footprints using the short term and long term scenario approaches (Figure F.22) should be reworked. For this purpose only outputs from the short term scenarios involving MesoLAPS winds should be merged.

6.4 DHI Response – Issue 2.

Figure F.22 (from Appendix F of Appendix Q1 of the EIS) has been reworked as recommended by Dr. Mills, see Figure 6.2. The main difference between the envelope plot for MesoLAPS only presented below and the combined envelope for Onslow and MesoLAPS winds included in figure F.22 is the plume extension towards east during summer, which is much smaller for MesoLAPS winds than for Onslow winds.

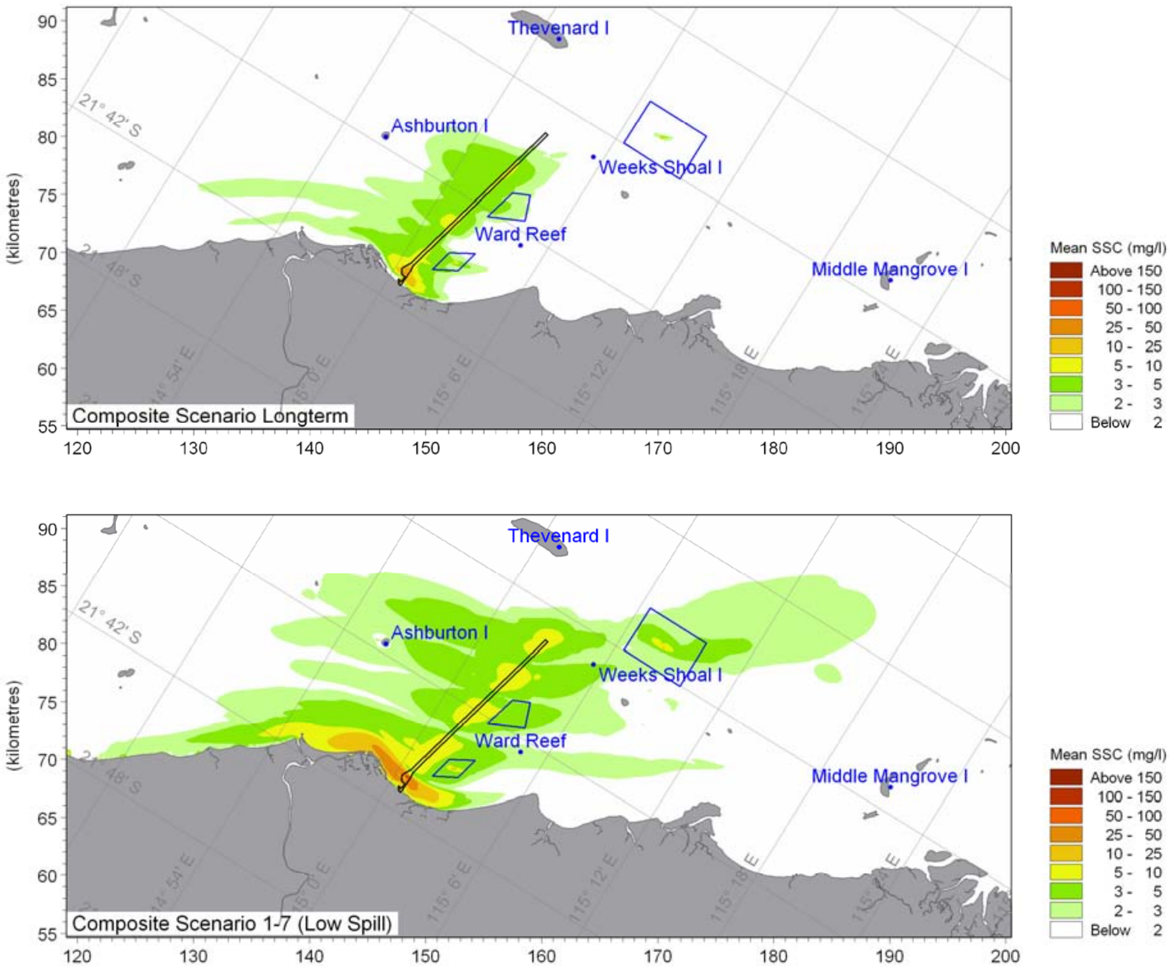


Figure 6.2 Reworked Figure F.22. The composite impact zone from a long term scenario (top) is compared to the envelope of impact zones derived for all climatic and dredge scenarios based on simulations with MesoLAPS winds.

Figure 6.3 and Figure 6.4 make a similar comparison between the footprint in terms of predicted potential impact zones derived from the long period simulation and the envelope of predicted potential impact zones derived through the shorter-term scenario modelling for SSC impacts on coral habitats. A similar comparison for potential sedimentation impacts on coral habitats is shown in Figure 6.5 and Figure 6.6.

The comparison to the envelope derived from MesoLAPS wind driven simulations only re-affirm the conclusions drawn in Appendix F of Appendix Q1 of the EIS:

1. The footprint derived through the long-term simulation generally lies well within the envelope developed through the scenario modelling as expected. This supports the notion that the shorter-term scenario modelling has sufficient conservatism built in and captures the critical combinations of releases and climatic drivers to establish the outer bounds for the predicted potential impact zones. It also supports the assumption that re-suspension from sediment derived from the long-term dredging programme will not add significantly to the predicted potential impact zones. There are two minor exceptions to this when looking at the predicted mean excess concentrations:
    a. The 3-5 mg/l area stretches slightly further to the west in the footprint from the long-term simulation at a location to the west of Ward Reef. This is due to limited overlap along the channel of the defined dredge segments. For the final delineation of the impact zones, the "edges" of the zones are interpolated between the individual scenarios to ensure that the full area is covered.
    b. A slight further extension westward of the 3 mg/l contour for the same area. This is due to the same effect potentially combined with added re-suspension in relation to a "strong climatic burst". This does not affect the important predicted impact zones for partial mortality of benthic receptors.
2. The footprint derived through the long-term simulation primarily stretches westward of the channel. This is due to the fact that MesoLAPS winds do not capture the nearshore eastward trend during summer well, and the dredging along the approach channel in loose material with high release rates takes place predominantly during transitional and winter months. This clearly demonstrates the fact that the long-term simulation represents one scenario – the footprint would be very different with a different starting time relative to the seasons, or a different (and equally possible) definition of the dredging sequence. For long-term (changeable) dredging programmes in variable climatic conditions, it requires a large number of simulations to ensure that critical combinations of dredging and climatic drivers are captured. The strength of the shorter term scenario modelling is that the critical dredging, release and climatic conditions can be isolated and combined in all possible ways to ensure that the critical combinations are captured. The model results will provide insight into which combinations of conditions are critical and should be managed in the planning of the dredging campaign.
3. The comparisons also demonstrate that the "actual" impact zone from a given dredge programme is likely to be significantly smaller than the "envelope" of predicted potential impact zones derived from the scenario modelling.

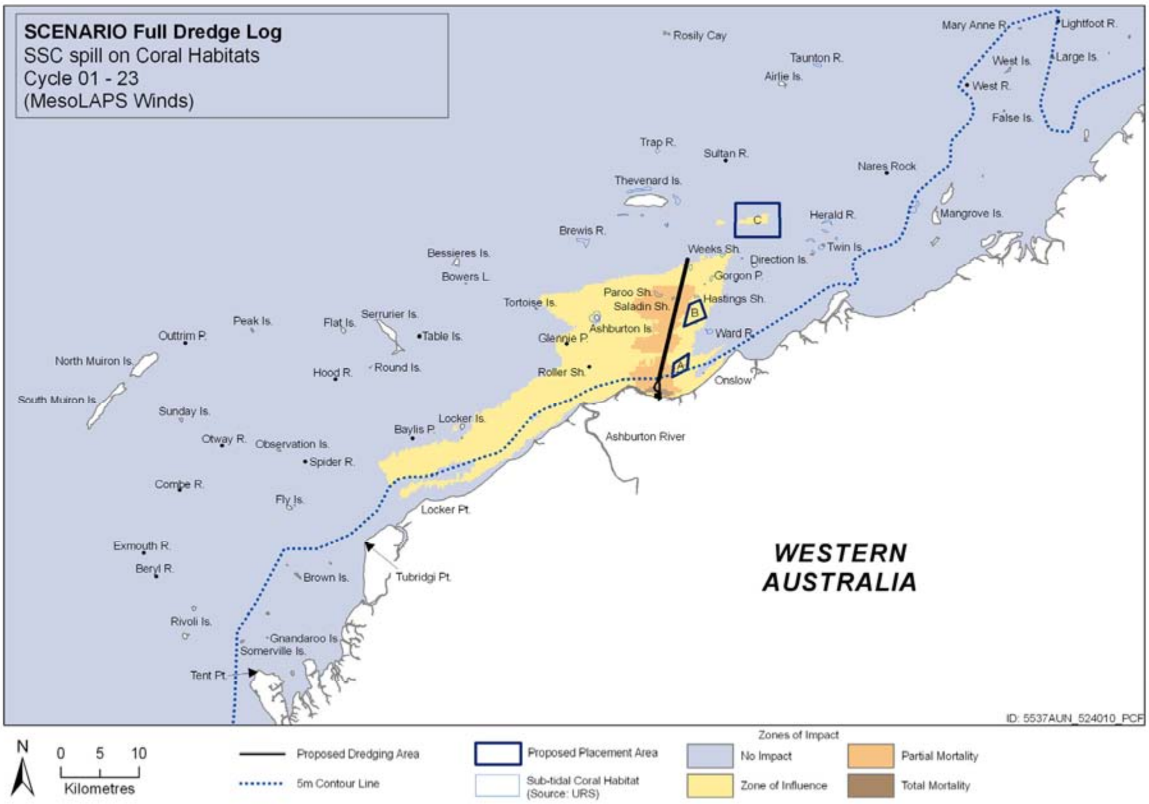


Figure 6.3 Footprint in terms of IZI from SSC on corals derived from the long period dredge simulation.

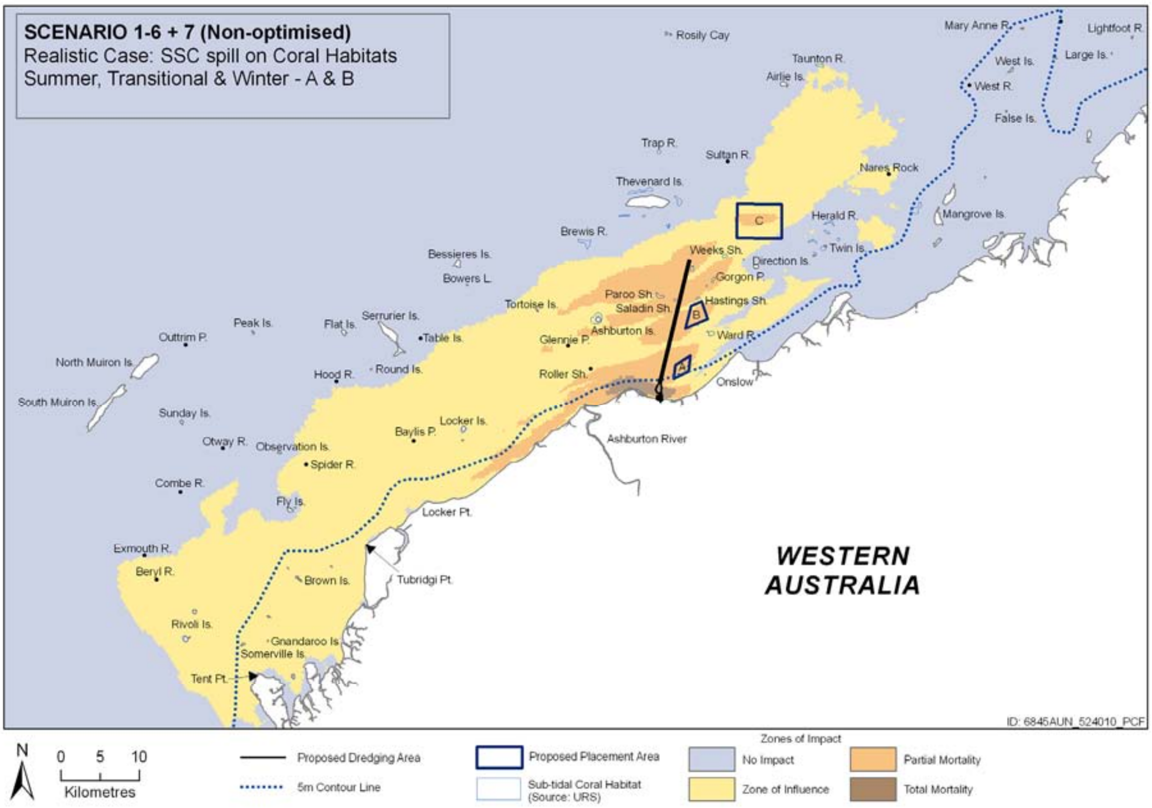


Figure 6.4 Envelope of IZI for SSC on corals derived from the shorter-term scenario modelling.

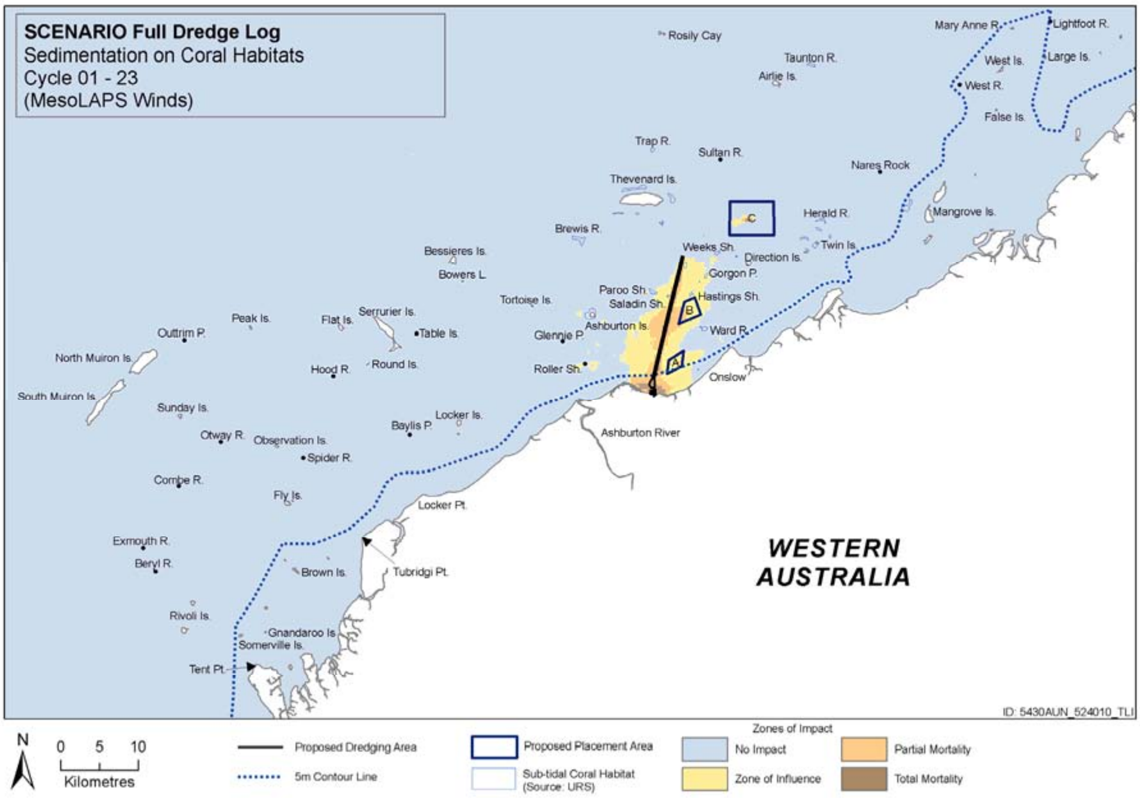


Figure 6.5 Footprint in terms of IZI from sedimentation on corals derived from the long period dredge simulation.

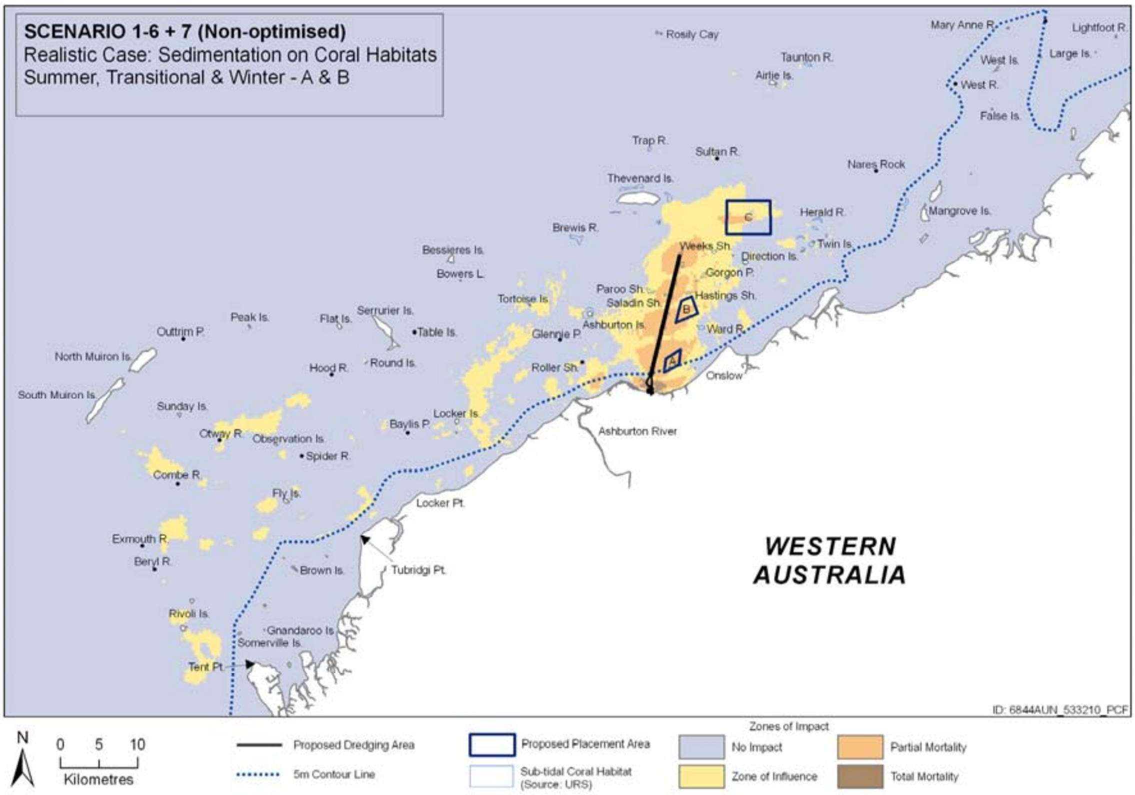


Figure 6.6 Envelope of IZI for sedimentation on corals derived from the shorter-term scenario modelling.

7 REFERENCES

Mills, D. (June 2010): *Review of DHI Report. Wheatstone Project, Dredge Spoil Modeling Report. Document: WHST-STU-EM-RPT-0139. DHI Report: MY5527-0 – Dredge Spoil Modeling, 10 May 2010*. Prepared for URS by Dr. Des Mills, Des Mills Marine Environmental Reviews. 8 June 2010.

Mills, D. (July 2010): *Review of DHI Technical Note. Wheatstone Project, Dredge Spoil Modeling Response to IPR Comments of 8th June 2010. DHI Report MY5527-0 Document: WHST-STU-EM-RPT-0142.* Prepared for URS by Dr. Des Mills, Des Mills Marine Environmental Reviews. 28 July 2010.

Review of DHI Technical Note
Wheatstone Project
Dredge Spoil Modeling

APPENDIX A:

Des Mills Marine Environmental Reviews

REVIEW OF DHI TECHNICAL NOTE

Wheatstone Project

Dredge Spoil Modeling

RESPONSE TO IPR COMMENTS OF 8TH JUNE 2010

DHI REPORT: MY 5527-0

DOCUMENT: WHST-STU-EM-RPT-0142

25 JUNE 2010

Prepared for URS by

Dr Des Mills

DES MILLS MARINE ENVIRONMENTAL REVIEWS

28 JULY 2010

TABLE OF CONTENTS

1. BACKGROUND

Chevron in conjunction with URS requested Des Mills Marine Environmental Reviews (MER) to conduct an Independent Peer Review (IPR) of the dredge spoil modeling studies conducted by DHI Water and Environment (DHI) for the Wheatstone Project.

MER (8 June 2010) reviewed a comprehensive DHI report entitled "Wheatstone Project – Dredge Spoil Modeling Report" (DHI, 10 May 2010).

DHI (25 June 2010) provided initial responses and outlined further work being conducted to address issues raised in the MER review of 8 June 2010.

This document provides MER follow up comments on the DHI report of 25 June 2010.

2. IPR ISSUES, DHI RESPONSES AND IPR COMMENTS

2.1 THREE-DIMENSIONAL EFFECTS

IPR ISSUE (8TH JUNE 2010)

While flow conditions in the shallower parts of the project area have limited vertical structure, this is not the case for measurements from [location P4] near the outer portion of the proposed shipping channel which show current directions varying with depth, being most frequently to the northeast in the upper water column and most frequently to the southwest in the lower water column. A two-dimensional, depth-averaged model, based on the assumption of well-mixed flow conditions, cannot reproduce this behaviour.

IPR COMMENT ON DHI RESPONSE

DHI states that the change with depth through the water column in the frequency of measured current directions "seems less noticeable for locations with similar depth to the outer channel from the ongoing field campaign, see Figure 3 to Figure 5".

From the additional current rose data provided in the DHI response of 25 June 2010, MER notes that variation with depth in the frequency of occurrence of current directions is also clearly present:

- at the "Channel" location for the months of August, September and October 2009, but not for July (Figure 3);
- at the "AWAC-01" location for the months of April, May, June and July 2009, but not for November, December 2009 and January 2010 (Figures 4 and 5).

DHI concludes that "the 3D [hydrodynamic] effects are generally weak compared to the overall current regime".

On the basis of the current data presented from the outer part of the project area (Figures 6 to 14) MER believes that this conclusion should be qualified, by noting that:

- the data presented do not show the total vertical change in currents throughout the entire water column, only throughout 50% (at P4), 60% (at "Channel") and 70% (at AWAC1) of the water column. In each case the near-surface and near-bottom boundary layers of the water column are not resolved by the measurements and it is in these boundary layers that vertical current shear would be expected to be greatest due to the action of wind and bed shear stresses;
- significant directional shearing is apparent for about 25% (at P4 - Fig 6), 7-14 % (at "Channel" - Figs 7 and 8) and 8-14% (at AWAC1 – Figs 9 to 14) of the duration of data records provided. As indicated above, the data only show the current shear through a middle portion of the water column, so that the percentage of time for which significant directional shearing occurs over the entire water column is likely to be underestimated by these data;

*DHI firmly believe that "the combination of a 2D model and the scenario approach generally will lead to a conservative envelope of possible impacts. This is described for a "line source" in **Appendix E** to the reviewed modeling report. 3D current structures in essence increase dispersion in the horizontal plane, which leads to lower depth-averaged concentrations within the plume. Generally speaking, a 2D model will thus lead to higher concentrations stretching further from the site in the current direction".*

Appendix E (Figures E.2 to E.7) shows the spatial extent and intensity of dredge plume scenario simulations derived from 2D modeling and from the vertical integration of 3D modeling results. Results are for dredge scenarios 6 and 7. The climatic scenarios used are thought to be Summer B, Transition B and Winter B, although this is not clear from the documentation.

Appendix E (Figures E8 to E19) of the DHI modeling report shows predicted zones of ecological impact intensity for corals based on dredge plume model outputs and tolerance limits for suspended sediment concentrations and net sedimentation rates. The zones are shown for dredge scenarios 6 and 7, each subject to the Summer B, Transition B and Winter B climatic scenario conditions. The zones were predicted from 2D plume simulations and the vertical integration of 3D plume simulation results.

Comparisons of the zones derived from the 2D and 3D modeling yielded the following:

- for the winter B scenario all zones were of similar or greater spatial extent for the 2D compared to the 3D modeling;
- for the summer B scenario the 2D modeling generally gave zones of similar or greater spatial extent compared to the 3D modeling ;
- for the Transition B scenario there were several cases for which the 3D modeling gave zones of greater extent, namely the zone of partial mortality based on NSR and the zones of influence, based on SSC and on NSR (see Figures E.12, E.15 and E.18);

In summary, the 2D modeling mostly led to zones of greater extent across these three climatic scenarios.

Note from Figures 15, 17, 19, 21 and 23 that the sequence and frequency distributions of speed and directional data for the simulated net currents corresponding to the "A" climatic scenarios differ significantly from those of their "B" scenario counterparts. Hence, simulated plumes may differ significantly between the Summer A and Summer B climatic scenarios, for example, and likewise for the transitional and winter scenarios.

MER Recommendation: A comparison of the plumes (and the resultant zones of effect) derived from the 2D and the 3D simulation results should be conducted for the Winter A, Summer A and Transitional A scenarios. These comparisons and the previously reported comparisons for the "B" scenarios should be considered together to determine whether the 2D modeling provides more conservative results overall compared to the 3D modeling approach.

2.2 Wind Data Applied In Modeling

IPR Issue (8th June 2010)

Both the two- and three-dimensional hydrodynamic models applied to this study have difficulties in accurately simulating wind-driven net current flows which drive large-scale plume excursions. For both models this is largely because of the lack of an entirely satisfactory and representative source of wind forcing data for the project area and surrounding region.

For the purposes of environmental impact assessment this uncertainty has been mitigated by merging dredge plume simulation results derived separately from the two-dimensional hydrodynamic model flows driven by OMS and MesoLAPS winds. This produces a broader spatial representation of the plume, since use of the OMS winds leads to higher simulated net currents and plume excursions when movement is to the east (mainly in summer), whereas use of the MesoLAPS winds leads to higher simulated net currents and plume excursions when movement is to the west (mainly in winter).

IPR Comment on DHI Response

MER agrees that merging two sets of dredge plume simulation results, one forced by OMS and the other by MesoLAPS winds, leads to a more conservative outcome than would have been the case for plume simulations forced by one of these wind sources only.

MER Recommendation: The numerical procedure for the merging of plumes should be explained in more detail, both for SSC and net sedimentation rates.

2.3 Climatic Scenarios

IPR Issue (8th June 2010)

It is important to understand whether the wind forcing data applied to the model for each of the seasonal climatic scenarios produces "strong", "weak" or "typical" net currents compared to long-term averages for these seasonal climatic types. This will have a bearing on the spatial extent and concentration/sedimentation of the simulated plume and is relevant to the provision of conservative estimates of the plume. Some discussion of this aspect was provided in draft versions of this report but has not been included in the final report.

IPR Comment on DHI Response

For five locations where current meter data are available, Figures 15-24 present:

- net currents (24 hour averages) simulated by the 2D hydrodynamic model driven by wind and tide conditions for the six selected 14-day time periods chosen to represent the climatic scenarios, and
- net currents derived from measured current data.

From Figures 15-24 DHI argues that the range of net current speeds and the dominant net current direction from any period of the measurements are able to be represented by one or other of the six periods of modeled net currents used for the various climatic scenarios. However, the measurements shown are confined to a couple of calendar years only, so that it is not possible to generalize this argument to fully include longer term inter-annual variability.

Furthermore, the sequence, persistence and frequency of occurrence of modeled net current speeds and directions used for the various climatic scenario periods do not fully represent the variability inherent in other periods of the measured net currents. This creates some uncertainty as to whether the plume and its impacts can be adequately represented in terms of six short term climatic scenarios.

DHI proposes to model the period 2002-2003 corresponding to an El Nino period (predominantly negative values of the Southern Oscillation Index (SOI)). This period is expected to have a greater frequency of occurrence of westerly winds compared to long-term averages. The aim is to assess whether the simulated net currents from this period can reasonably be characterized by the set of six climatic scenarios already selected.

MER Recommendation: The period 1999-2000 should also be modeled as these years had clear positive SOI values, corresponding to a La Nina period, which may be expected to have a smaller frequency of occurrence of westerly winds compared to the long-term average. The aim is to assess whether the simulated net currents from this period can reasonably be characterized by the set of six climatic scenarios already selected.

2.4 Sediment Modeling

IPR Issue (8th June 2010)

Augmenting the depth-averaged dredge plume model with an assumed form for the vertical SSC profile, taken from the work of Teeter (1986), is of potential concern. The Teeter profile is based on underlying assumptions (e.g. constant bed shear stress) which may be inappropriate in the context of modeling dredge plumes in a dynamic marine environment. As a consequence, it is possible, under some circumstances, that the model may misrepresent sediment deposition rates which in turn may result in misrepresentation of suspended sediment concentration gradients along the dredge plume axis. This is discussed in more detail in Section 7 of this review.

If the dredged sediment spills are all fines in suspension that are vertically well mixed throughout the water column then this may not be a significant issue. However if the spills include silt sizes with greater settling velocities (e.g. 3 or 4 mm/s) that are more intermittently suspended these sediment fractions are likely to develop stronger vertical SSC profiles and the validity of using two-dimensional modeling augmented with the Teeter profile would need to be questioned.

IPR Comment on DHI response

DHI states that the focus of the dredge plume modeling for the Wheatstone Project has been on fine cohesive sediments with low settling velocities, for which the Teeter vertical profile has been used in the model.

For a modeling focus on fine sediments with low settling velocities, as stated in the IPR issue, the use of the Teeter profile may not be a significant issue.

However, in relation to this focus on fine sediments it is relevant to question:

- whether the sediment fractions as defined in the model are representative of the expected sediment distribution in the dredge plume, and
- whether it can be argued that the sediment fractions as defined in the model will generate a conservative estimate of the impacts.

These questions are addressed under the next issue.

2.5 Sediment Fractions

IPR Issue (8th June 2010)

The sediment settling velocity (~ particle size) distributions of dredge spill sediments from sources other than overflow have not been specified. These sediment distributions should be documented for the various types and sources of spill and the range of expected transport behaviors should be explained. A more comprehensive justification should be provided for the number of sediment fractions (with defined settling velocities and percentage mass) and the overall range of particle sizes (settling velocities) represented in the model.

Sediment fractions presently included in the model have been assigned settling velocities of 1 mm/s or less. These fractions are expected to be fairly well-mixed (vertically) in suspension (Rouse number << 1) for much of the time and only to deposit relatively slowly when bed shear stress levels are sub-critical. In order to better represent the dredge plumes and their impacts, the model may require additional silt fractions (including settling velocities of about 3 or 4 mm/s) which are in incipient rather than full suspension for much of the time (Rouse number value of about 1) with more pronounced vertical SSC profiles, and which deposit more rapidly when bed shear stress for deposition is below critical value.

As the sediment fraction settling velocity increases the vertical profile of SSC will become less uniform and the application of a two-dimensional model less appropriate. For a typical water depth (10 m) and sediment settling velocity of 3 mm/s the settling time scale is about 1 hour and over this time period the bed stress can vary significantly during the acceleration and deceleration of the ebb and flood tidal currents, contrary to assumptions on which the Teeter profile is based.

IPR Comment on DHI Response

DHI acknowledges the presence of particles with settling velocity up to 4 mm/s in the measured particle size distribution for the TSHD overflow. DHI argues that grouping sediments with settling velocity range from 0.8 – 4 mm/s into one fraction and assigning a settling velocity of 1 mm/s to that fraction tends to give a conservative result for dredge spills due to overflow, since this will lead to a greater proportion of the simulated dredge spill travelling further away from the source as suspended material.

For the modeling of plumes generated by placement of dredged material, DHI uses a particle size distribution (PSD) the same as that assumed for TSHD overflow, which has a greater proportion of fines compared to what would be expected in the released placement material. DHI states that this will provide a conservative representation, as the simulated plumes will spread further from the placement *site and contribute more to potential impacts further away from the placement site compared to a coarser distribution.*

MER agrees that the simulated SSC distribution of the plumes, modeled using the adopted overflow PSD (Appendix G, Table G.1), would be expected to be conservative in extent and intensity. However, the simulated net sedimentation rate may be underestimated just beyond the boundary of the mixing zone, some distance away from the source, since medium fine silt is represented in the model as fine silt which will not settle as rapidly and will be advected further in suspension. This may affect the extent of zones of effect as predicted from net sedimentation rates.

A similar qualification in relation to net sedimentation rates and their corresponding zones of impact should be made in relation to the modeling of plumes generated at the placement sites, and by draghead and propeller disturbance.

In Figures 25-30 DHI presents mean SSC results from dredge plume simulations for dredge scenario 6 and high spill rates for the Summer A, Transition A and Winter A climatic scenarios. The SSC contributions of each of the six "standard" sediment fractions in the model (representing clays and fine silts - see Table G.1) are shown as well as the contributions of two additional coarser fractions representing medium fine silt and fine sand.

The simulated SSC contributions of the two additional coarser fractions are clearly smaller in spatial extent and low in concentration compared to the contributions from the six "standard" fractions, and do not contribute significantly to the total SSC of the plumes. This suggests that the net sedimentation rates are also limited in spatial extent and not likely to affect impact zones, especially in locations where there are sensitive receptors.

On the basis of this information, the implementation of the sediment fractions into the model appears reasonable.

2.6 Sediment Resuspension

IPR Issue (8th June 2010)

The report identifies "significant and repeated resuspension of [dredged] material" by currents and waves which can regenerate plumes far from the dredge location. This has the potential to redistribute dredged sediment material (e.g. migration of areas of net sedimentation) over time-scales considerably greater than 14 days, which cannot be represented by the short-term scenario simulations.

DHI has tested the model for this effect and found that, with the present settings for the sediment fractions, there is negligible migration of the SSC footprint or net sedimentation areas over an extended simulation period. This may be because the sediment fractions specified in the model are expected to remain in full suspension for most of the time under the range of current and wave conditions encountered in the Wheatstone area.

By contrast, coarser silts fractions with settling velocities of 3 or 4 mm/s are likely to experience greater deposition rates when bed stress levels are sub-critical. The transport of these intermittently suspended coarser silt fractions is likely to differ (in rate and possibly direction) from the transport of the finer fractions represented in the model, and may not be fully represented within a fourteen day simulation period.

IPR COMMENT ON DHI RESPONSE

DHI (May 2010), in Appendix F, considered the issue of repeated dredged sediment resuspension by currents and waves over extended time periods. In particular, the influence of repeated resuspension on the spatial extent of predicted zones of impact and influence was examined.

The dredge plume model was run for a two month summer period with (a) no sediment resuspension, (b) resuspension by currents only, and (c) resuspension by currents and waves combined. The model results suggest that "resuspension can significantly increase the area [that is occasionally] affected by low concentration plumes." In the model simulation, much of the resuspension occurs "in short bursts during spring tides" so that "the duration of the resulting plumes is low". The model also suggests that "the areas covered by higher concentration plumes are largely unchanged" by the effects of resuspension.

In another test the model was run for an extended period of 224 days, using 16 repetitions of a 14 day summer climatic (wind forcing) scenario. The history of the dredged sediment distributions was maintained throughout the course of this simulation. The model results (Figures F.5 to F.12) demonstrated that, after the second repetition, the summary statistics for the suspended sediment concentration fields remain virtually unchanged for the rest of the simulation, suggesting that "the changes due to additional resuspension not captured through a one month period" are only very low concentration changes which would not be expected to have a significant influence on the extent of predicted zones of impact or influence. In terms of net sedimentation, the model results (Figure F.13) show an accumulation throughout the simulation period. As the simulation progresses net sedimentation is indicated further away from the source. Whether this represents a migration of areas of net sedimentation, or an accumulation pattern that is essentially spatially invariant over time, can be better illustrated by plotting net sedimentation rates per 14 days throughout the simulation (i.e. the difference between net sedimentation at the end of successive 14 day periods).

MER Recommendation: Replot Figure F.13 as net sedimentation change for each 14 day period to determine whether the spatial distribution is stationary or migrating over time.

Section F4.2 presents the statistical outputs for SSC for each 14 day period from a full dredge program simulation of two years duration, driven by MESOLAPS winds. The history of the dredged sediment distribution (including the effects of resuspension) is retained and allowed to evolve throughout this period. The statistical outputs for each 14 day period are merged to produce a cumulative footprint of these outputs for the entire dredge campaign (Figure F.22 - top). This is compared to the results of merging of the statistical outputs from the short term scenario method (Figure F.22 – bottom). These are not strictly comparable, since the short term results account for the variability of both the Onslow and the MesoLAPS winds, whereas the longer term simulation results are driven by MesoLAPS winds only. This accounts in no small way for the difference in the plume footprint to the east of the project area. A more valid comparison would be provided by the merging of outputs from the short term scenarios involving MesoLAPS winds only.

MER Recommendation: The comparison of dredge plume footprints using the short term and long term scenario approaches (Figure F.22) should be reworked. For this purpose only outputs from the short term scenarios involving MesoLAPS winds should be merged.

2.7 Sediment Suspension by Shipping Operations

IPR Issue (8th June 2010)

It is recommended that the scope of this study be extended to evaluate the sediment suspension and plume generation caused by shipping operations (for the project operating at capacity), including when large vessels (with tug boats) are maneuvering onto or off berths.

IPR Comment on DHI Response

DHI considers that the sediment plume generation caused by shipping operations (for the port operating at capacity) is likely to be a "minor if not insignificant issue", because:

- *only limited siltation of fines into the navigation channel is predicted;*
- *plumes resulting from each ship transit will be shortlasting and small in comparison with plumes induced by dredging.*

Section 6.3 of DHI (2010) provided an assessment of channel sedimentation under "normal" conditions and estimates in-channel sediment build up rates in the range of 1-20 cm/year. Only a portion of this material would be fines. Assuming 200 vessels visiting the PLF per year (i.e. 400 vessel transits) then on average each vessel transit would have available less than 0.05 cm sedimentation to generate turbidity plumes. Assuming an average vessel transit time of 1.5 hours, the 400 transits occupy about 7% of the year. This is likely to cause only a minor effect compared to the capital dredging works.

It is assumed that managed artificial bypass of sediments accumulating near the MOF breakwater would be conducted periodically, limiting sedimentation rates to the MOF channel. It is also assumed that, after passage of a cyclone with potential to cause major sediment mobilization and deposition, the channel would be surveyed and its design depth would be restored through maintenance dredging, if necessary, prior to resumption of normal shipping operations.

3 SUPPLEMENTARY ISSUE

3.1 Procedure for Merging Plume Scenario Simulation Results

The report refers to the merging of the outputs derived from different dredge plume scenario simulations. However the exact numerical procedure used to effect this merging has not been detailed in the report.

The outputs for each dredge plume scenario simulation are given as spatial distributions of pre-selected statistics of the suspended sediment concentrations and as net sedimentation rates for each 14 day scenario period. The pre-selected statistical measures are those required by the ecological tolerance limits.

It is assumed that the merging of simulated dredge plume statistical outputs from the various short term scenarios is performed on a cell-by-cell basis across the model grid. For example, for each model cell, the maximum "percent exceedance of 25 mg/L SSC" from the various scenarios under consideration can be determined and then compared with the ecological tolerance limits to determine the level of ecological impact intensity for that model cell. In this way it is possible to build up the spatial distribution (or zones) of different levels of ecological impact intensity.

MER Recommendation: DHI should explain the numerical procedure for merging plume scenario simulation results.

4. REFERENCES

DHI (2010). *Wheatstone Project. Dredge Spoil Modelling Report.* Prepared by DHI, 10 May 2010.

DHI (2010). *Wheatstone Project. Dredge Spoil Modelling - Response to Independent Peer Review Comments of 8th June 2010.* Prepared by DHI, 25 June 2010.

MER (2010). *Review of DHI Report "Wheatstone Project. Dredge Spoil Modeling Report".* Prepared for URS by Des Mills Marine Environmental Reviews, 8 June 2010.

Wheatstone Project
Dredge Spoil Modelling

A P P E N D I X   F F :

Documentation of Climatic Scenarios

Revision 1 – November 15, 2010.

CONTENTS

FIGURES AND TABLES

FF DOCUMENTATION OF CLIMATIC SCENARIOS

FF.1 Introduction

A description of the criteria for the climatic scenario selection for the dredge plume modelling and the selected periods was included in Section 5 of Appendix Q1 of the Wheatstone Draft EIS/ERMP.

Appendix FF to Appendix Q1 of the Draft EIS/ERMP contained backup information for the scenario. Unfortunately, some of the documentation was left out, and some outdated information was included.

The present Appendix should be seen as a replacement of Appendix FF to Appendix Q1 of the EIS. It updates the information in the Draft EIS/ERMP and contains additional documentation of the climatic scenarios, including the effects of inter-annual variability requested by the independent reviewer.

FF.2 Overview

The wind driven net currents have been shown to be a dominant factor in the transport and dispersion of plumes generated from the dredging activities. It is therefore of key importance to be able to reproduce and capture the seasonal variability in the net currents.

The climatic scenarios should encompass a range of conditions that can be expected to capture the conditions experienced during the dredging period.

FF.2.1 Climatic Characteristics

During the summer half of the year from October to March, interaction between a low pressure system induced by heating of the continental land mass and the Asian monsoon tends to draw air toward the Australian continent. This leads to predominantly westerly and south-westerly winds at the site. During the winter months (June to August), the southeast trade winds bring cool dry air from over the Australian continent, leading to predominantly north-easterly to south-easterly winds at the study area. Winds during the transitional months of April, May and September are normally variable and may show predominance of either the summer or winter regime at a weaker level.

The predominant westerly to south-westerly winds during summer tend to drive coastal net currents running towards north-east, while the predominant winter winds lead to south-westerly net currents. It should be noted that there is also variability in the winds and resulting net currents during summer and winter, and it cannot be assumed that the net currents only flow towards north-east during summer and towards south-west during winter.

FF.2.2 Scenario Criteria

In terms of potential impact from the dredge plume and associated sedimentation, a single climatic condition cannot be singled out to be the “most conservative”. In simplified terms, strong and persistent net currents will have a higher potential for impacts at larger distances from the spill sources as the stronger net currents will carry the plumes further away from the sources at higher concentrations, and also lead to higher rates of sedimentation further away from the sources. In contrast, the potential for impacts closer to the sources may be higher for weaker (or no) net currents when the plumes tend to remain closer to the source and sedimentation rates closer to the sources are higher. The relationships are more complex than the simplified description above as there are other factors influencing the plume dispersion and potential impacts. Some important factors include:

- Tidal currents are relatively strong and dominate for weak net currents.
- Stronger net currents will tend to keep the sediment in suspension.
- Stronger wind conditions leading to the stronger net currents also generate larger waves, which will affect the sedimentation and resuspension.

There is thus a range of climatic drivers that determine the overall plume dispersion and potential impacts. For the plume modelling, it is essential to capture conditions representative of the seasons and encompassing a range of conditions that are likely to produce the worst conditions throughout the potential impact area. Six key climatic conditions have been targeted for the climatic scenarios:

1. Relatively strong and persistent net easterly (north-easterly) flow for a "strong" summer condition.
2. Weaker and more variable, predominantly net easterly flows for a "representative" summer condition.
3. Relatively strong and persistent net westerly (south-westerly) flow for a "strong" winter condition.
4. Weaker and more variable, predominantly net westerly flows for a "representative" winter condition.
5. Variable conditions with relatively strong winds (and resulting net currents and waves) during the "transitional" period.
6. Transitional period with weaker winds and weaker resulting net currents and waves.

As described in Section 5 of Appendix Q1 to the Draft EIS/ERMP, it has for the present case been chosen to base the climatic scenarios on selected periods of measured climatic conditions to drive the models rather than "made up" climatic scenarios. This is to ensure that realistic variability in the climatic drivers is captured. Through statistical assessment of the winds and modelling of net currents, year 2007 was found to contain periods of persistent and relatively strong summer and winter conditions, and the climatic scenarios were selected from 2007, see Table FF.1.

The hydrodynamic and sediment transport models have been set up to model two continuous months for each of summer, transitional and winter conditions. Statistical analysis for input to the impact assessment is carried out for the second 14-day period of each of the months. This in effect means, for each climatic scenario, a "warm-up" period of two weeks for the first period and one and a half months for the second analysis period.

The winds and net currents for the selected periods are documented in the following Sections.

Table FF.1 Selected climatic scenarios 2007

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

FF.3 Winds

The summer months from October to March are characterised by predominantly westerly and south-westerly winds at the site, while the winter months (June to August) have predominantly easterly to south-easterly winds at the study area. Monthly Statistics of wind speeds at Onslow are illustrated in Table FF.2 and Figure FF.1, showing the strongest summer winds during January and the strongest summer winds during July.

Table FF.2 Monthly Wind Speed Exceedence at Onslow (sourced from Wheatstone LNG Terminal Metocean Criteria report)

	10-minute, 10m Wind Speed (m/s)			
Month	50%	10%	5%	1%
Jan	7.3	10.4	11.2	12.8
Feb	5.7	8.7	9.5	11.2
Mar	5.2	8.4	9.8	13.9
Apr	4.7	6.8	7.5	11.2
May	3.9	5.9	6.8	8.7
Jun	3.8	5.9	6.6	7.9
Jul	4	6.3	7.3	9.2
Aug	3.8	6.1	6.8	8.3
Sep	5.2	7.5	8.2	9.3
Oct	5.6	8.2	8.9	10.2
Nov	6.2	9	9.8	11
Dec	6	9	9.8	10.9

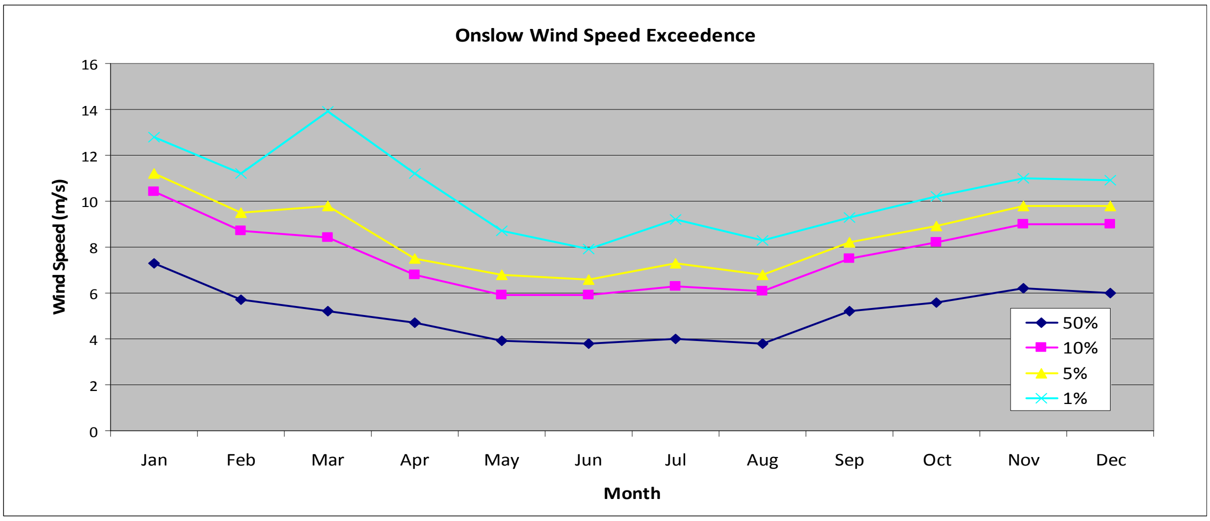


Figure FF.1 Monthly wind speed exceedence at Onslow

Monthly "net" winds, i.e. the resultant speed and direction from vector added winds for each calendar month, are illustrated for Barrow Island and Onslow Airport from 2000 to 20008 in Figure FF.2. Onslow Airport was used rather than Onslow Met Station (applied in the modelling) due to the limited time span of data available from Onslow Met Station. A comparison of the winds from Onslow Met Station and Onslow Airport has shown that they are very similar.

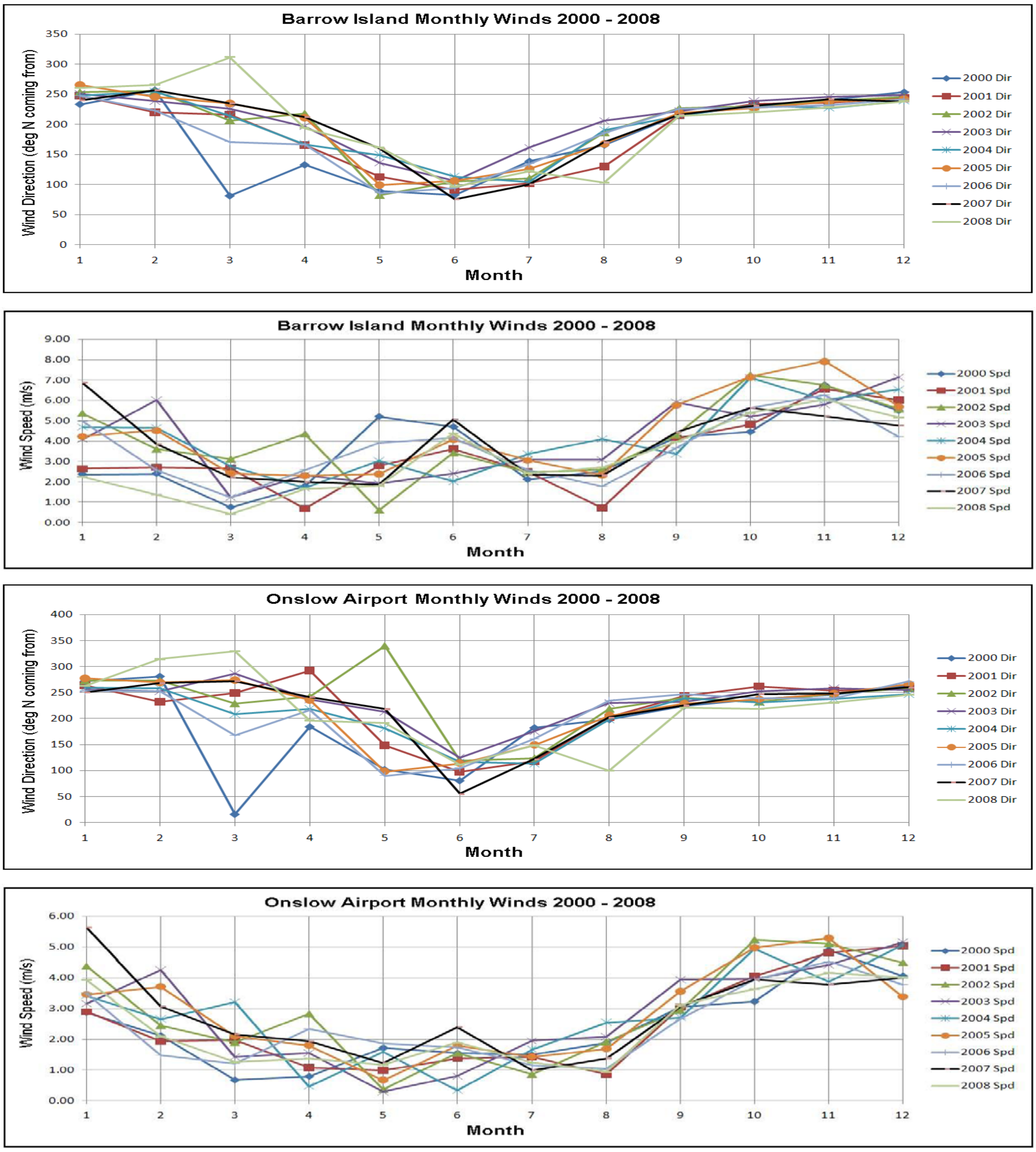


Figure FF.2 Net monthly winds (speed and direction) for the period 2000 – 2008 for Barrow Island and Onslow Airport.

Some important observations include:

- Net south-westerly winds dominate from September until about March
- Easterly winds dominate in June and July and to a less degree in May.
- There is higher directional variability in the net flows during winter and transitional months than during summer.
- 2007 falls within the general band of net flows, but with the highest net speeds in January and June within the 9 year record.

- The January 2007 net flow has same direction and is slightly stronger than the general levels from October through January for the 9 year. This is considered suitable for "strong" summer conditions.
- June 2007 flows likewise are at the top of the range for the 9 year band, which is considered appropriate for "strong" winter conditions.
- February and July net flows fall within the average values for "weaker" net flow conditions and have been selected as representative for the weaker net flow conditions for Summer and Winter, respectively.
- April and May 2007 fall within the band of values for the transitional period over the 9 years analysed.

The "structure" of the wind fields from the selected periods have been compared through wind roses. Monthly wind roses for 2007 have been compared to the period from 2000 – 2008 for stations with long term records available see Figure FF.3 to Figure FF.8 for representative Summer, Transitional and Winter month comparisons.

The wind roses are effective in comparing the overall wind patterns, although it is noted that the long-term wind roses tend to "smooth out" the inter-annual variability.

The following is noted from the wind roses:

- A similar structure, but with a tendency to stronger winds off-shore is seen for summer conditions with winds blowing onshore.
- The January 2007 winds are stronger and more persistent than average over the 9 year period.
- In particular the (easterly) winds blowing off-shore are significantly lower at the nearshore than the offshore stations for July.

A detailed assessment of different wind sources and the resulting net currents and plume dispersion led to both Onslow Met Station (OMS) and MesoLAPS winds being used for the dredge plume modelling and impact assessment. This was due to the following considerations:

- The MesoLAPS wind fields provide a spatial distribution which is desirable when there are significant spatial variations over the model domain.
- MesoLAPS have insufficient spatial resolution to resolve the land-sea breeze. This means that there is a significant risk that the MesoLAPS will produce non-conservative net currents, waves and sediment plumes for nearshore dredging during summer conditions.
- The OMS winds are measured close to the coastline, and underestimate the easterly winds during winter further off-shore, which leads to a significant risk of underestimating the plume dispersion towards west during winter.

By running both with the OMS and the MesoLAPS winds, it is considered that conservative drivers are obtained for both summer and winter conditions. Two full sets of simulations (for all combinations of dredge scenarios, climatic conditions and spill rates) have been run for each of the OMS and the MesoLAPS winds, and conservative envelopes of impact zones derived for the impact assessment based on the maximum extent of all scenarios (see Appendix N2 of the Draft EIS/ERMP for details).

Running both OMS and MesoLAPS winds may be viewed as running twice the number of climatic scenarios.

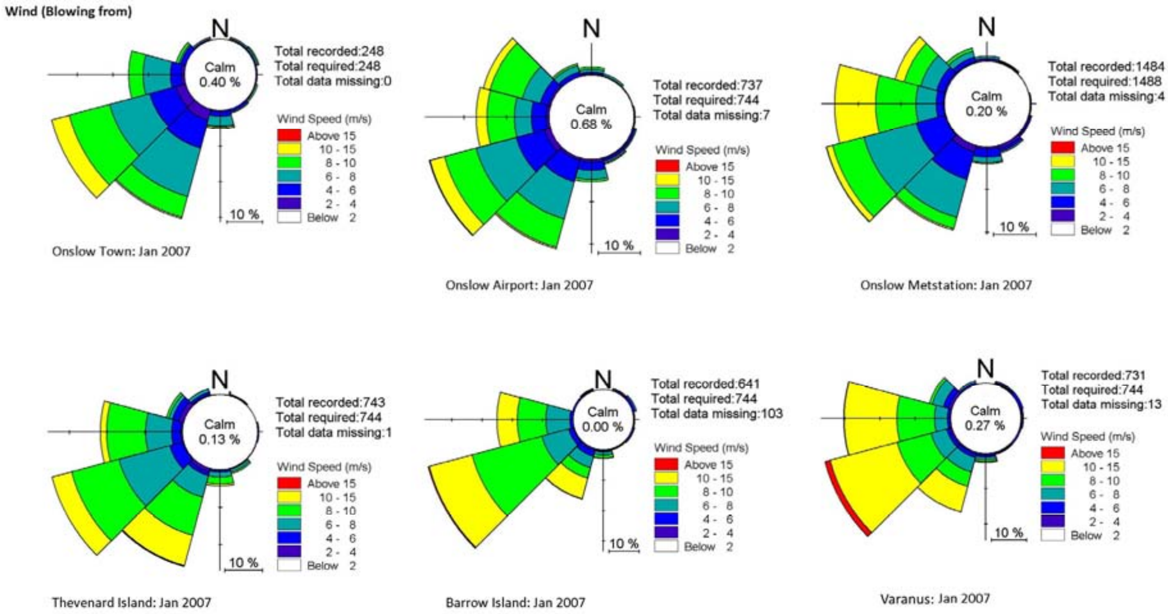


Figure FF.3 Wind roses for selected met stations based on January 2007 data.

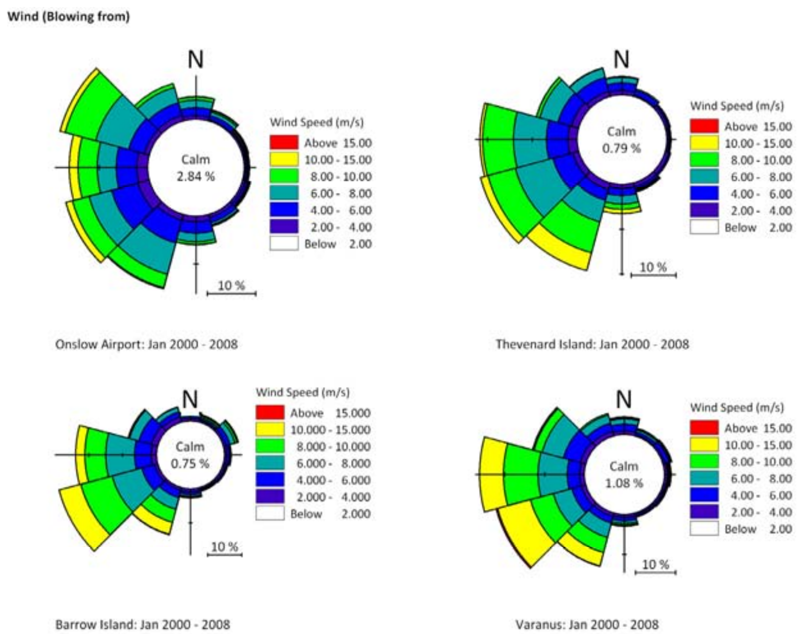


Figure FF.4 Wind roses for selected met stations based on January data from 2000 - 2008.

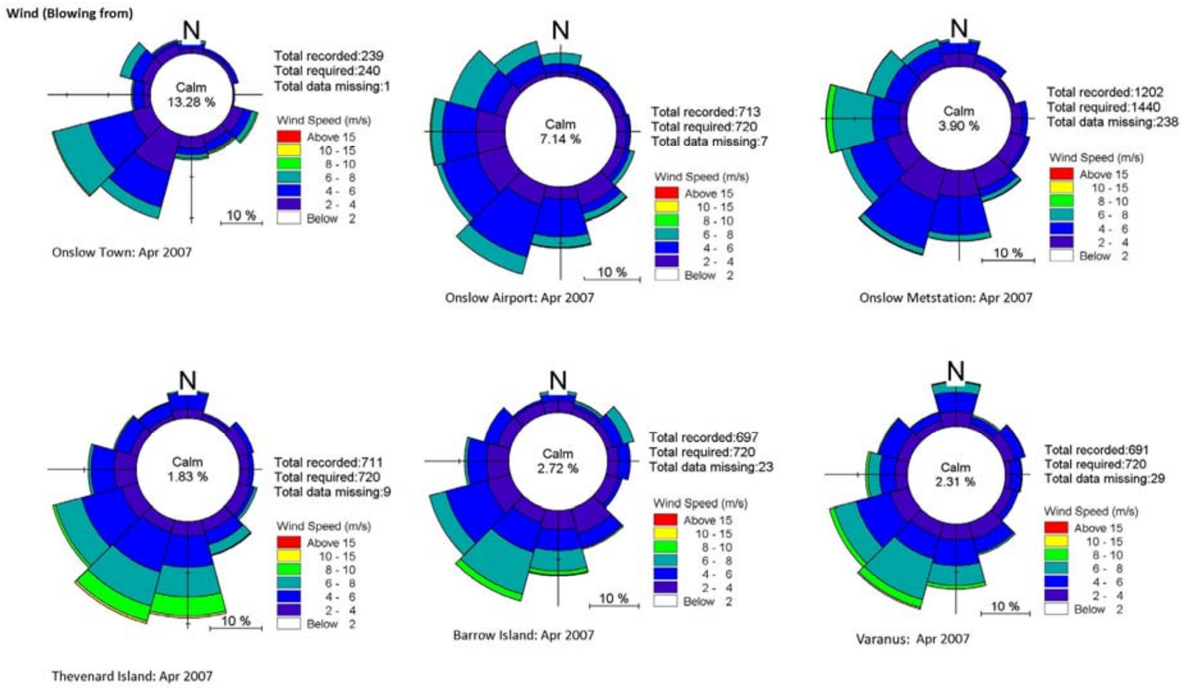


Figure FF.5 Wind roses for selected met stations based on April 2007 data.

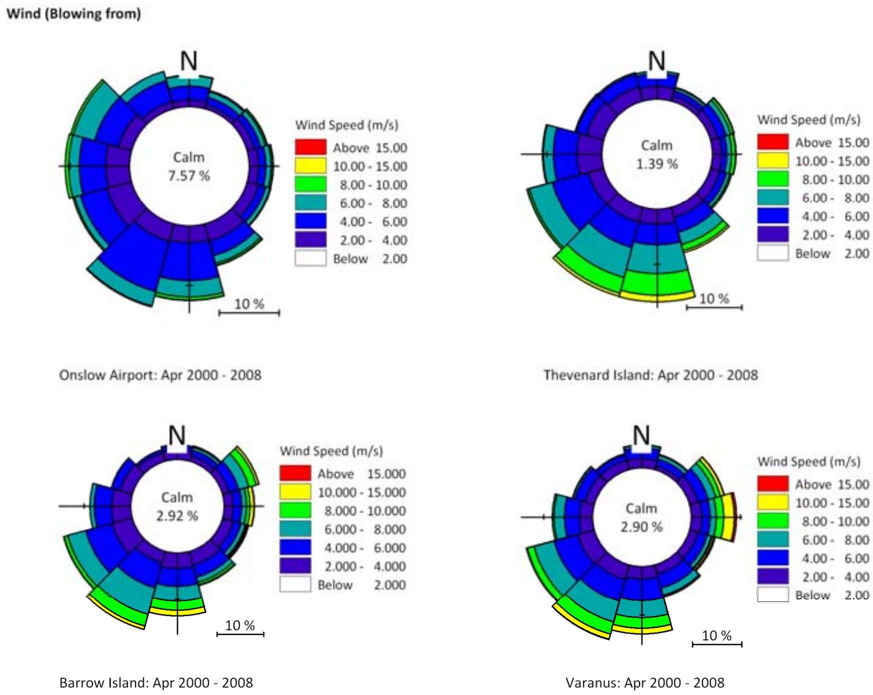


Figure FF.6 Wind roses for selected met stations based on April data from 2000 - 2008.

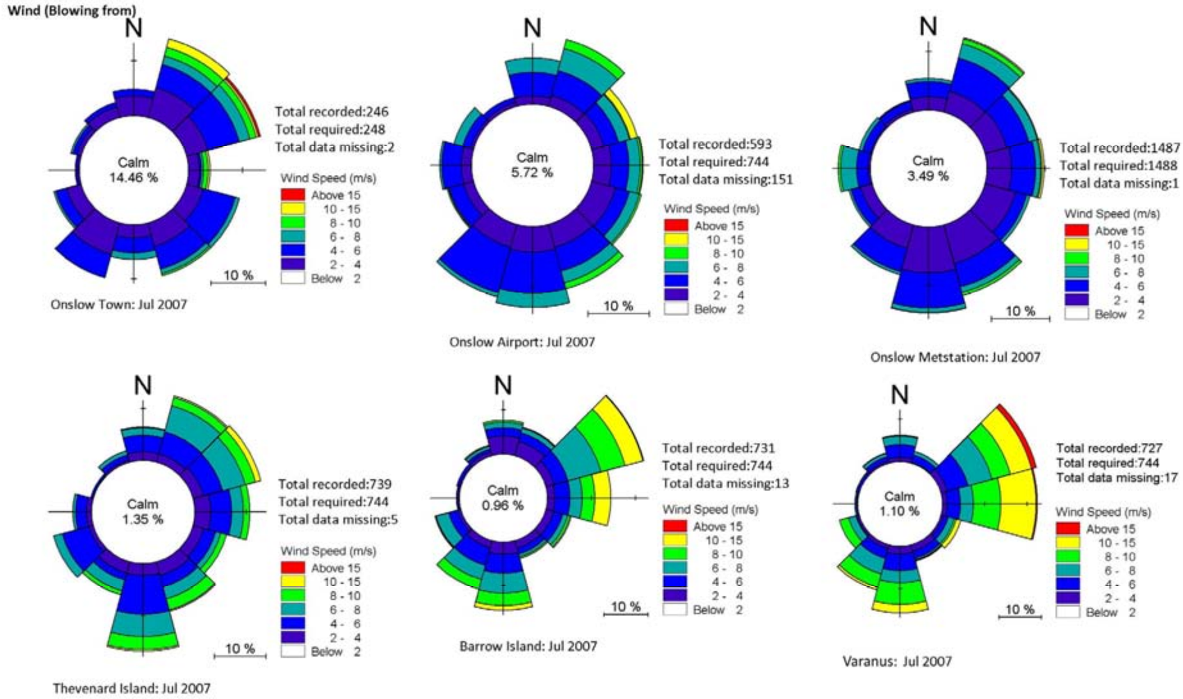


Figure FF.7 Wind roses for selected met stations based on July 2007 data.

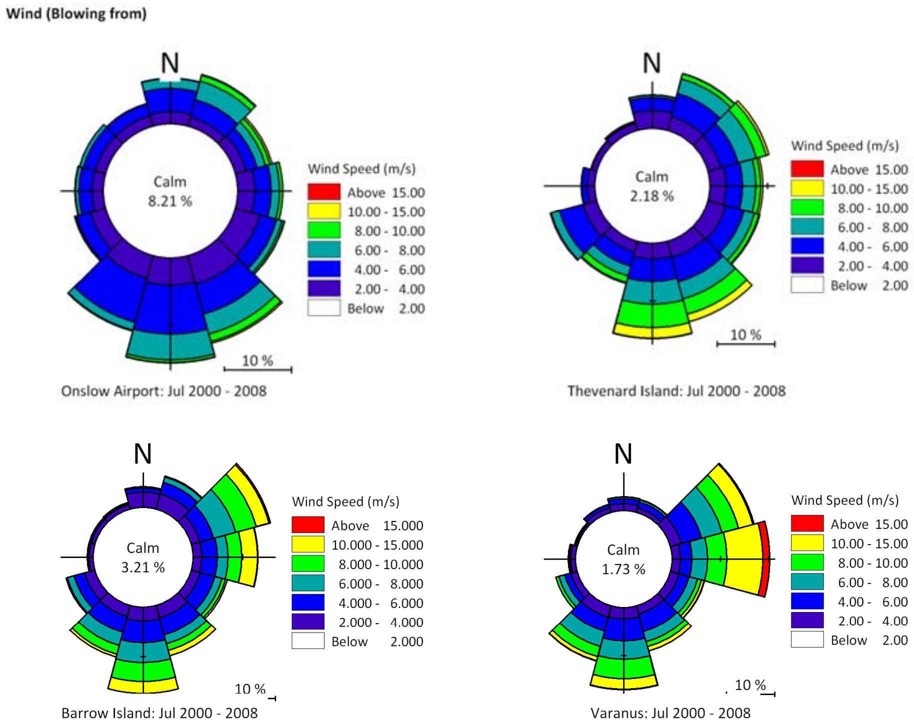


Figure FF.8 Wind roses for selected met stations based on July data from 2000 - 2008.

FF.4 Net Currents

Whereas the local winds have been demonstrated to be the main driver for the net currents, it is not a straight forward correlation between wind and current fields.

Both measured data and the calibrated model have been used to assess the wind driven net currents. The model validation to the net currents derived from the data was previously demonstrated in Appendixes D and JJ to Appendix Q1 of the Draft EIS/ERMP.

The present assessment has used the models to expand the data set to enable an assessment of inter-annual variability. This approach is considered valid given the good validation obtained for the wind driven net currents and the fact that the assessment is mainly comparative, i.e. the net currents generated by winds over an extended number of years is compared to the wind driven currents derived in the same way for the periods chosen for the climatic scenarios.

FF.4.1 2D Patterns of Net Currents

To illustrate the overall patterns of the wind driven net currents, 2D patterns of monthly net currents driven by MesoLAPS winds are shown over a 2-year period in Figure FF.9 to Figure FF.32, which show both regional currents and a more detailed plot covering the expected main potential impact area.

The following is noted from the simulated net drift patterns:

- The main flow pathway follows the shelf break from seaward of Exmouth up toward the Montebello Islands.
- The proposed channel is in a location with reducing net current speeds from west of the channel toward the east.
- Net current speeds pick up again, albeit in less organised flow patterns, over the shallow area between the Mangrove Islands and Barrow Island.
- In line with the winds, there is a clear predominance for a net north easterly flow which dominates from September till February
- Winter leads to shorter duration westerly net currents, dominant in May, June, July in 2006 and only June and July in 2007.
- As expected from the net wind records, January and June for 2007 have relatively high net currents in easterly and westerly direction, respectively.

It is noted that the illustrated net currents are depth-averaged currents. In the coastal, shallow waters, the currents are “embedded” in the tidal currents that normally dominate (except during combinations of neap tide and stronger net current fields). The currents generally attain a logarithmic profile over depth. In deeper water with lower tidal currents, the wind driven currents are concentrated at the surface, and the plots in Figure FF.9 to Figure FF.32 would generally not capture the full strengths of the net currents in the off-shore region (which is of no consequence to the dredge plume modelling).

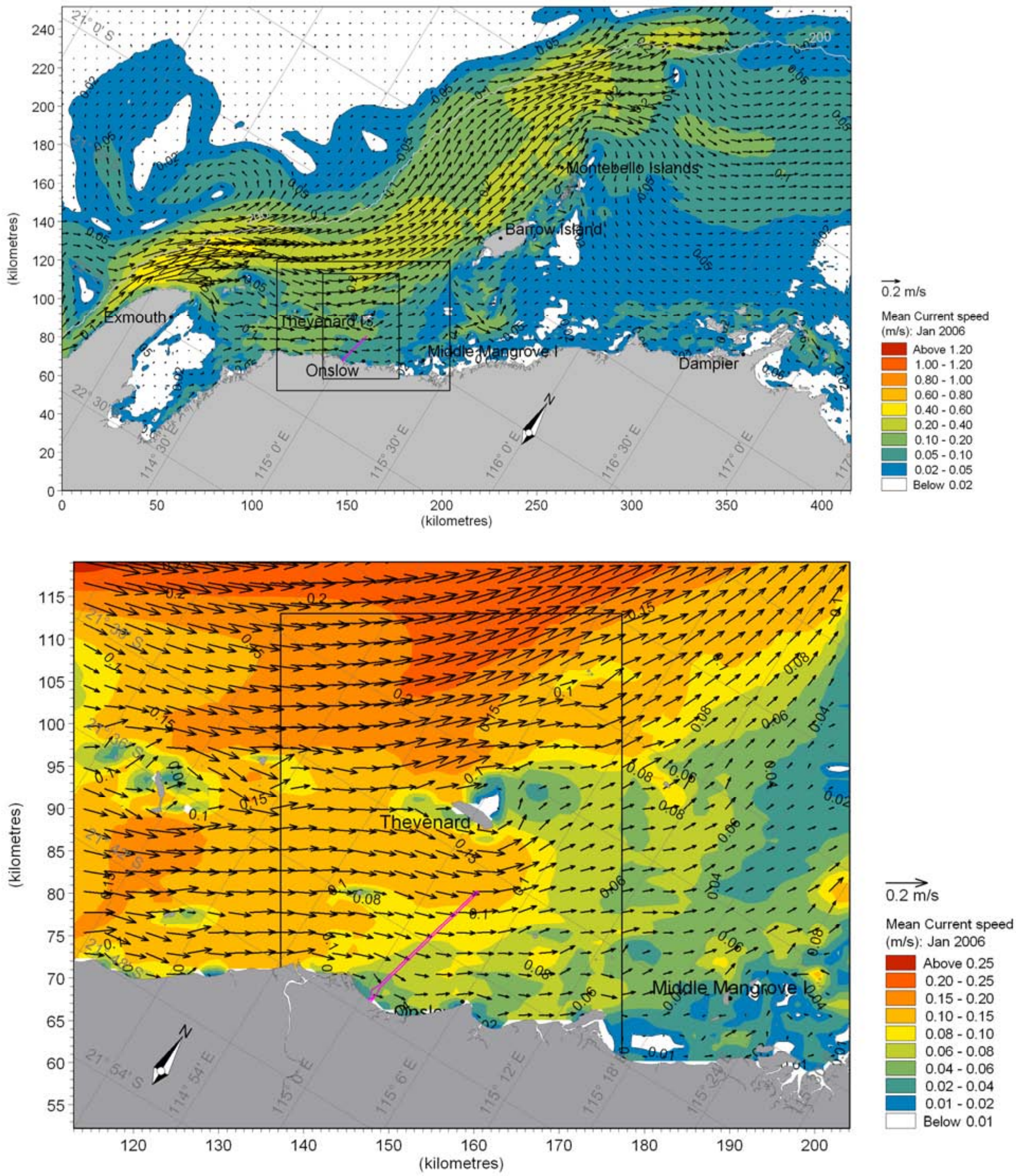
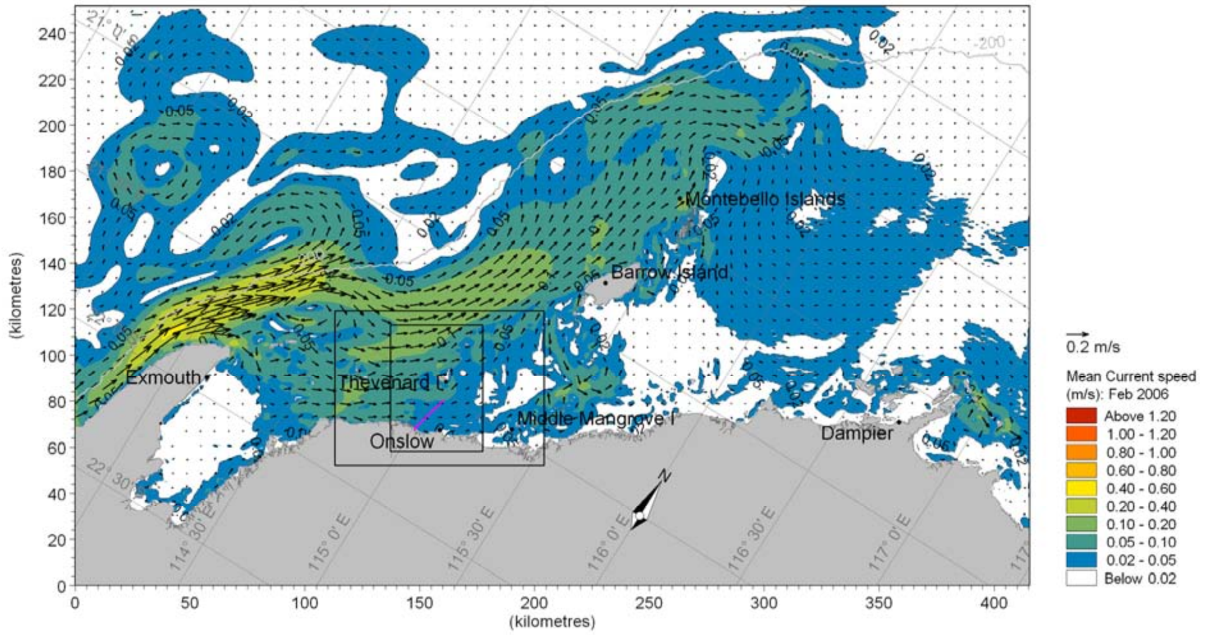


Figure FF.9 Simulated average net currents during January 2006 driven by winds from hourly MesoLAPS



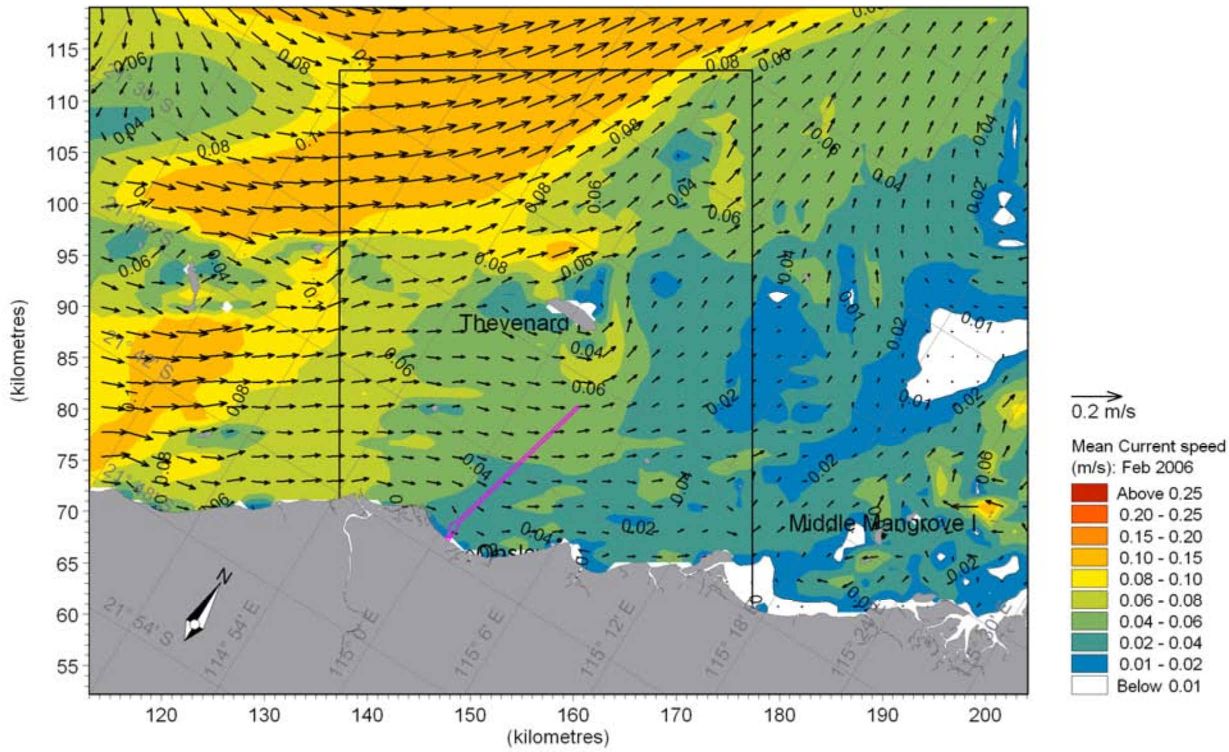


Figure FF.10 Simulated average net currents during February 2006 driven by winds from hourly MesoLAPS

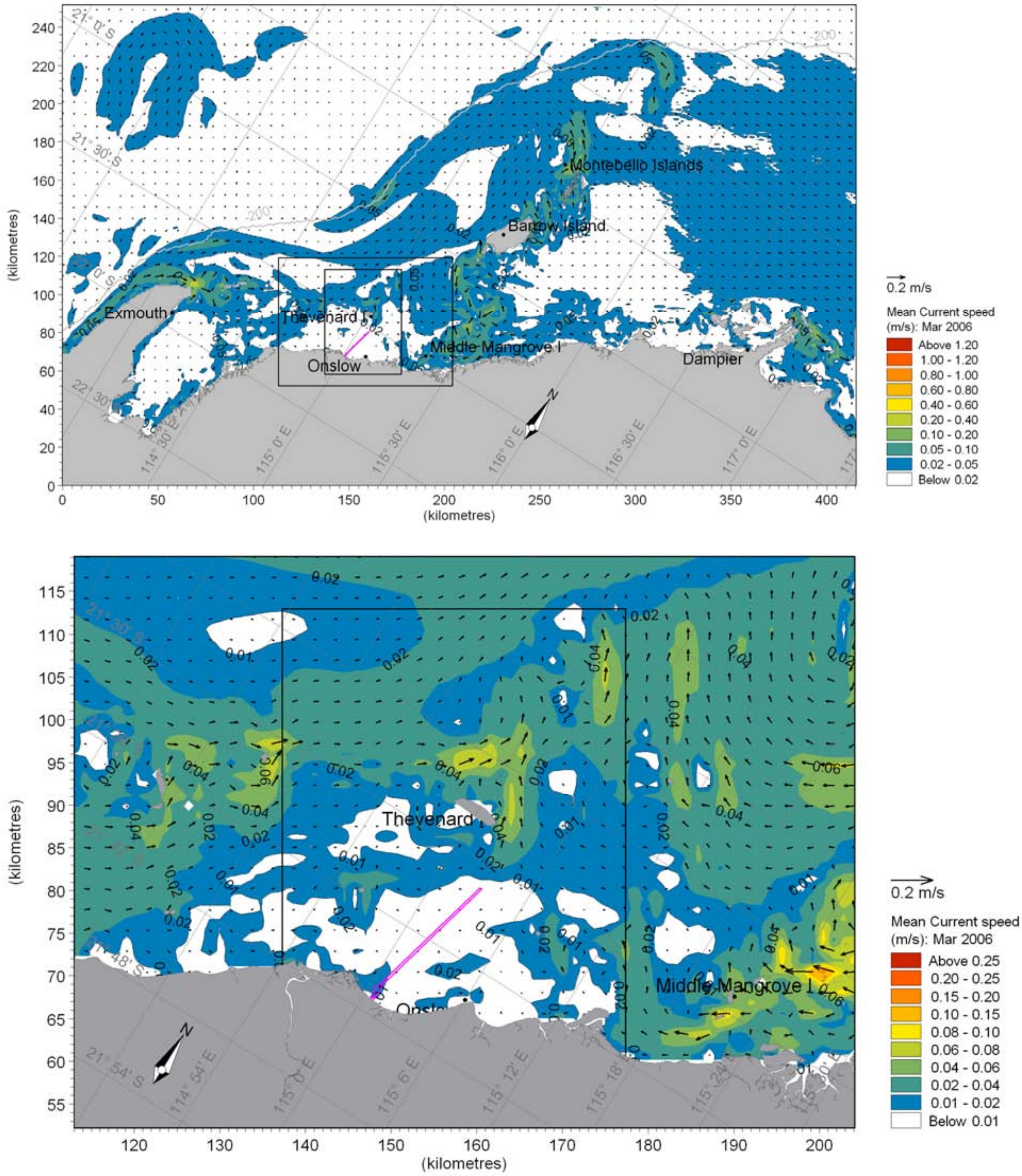


Figure FF.11 Simulated average net currents during March 2006 driven by winds from hourly MesoLAPS

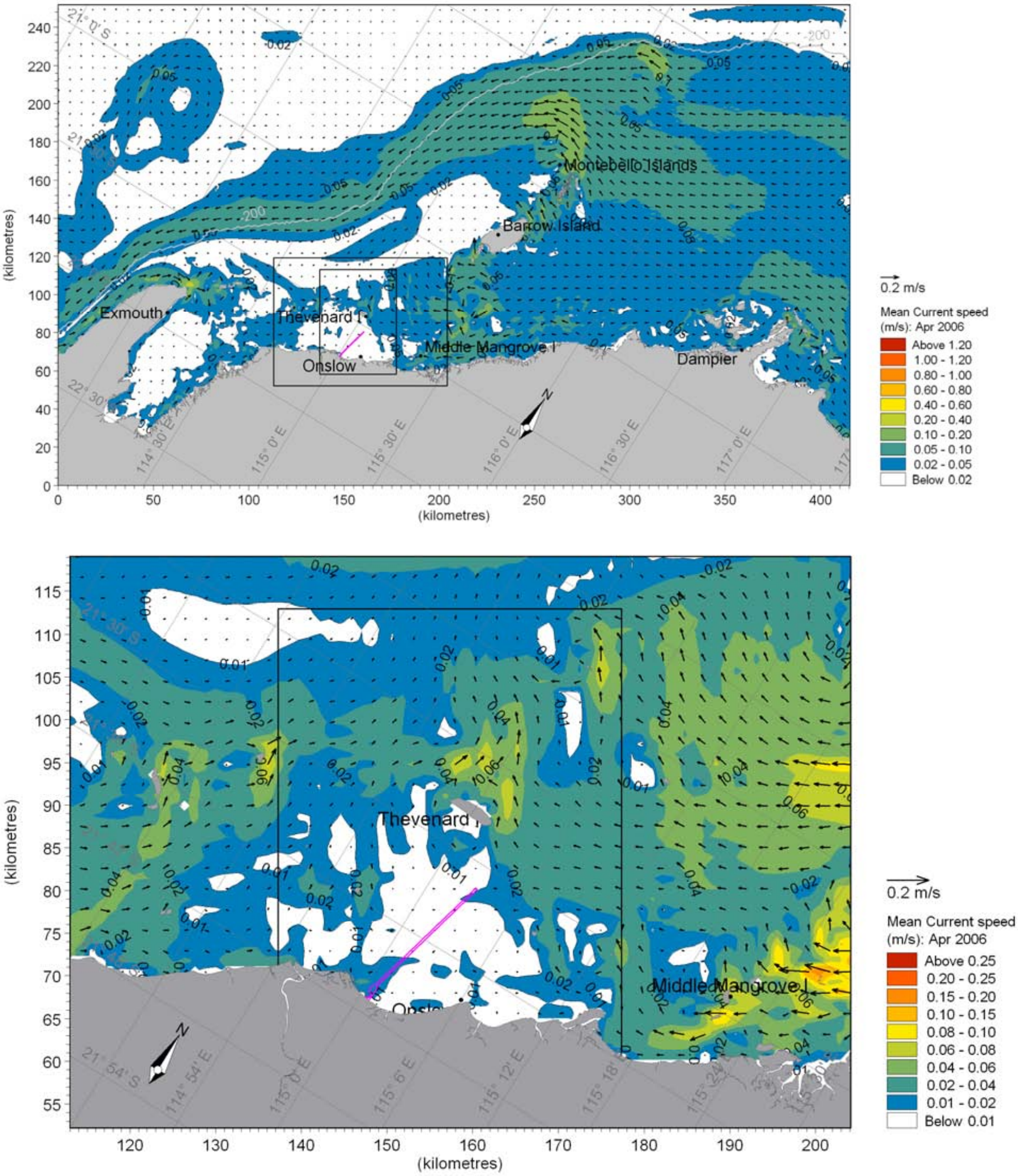


Figure FF.12 Simulated average net currents during April 2006 driven by winds from hourly MesoLAPS

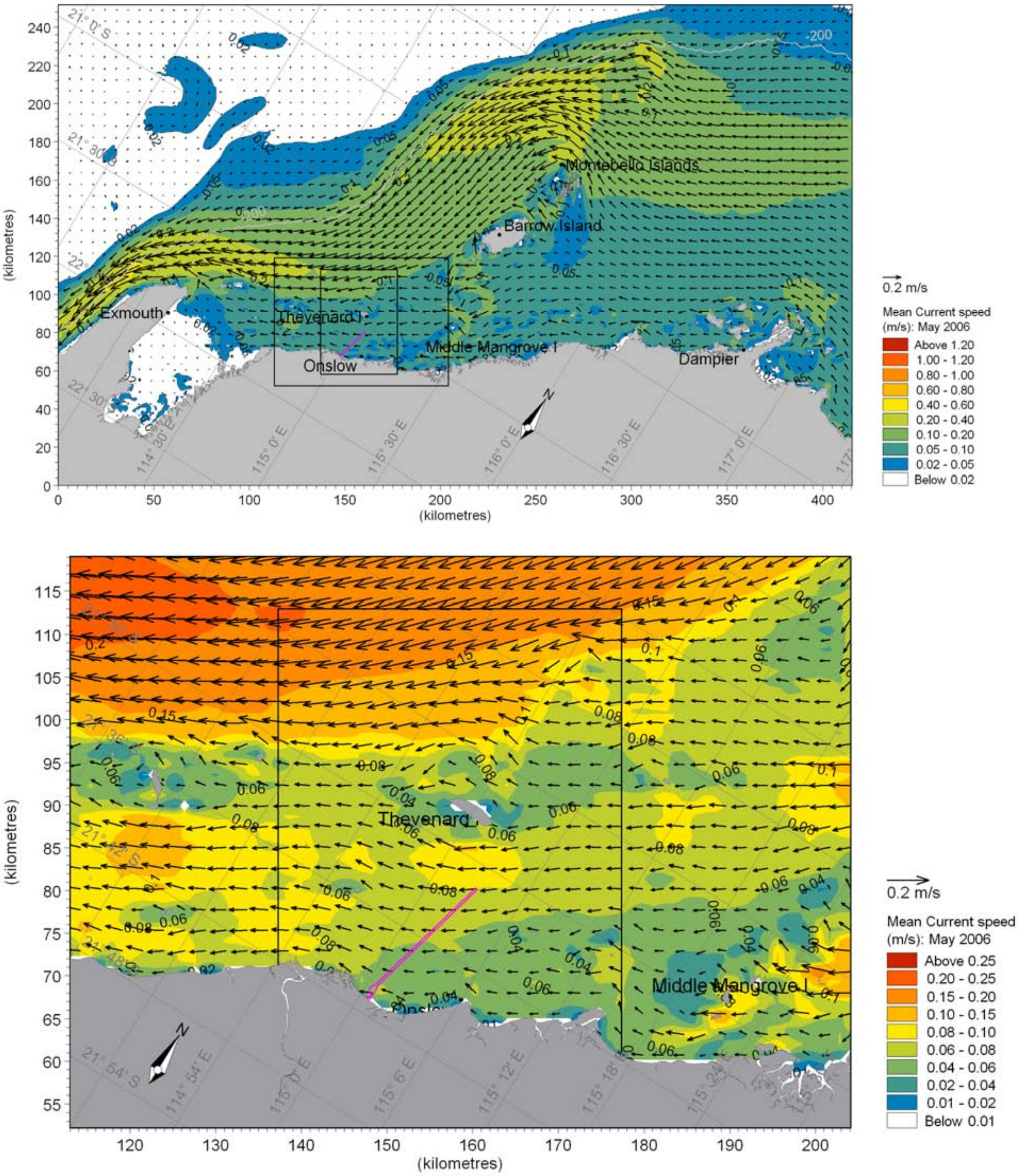


Figure FF.13 Simulated average net currents during May 2006 driven by winds from hourly MesoLAPS

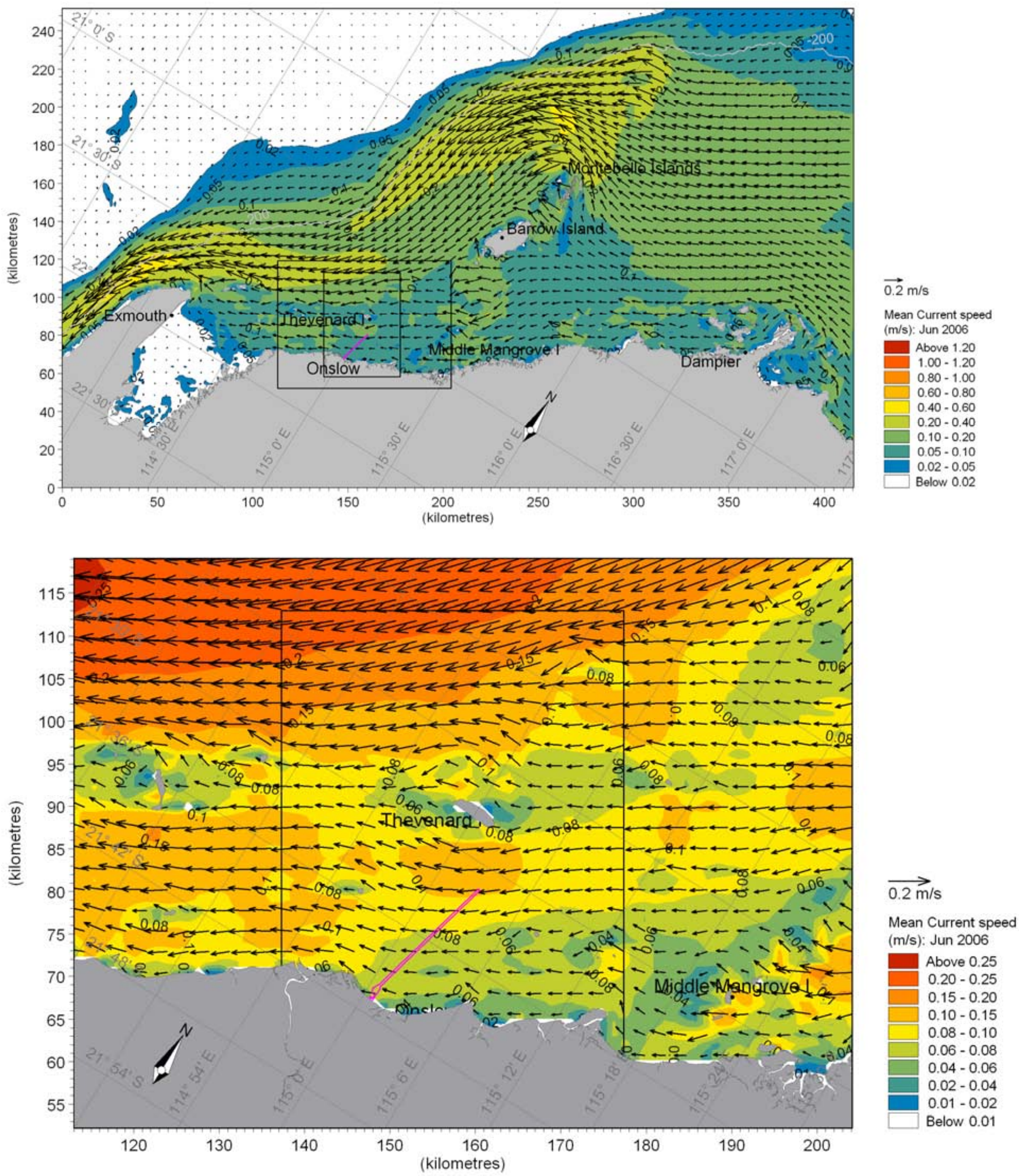


Figure FF.14 Simulated average net currents during June 2006 driven by winds from hourly MesoLAPS

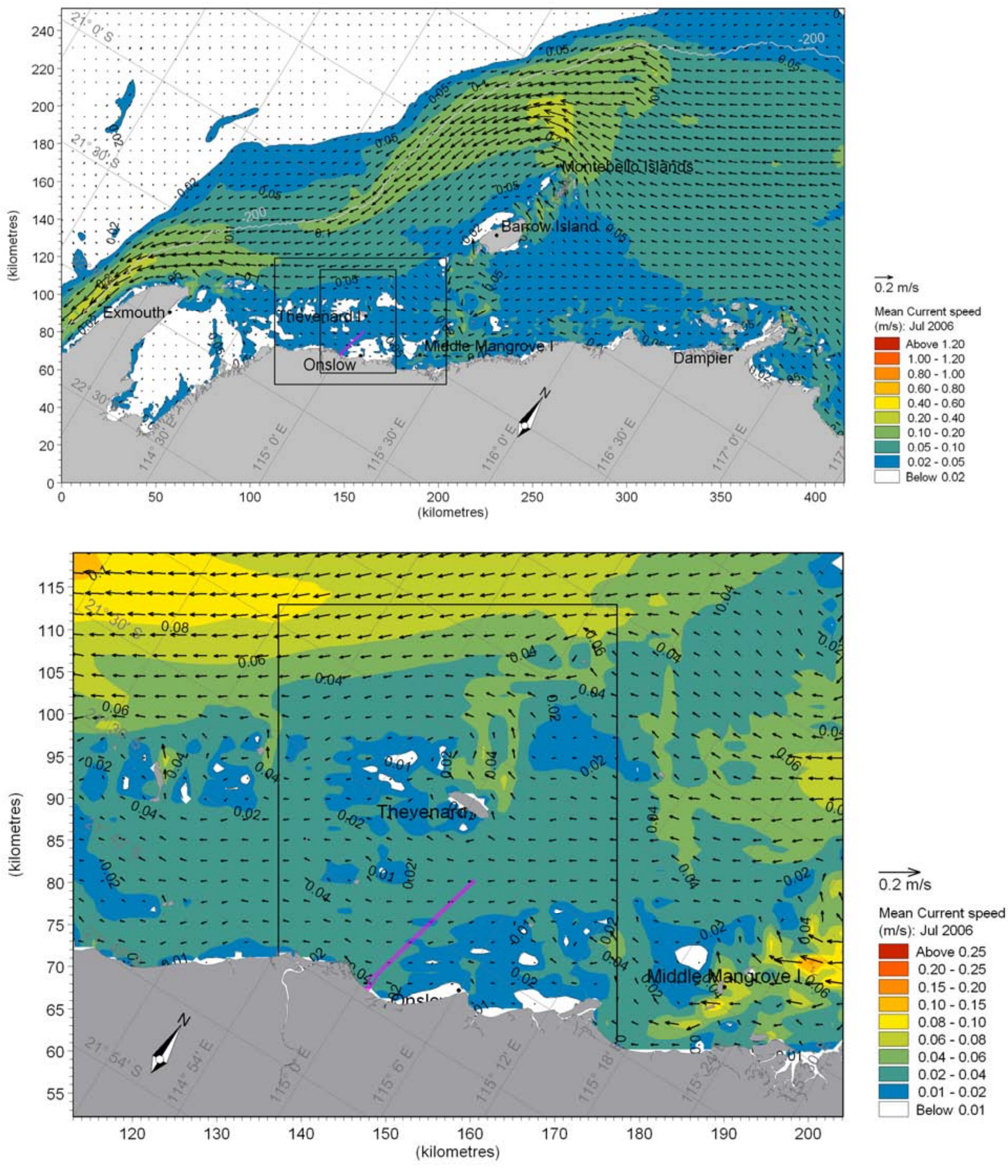


Figure FF.15 Simulated average net currents during July 2006 driven by winds from hourly MesoLAPS

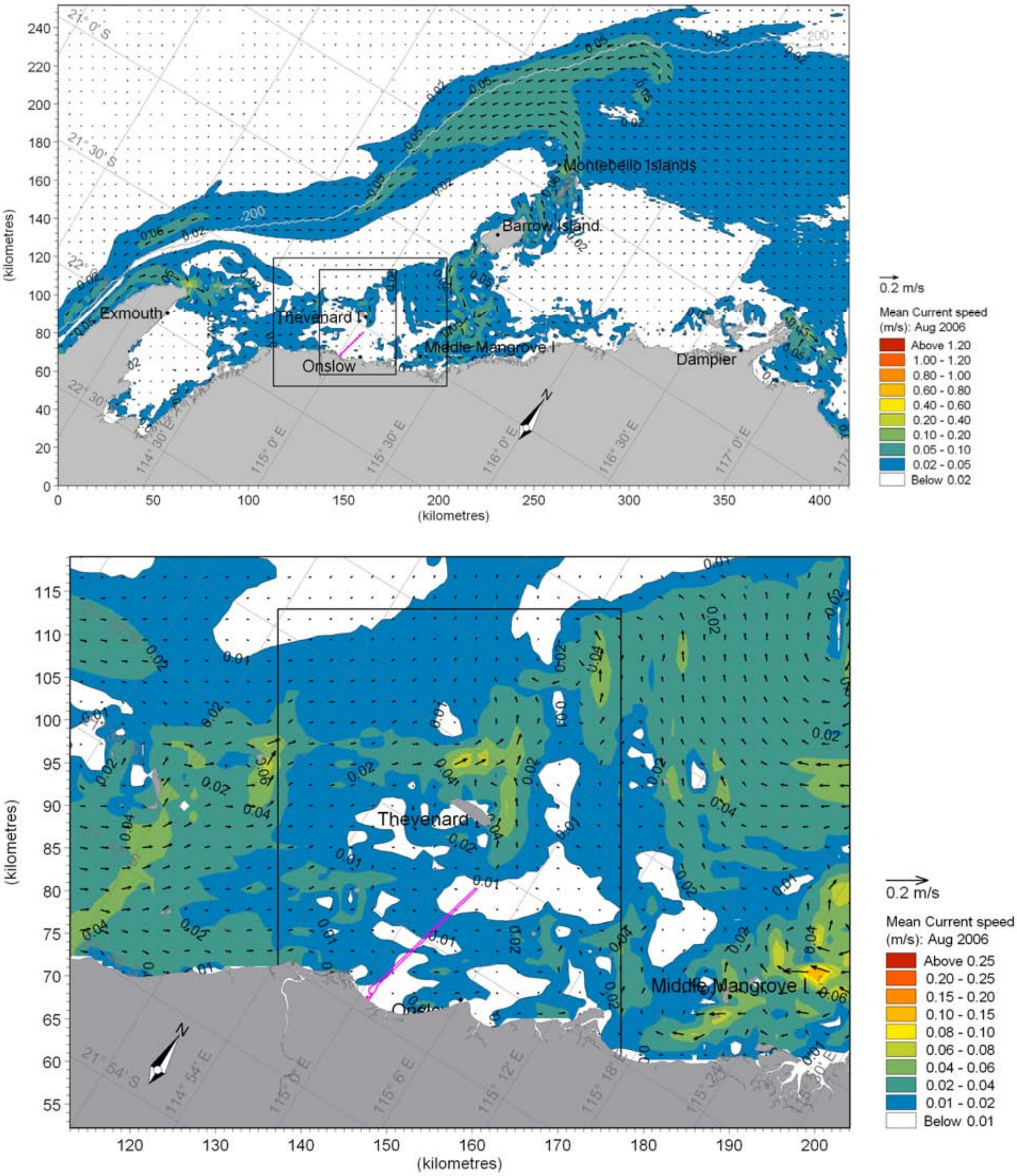


Figure FF.16 Simulated average net currents during August 2006 driven by winds from hourly MesoLAPS

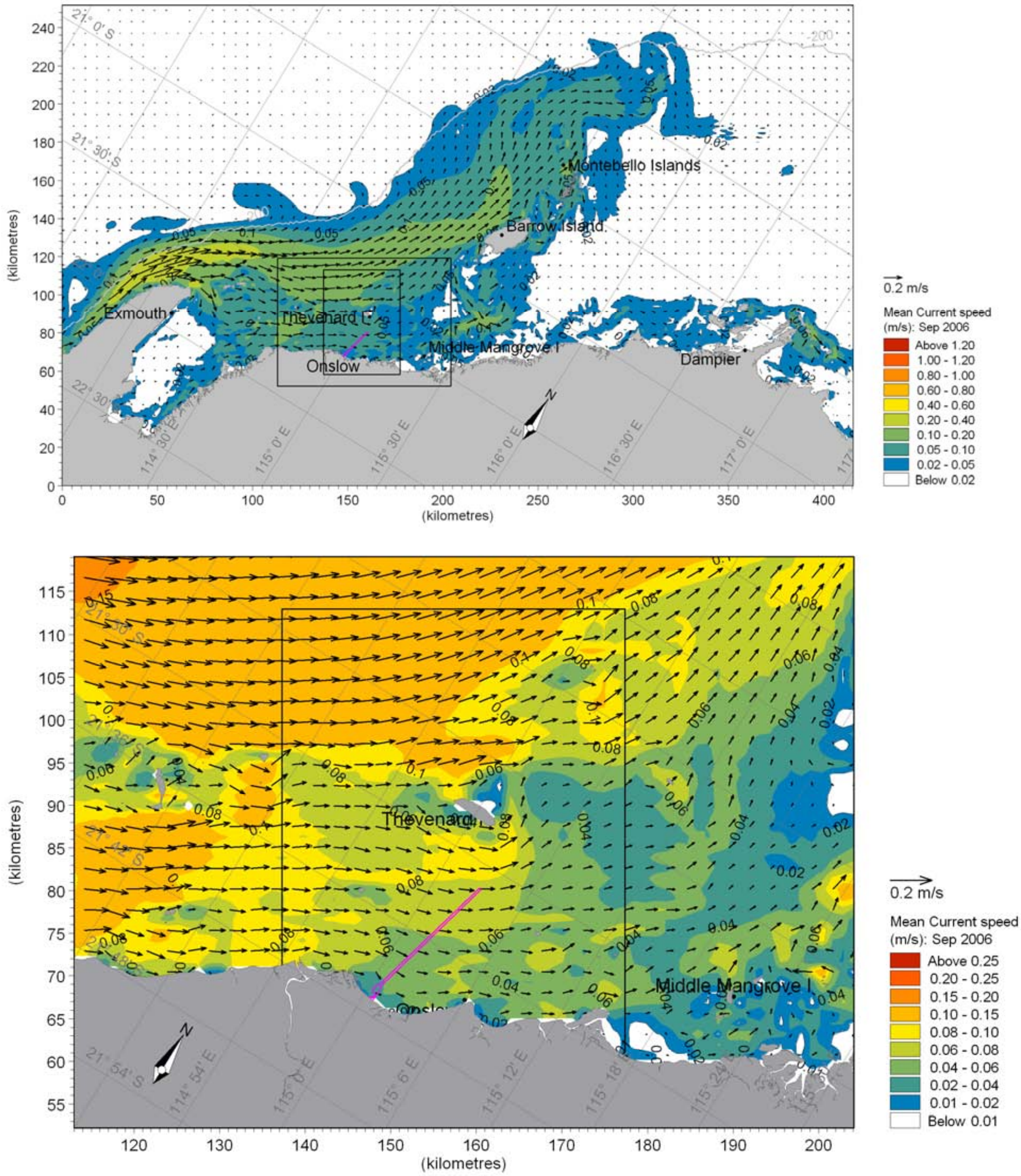


Figure FF.17 Simulated average net currents during September 2006 driven by winds from hourly MesoLAPS

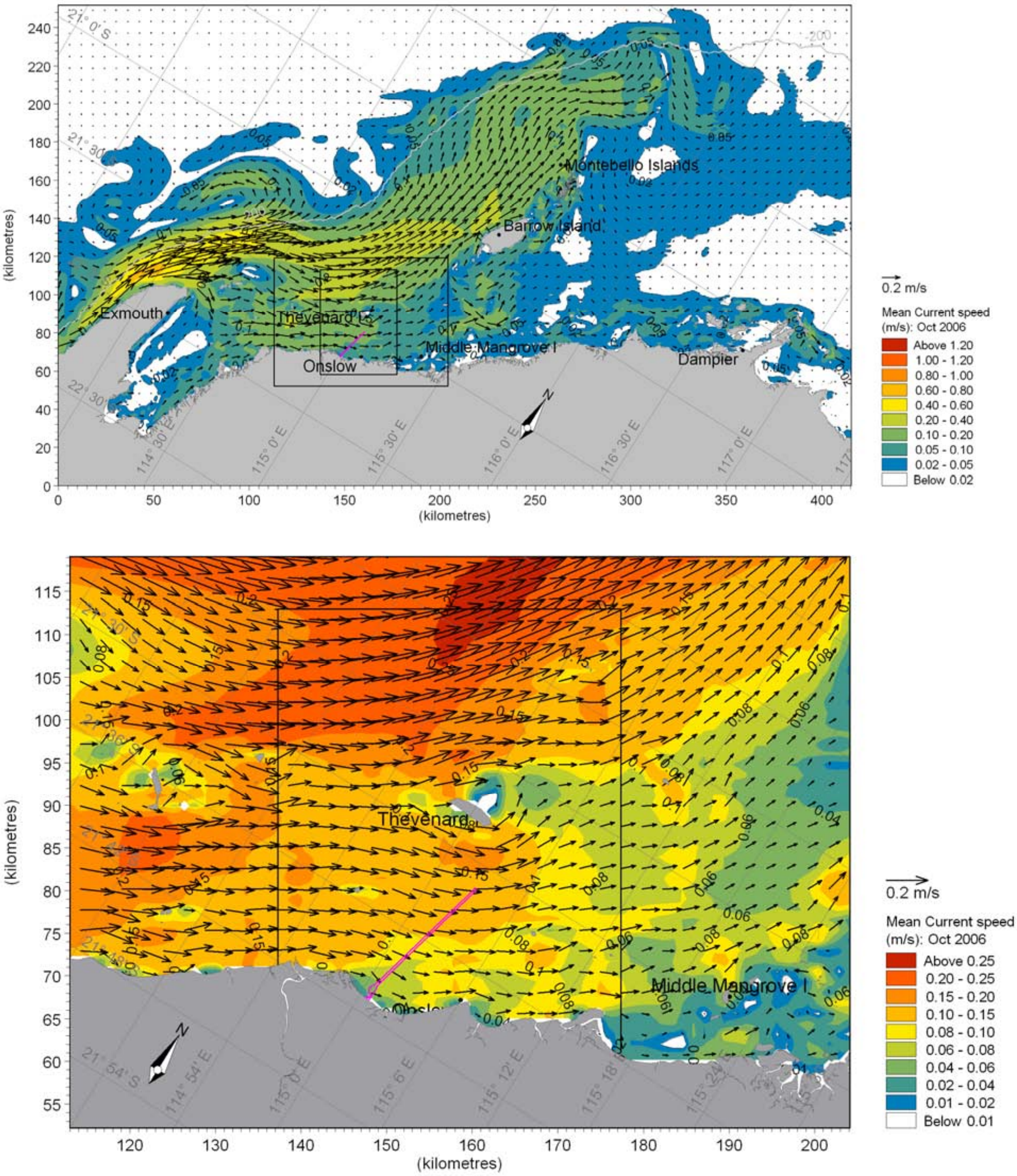


Figure FF.18 Simulated average net currents during October 2006 driven by winds from hourly MesoLAPS

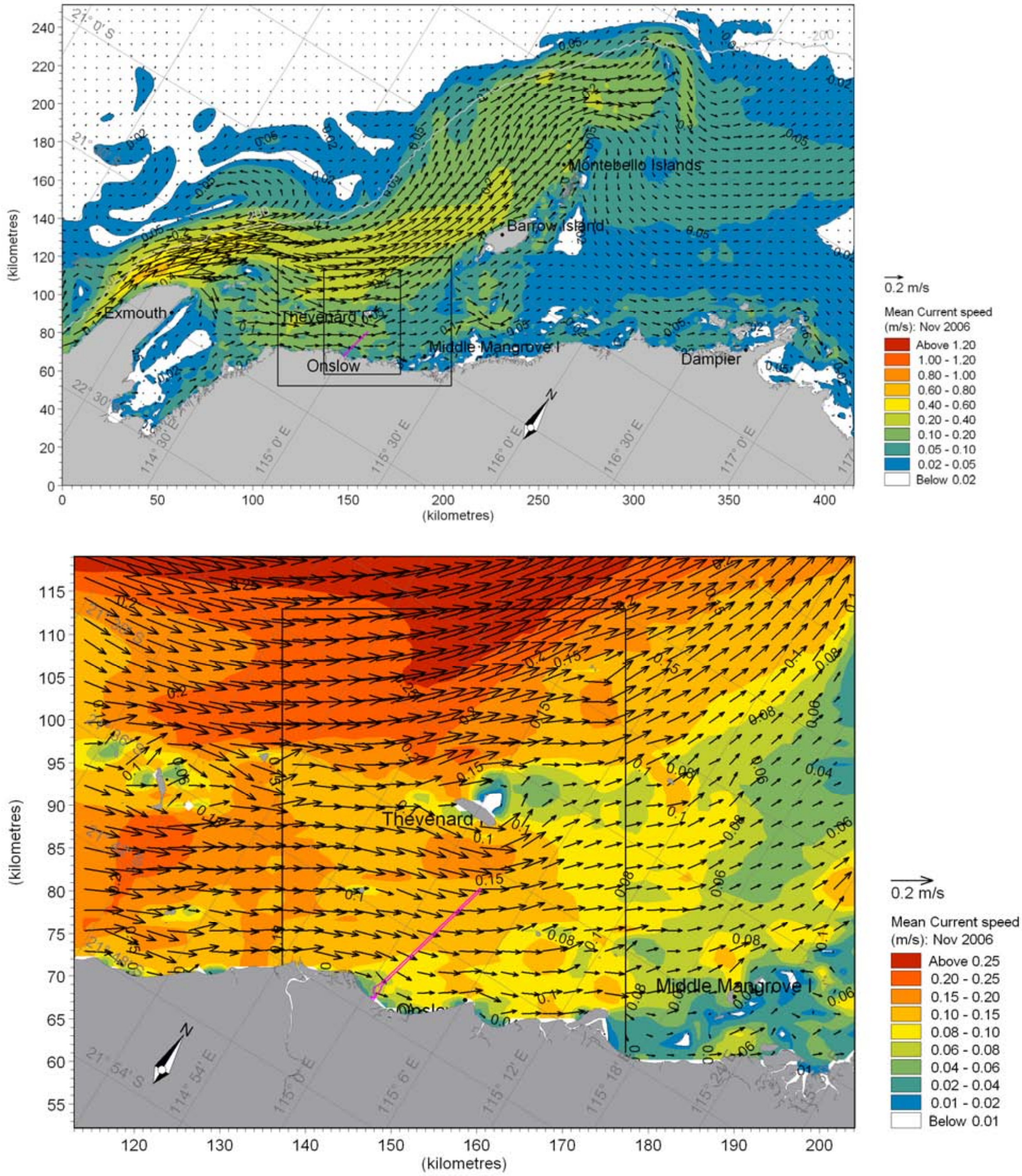


Figure FF.19 Simulated average net currents during November 2006 driven by winds from hourly MesoLAPS

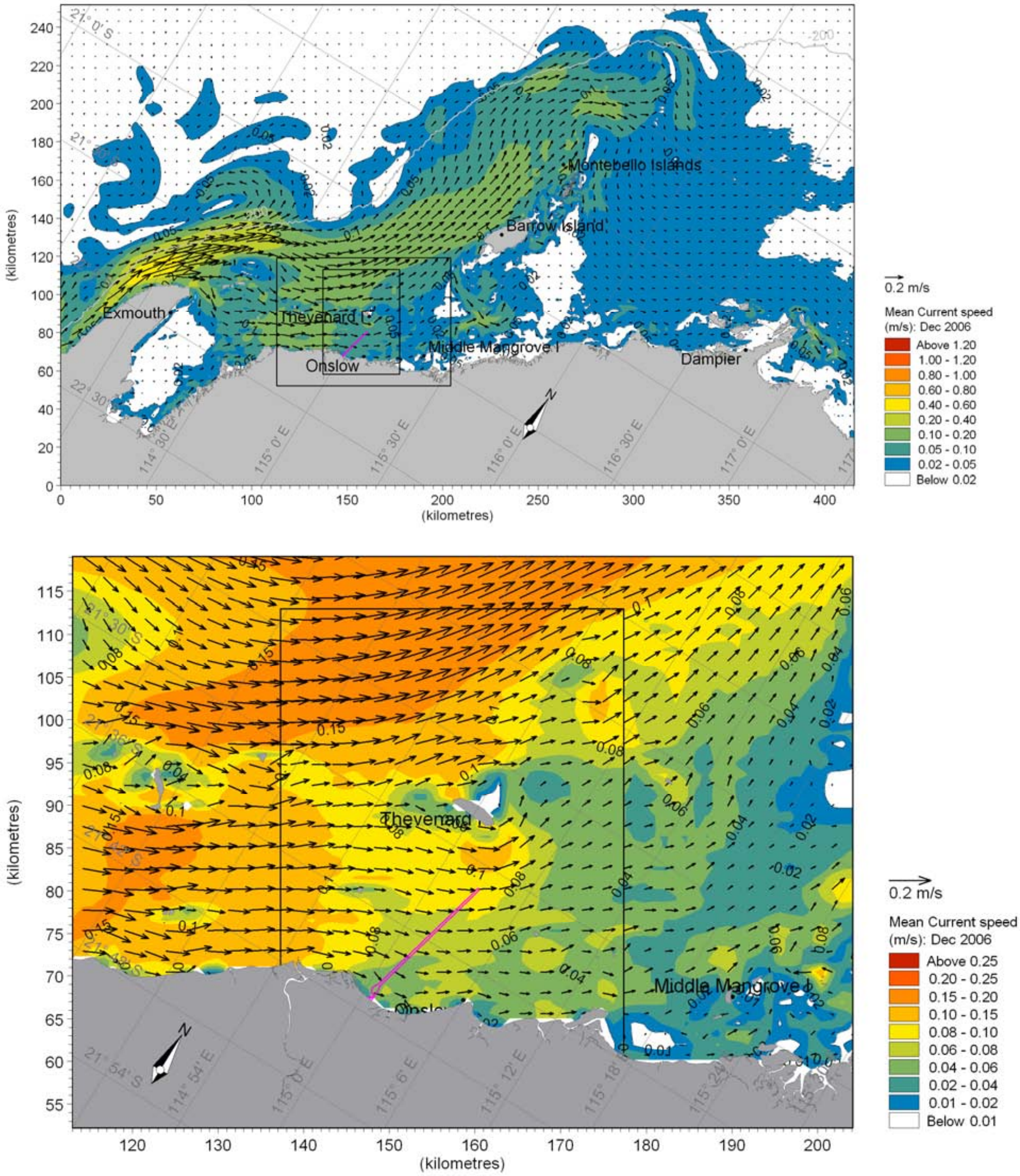


Figure FF.20 Simulated average net currents during December 2006 driven by winds from hourly MesoLAPS

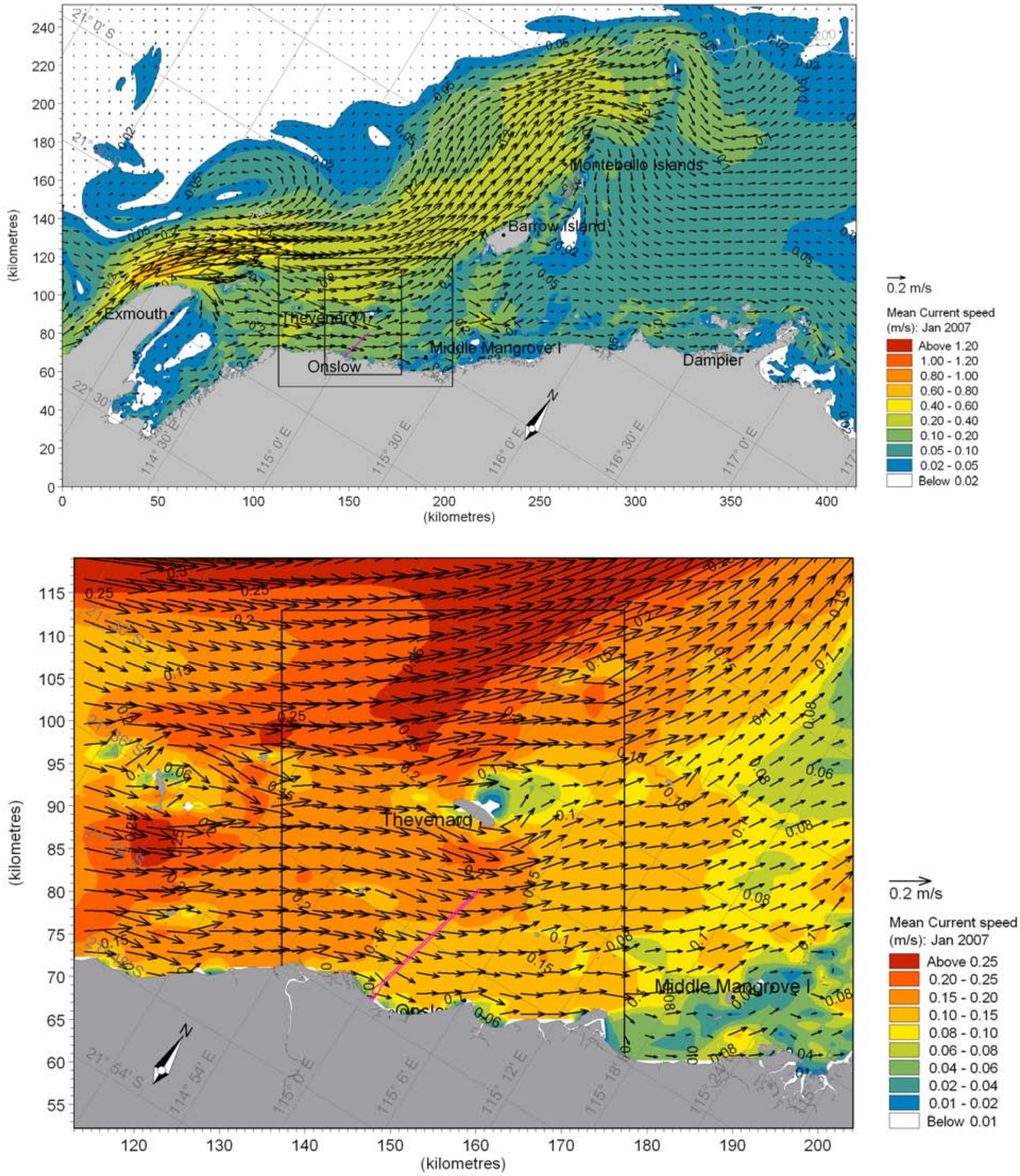


Figure FF.21 Simulated average net currents during January 2007 driven by winds from hourly MesoLAPS

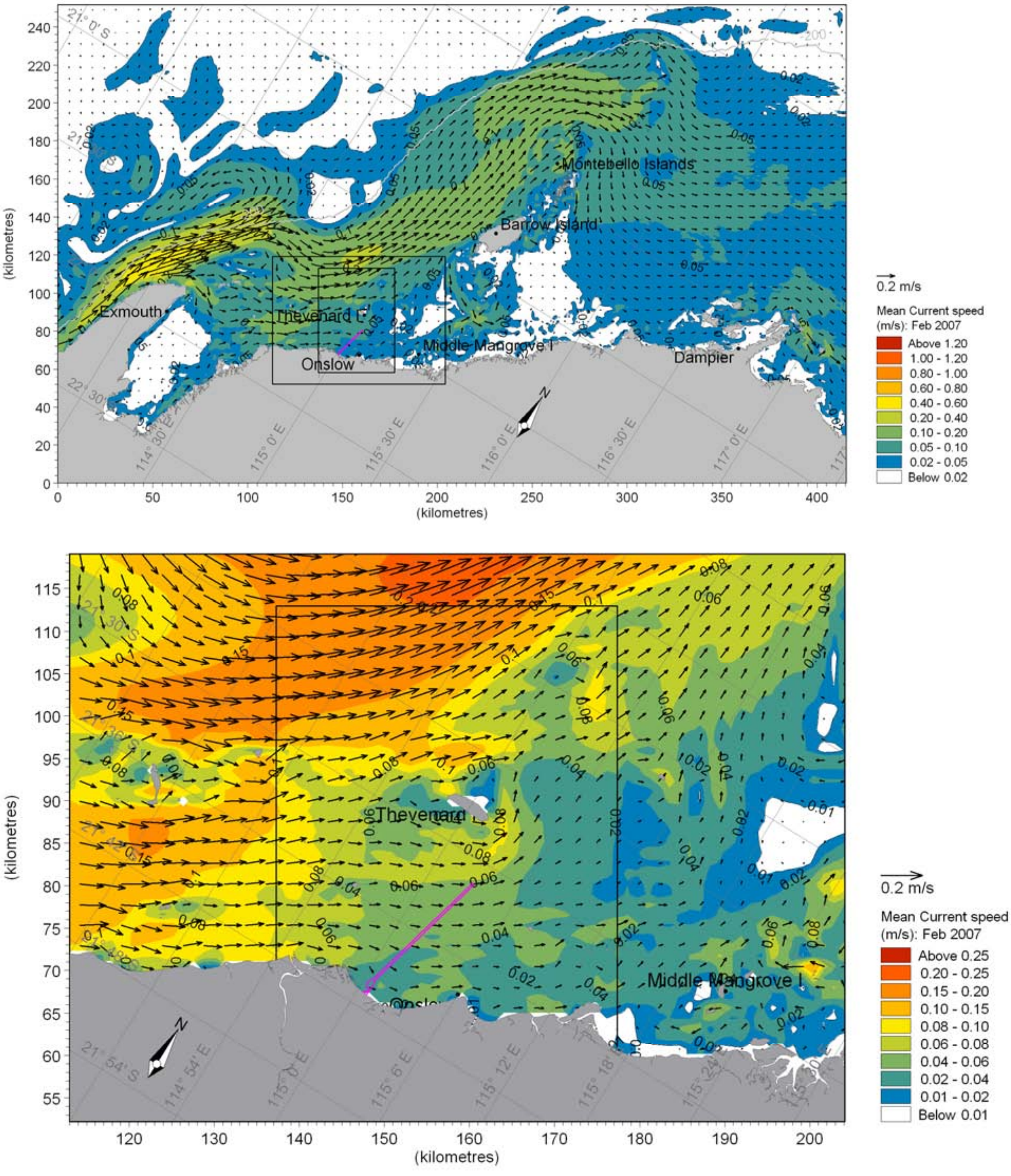


Figure FF.22 Simulated average net currents during February 2007 driven by winds from hourly MesoLAPS

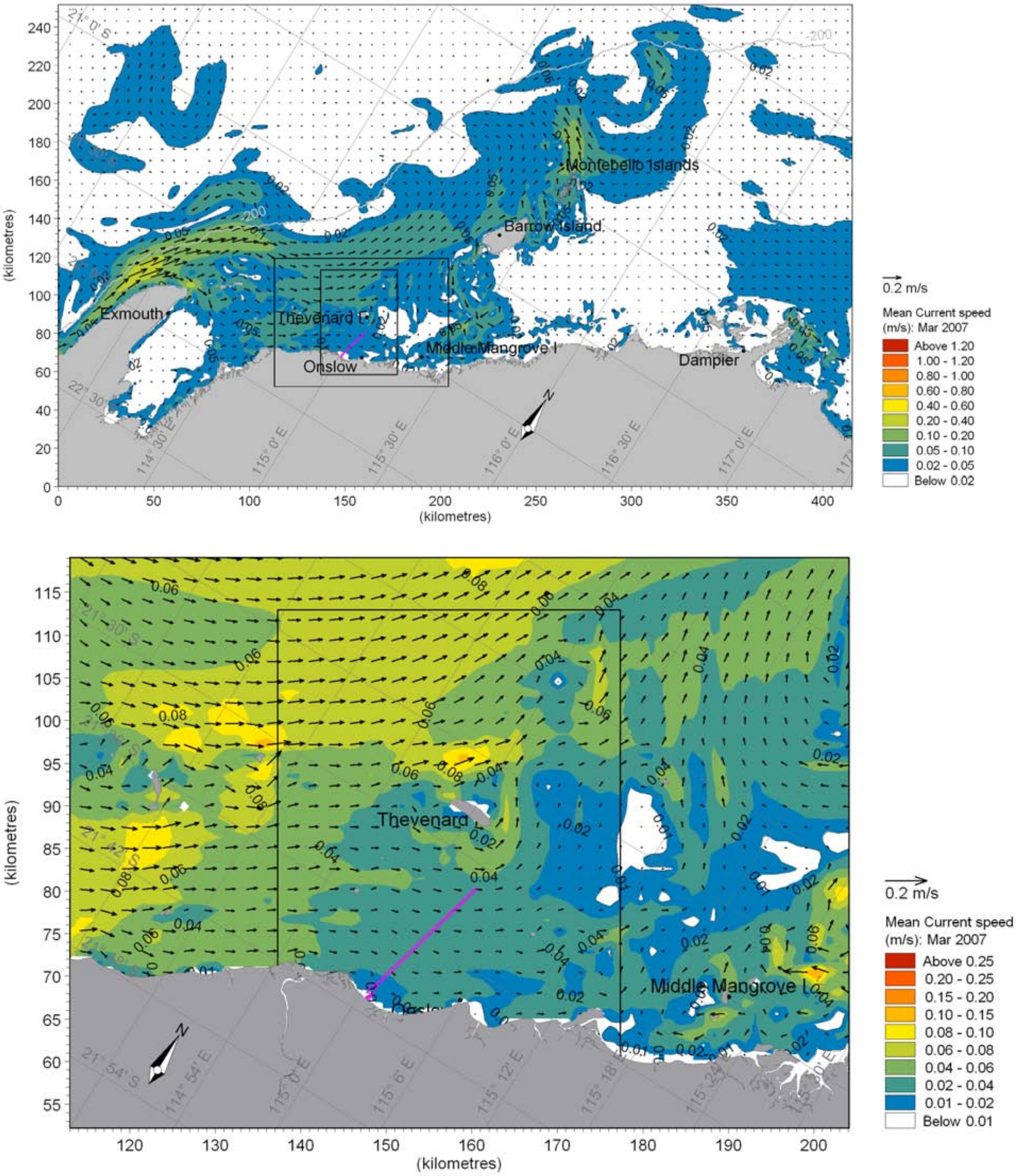
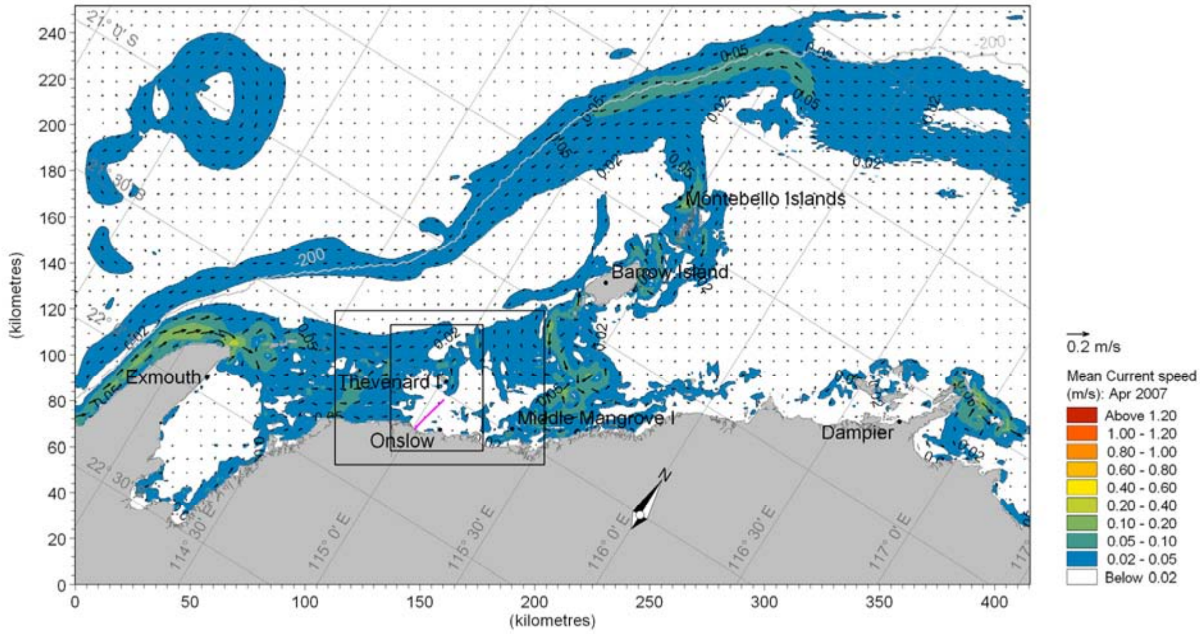


Figure FF.23 Simulated average net currents during March 2007 driven by winds from hourly MesoLAPS



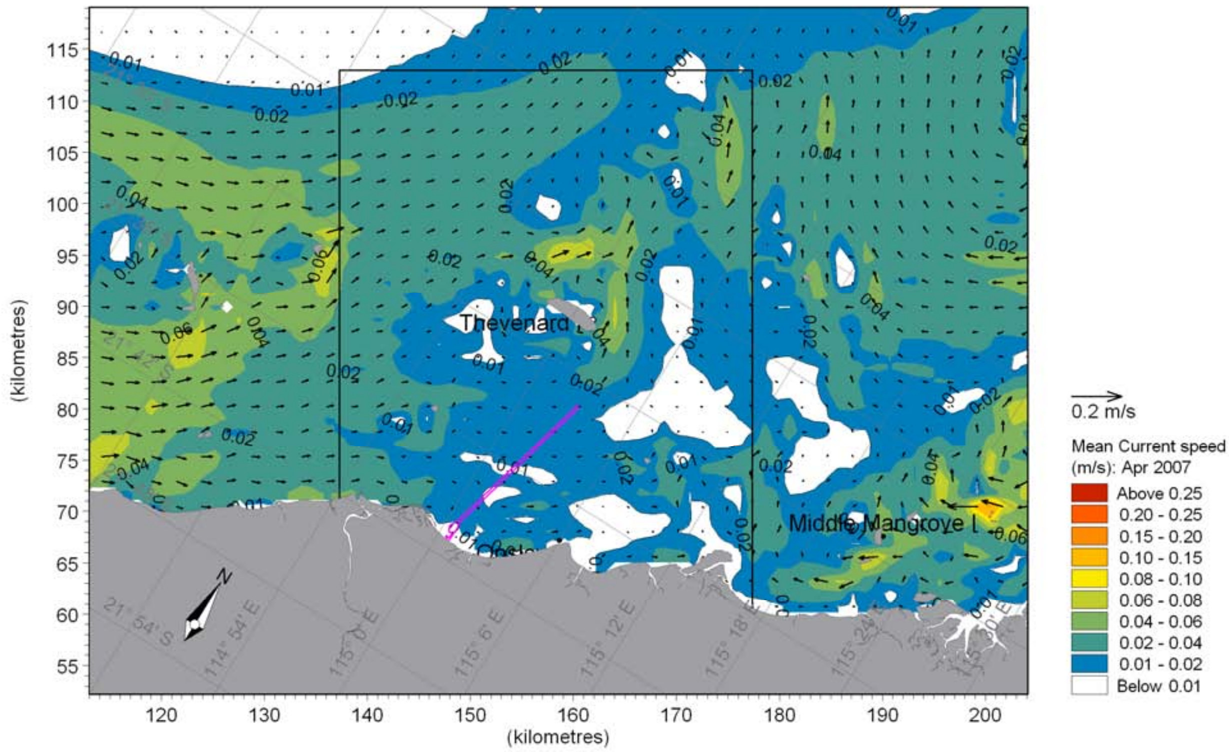


Figure FF.24 Simulated average net currents during April 2007 driven by winds from hourly MesoLAPS

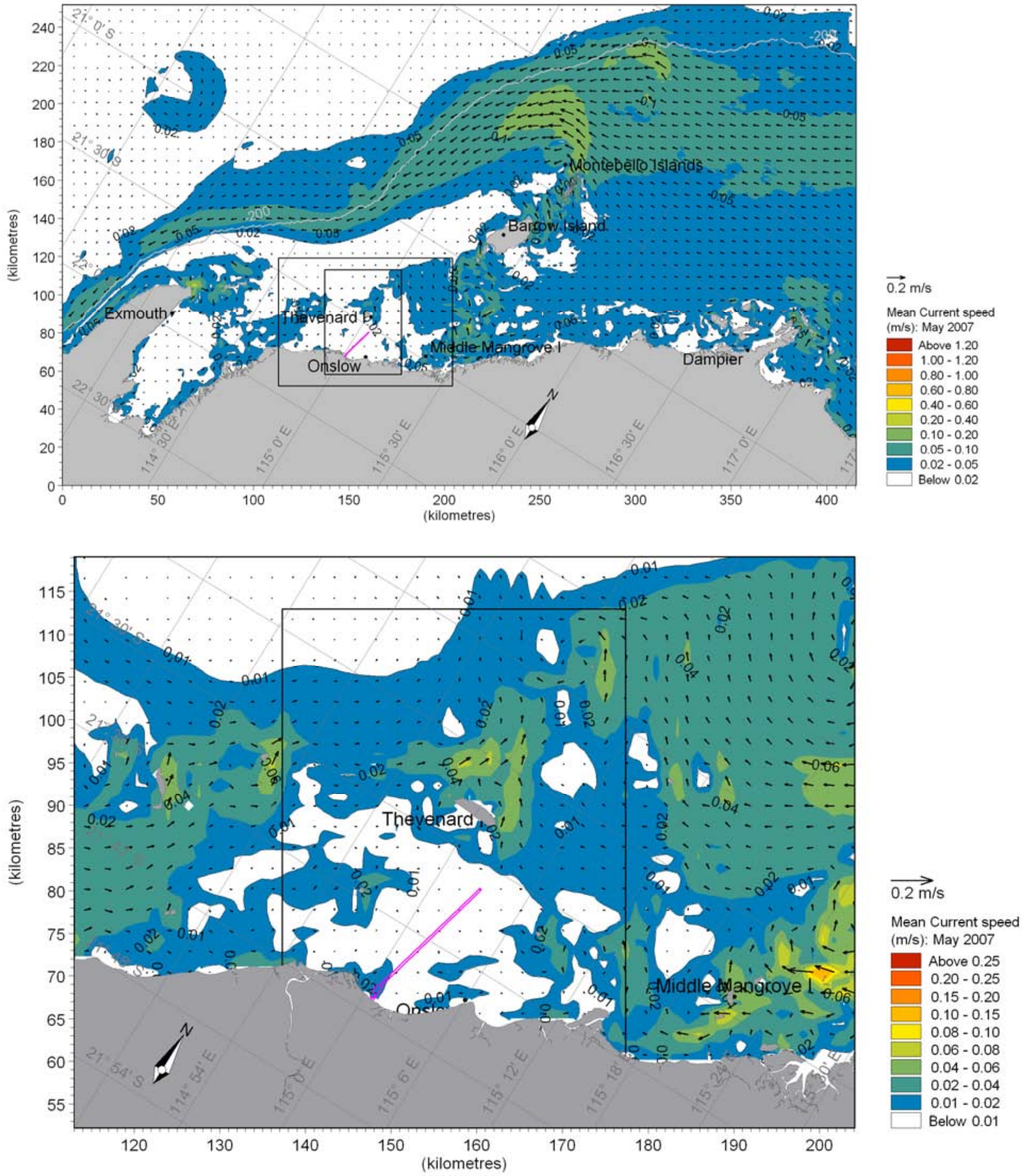


Figure FF.25 Simulated average net currents during May 2007 driven by winds from hourly MesoLAPS

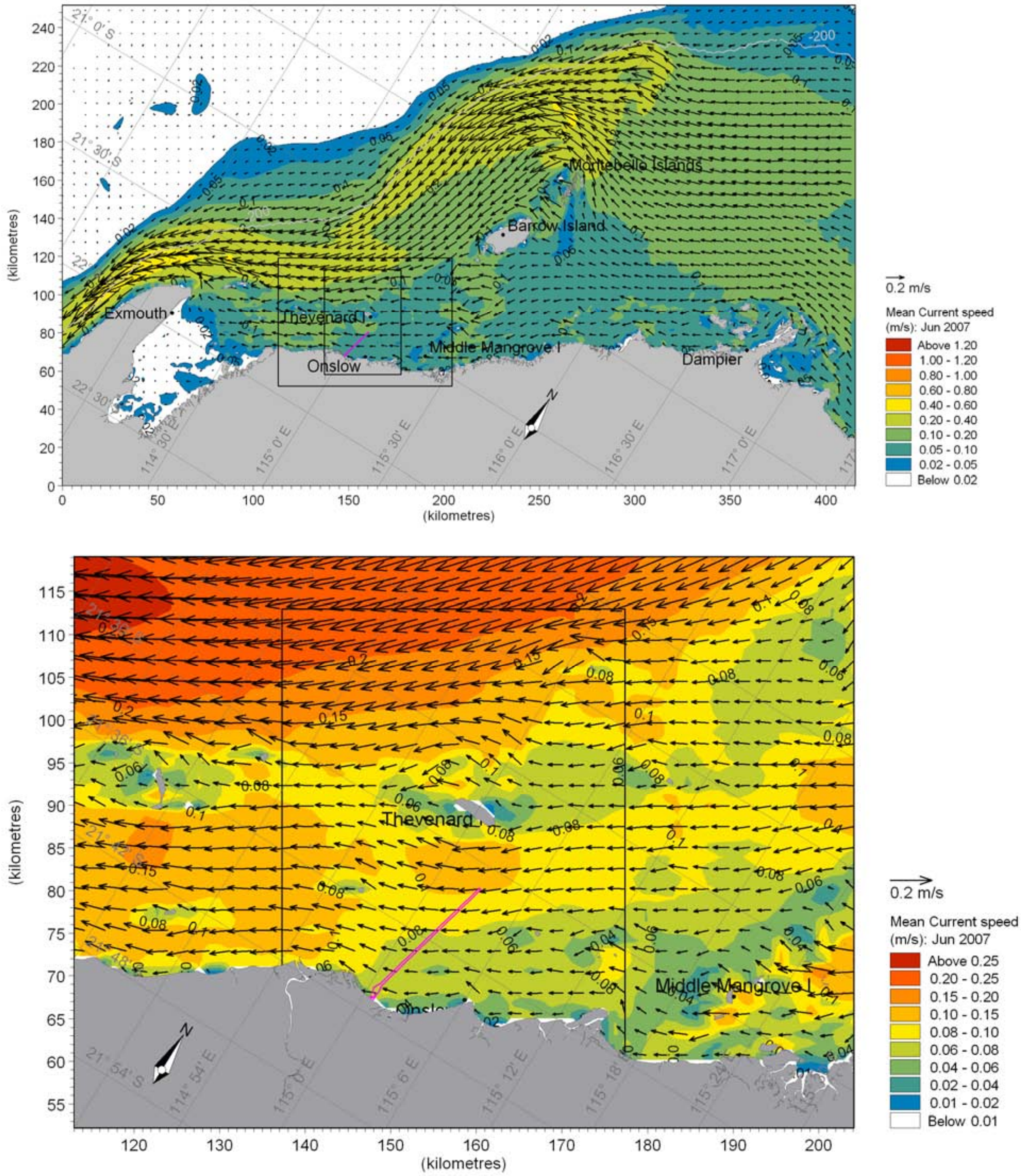


Figure FF.26 Simulated average net currents during June 2007 driven by winds from hourly MesoLAPS

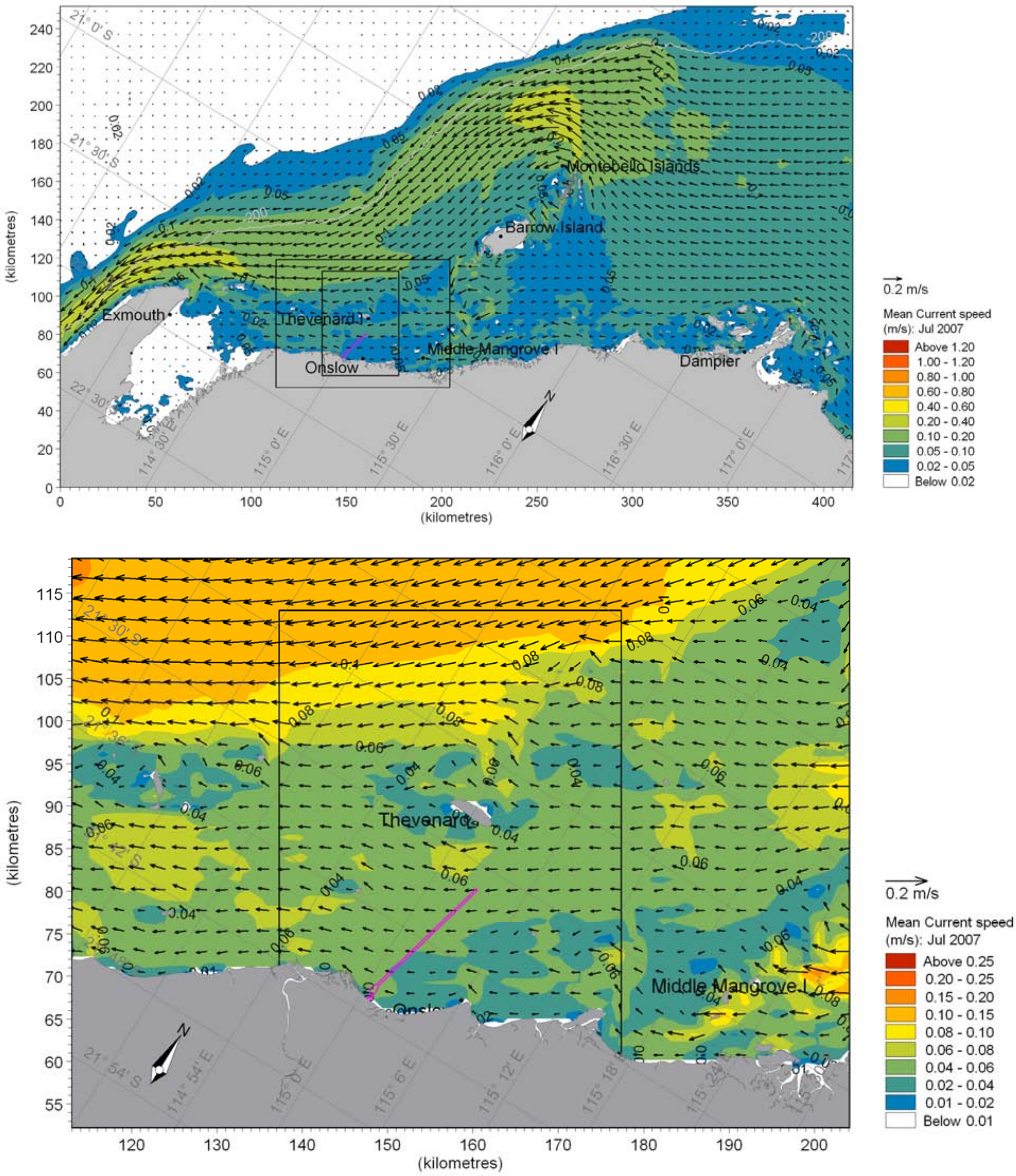


Figure FF.27 Simulated average net currents during July 2007 driven by winds from hourly MesoLAPS

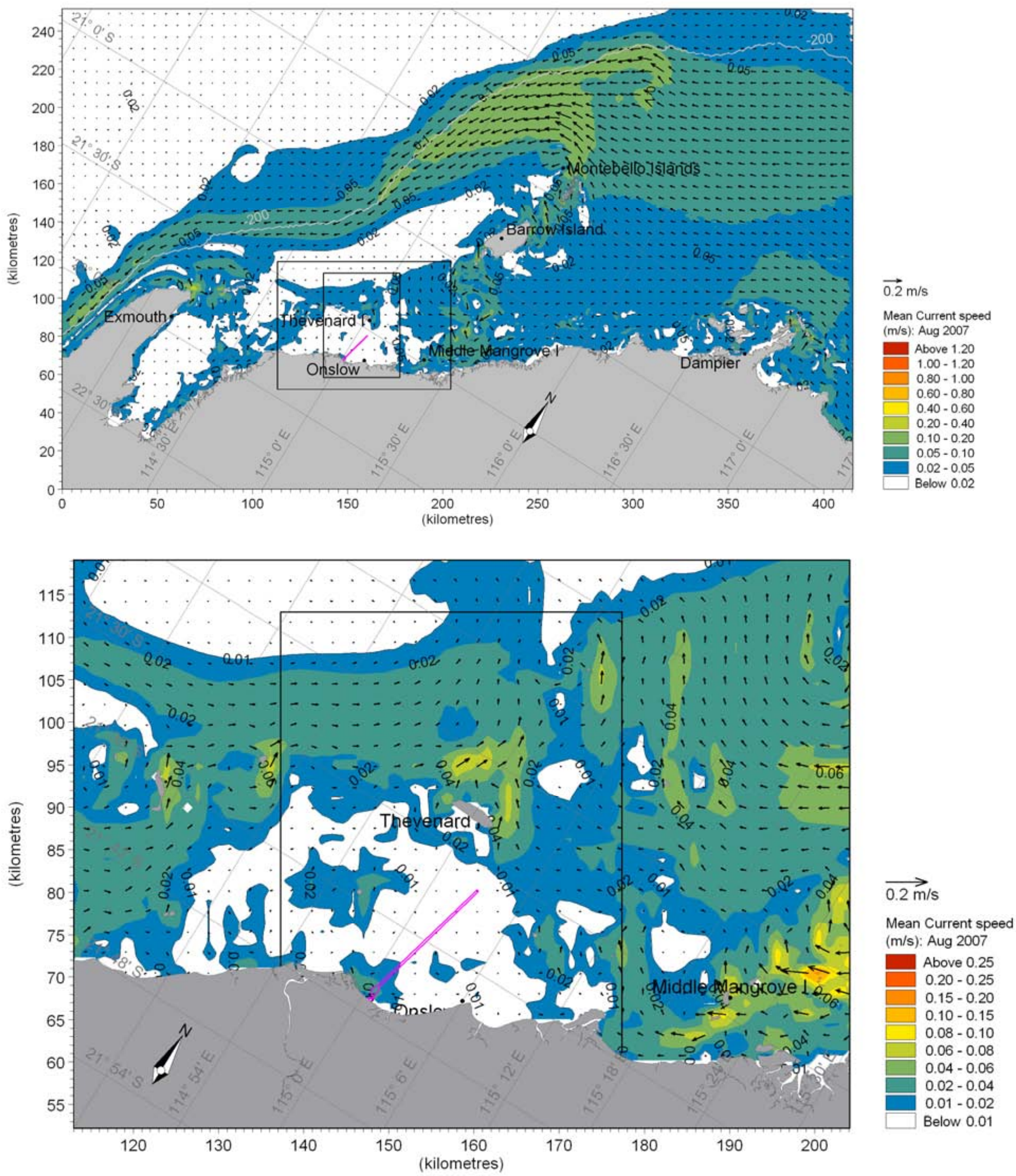


Figure FF.28 Simulated average net currents during August 2007 driven by winds from hourly MesoLAPS

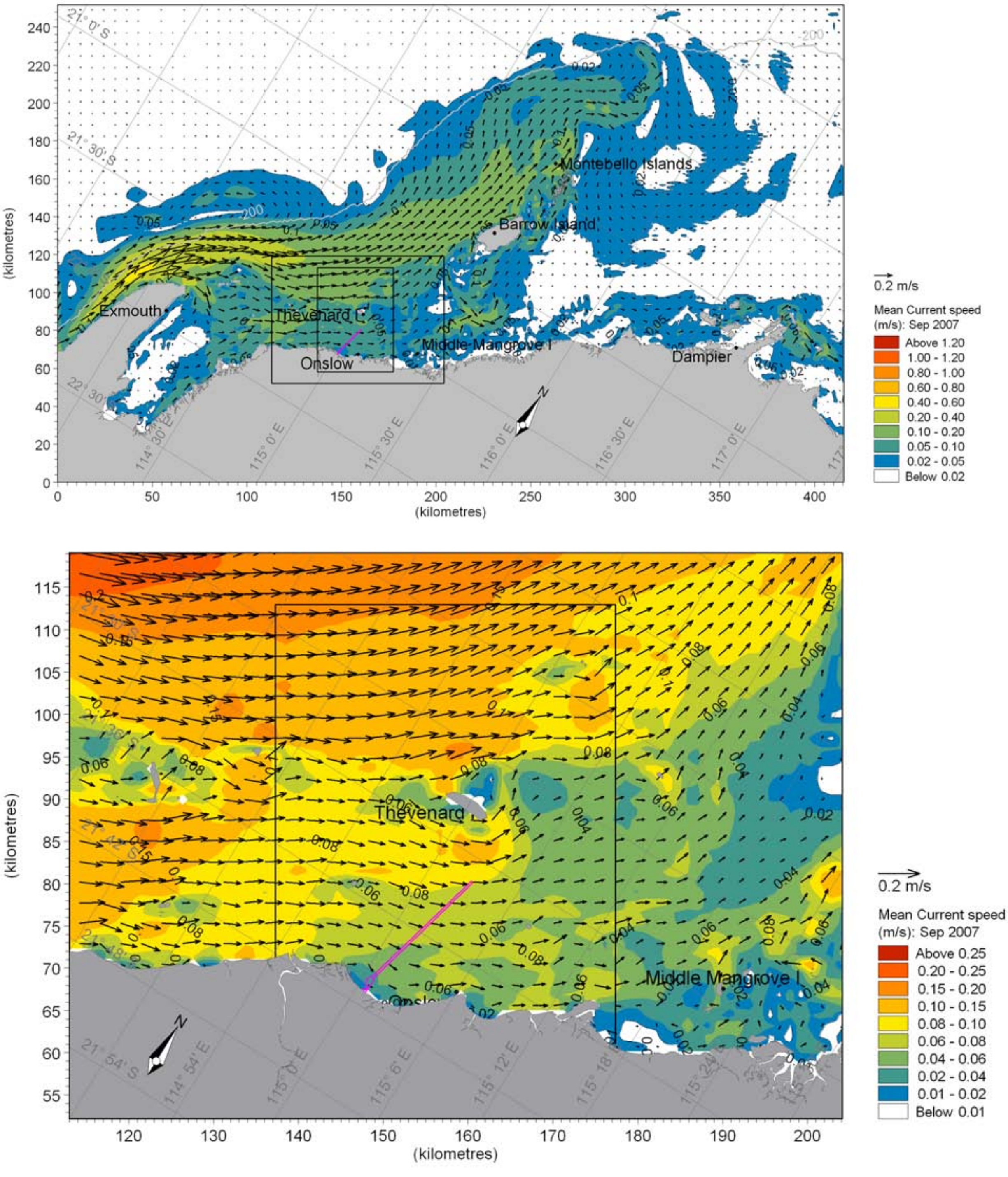


Figure FF.29 Simulated average net currents during September 2007 driven by winds from hourly MesoLAPS

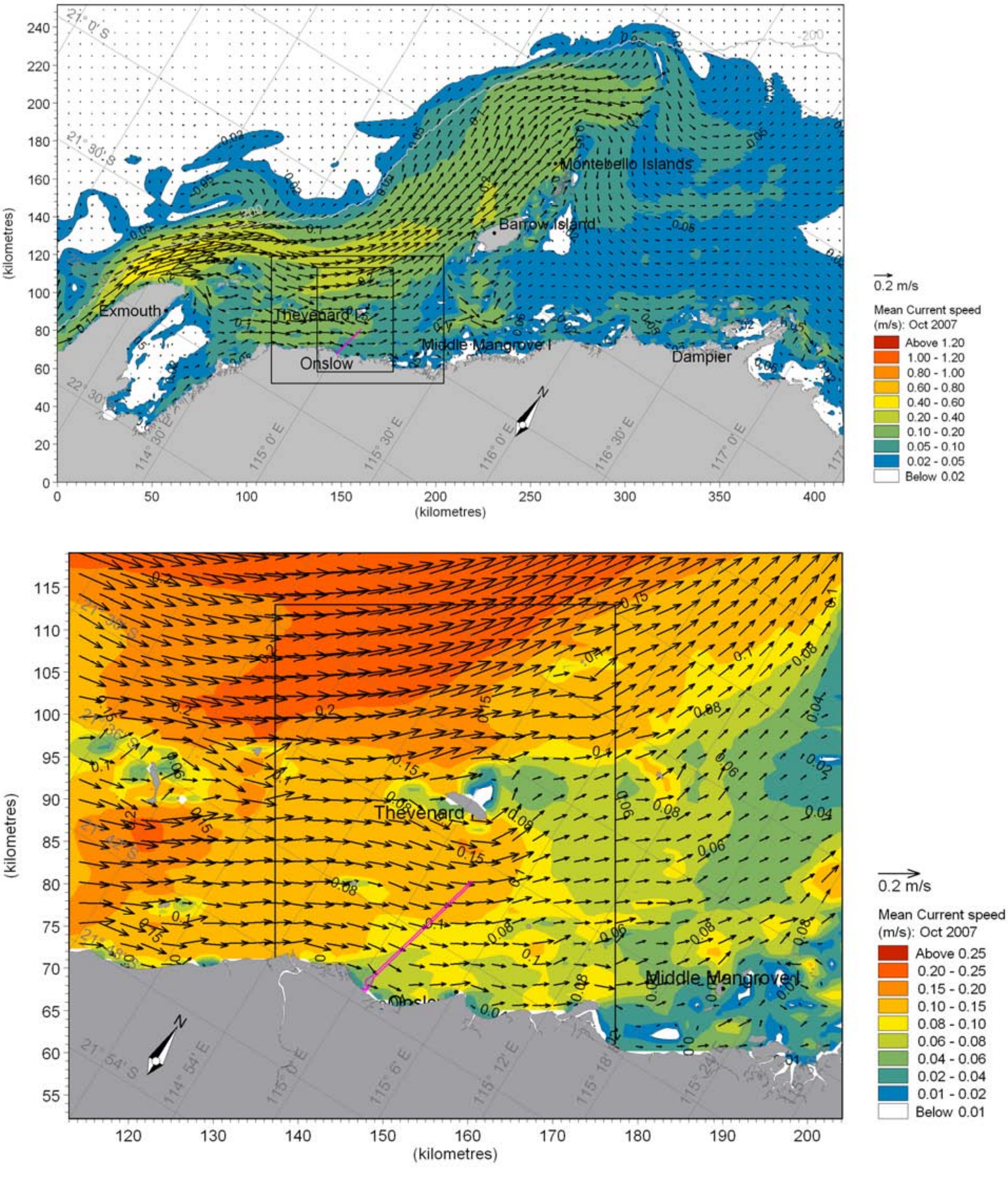


Figure FF.30 Simulated average net currents during October 2007 driven by winds from hourly MesoLAPS

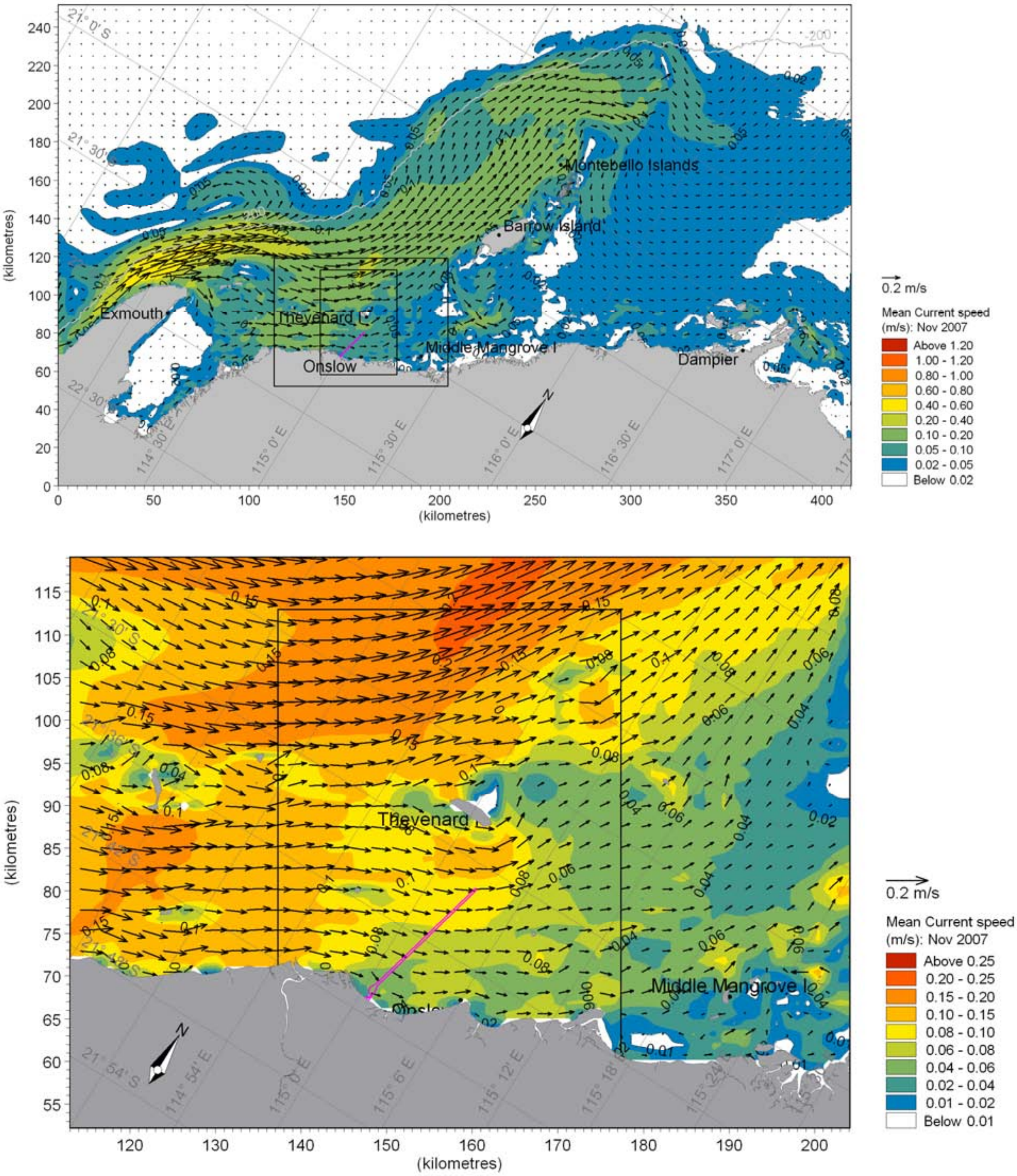
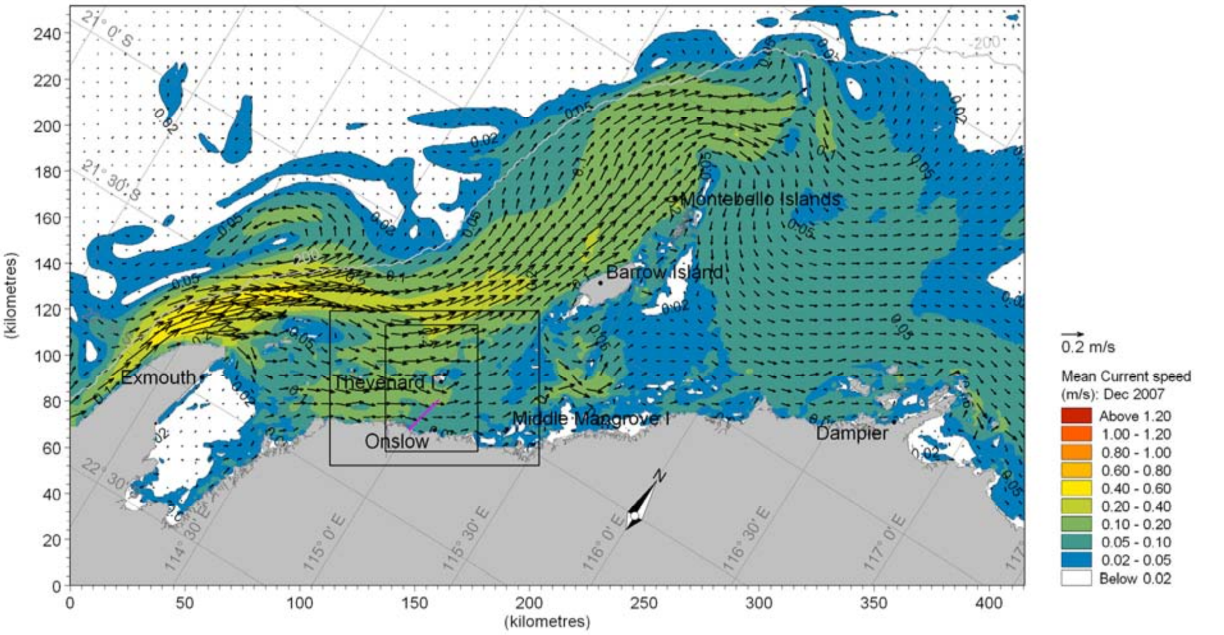


Figure FF.31 Simulated average net currents during November 2007 driven by winds from hourly MesoLAPS



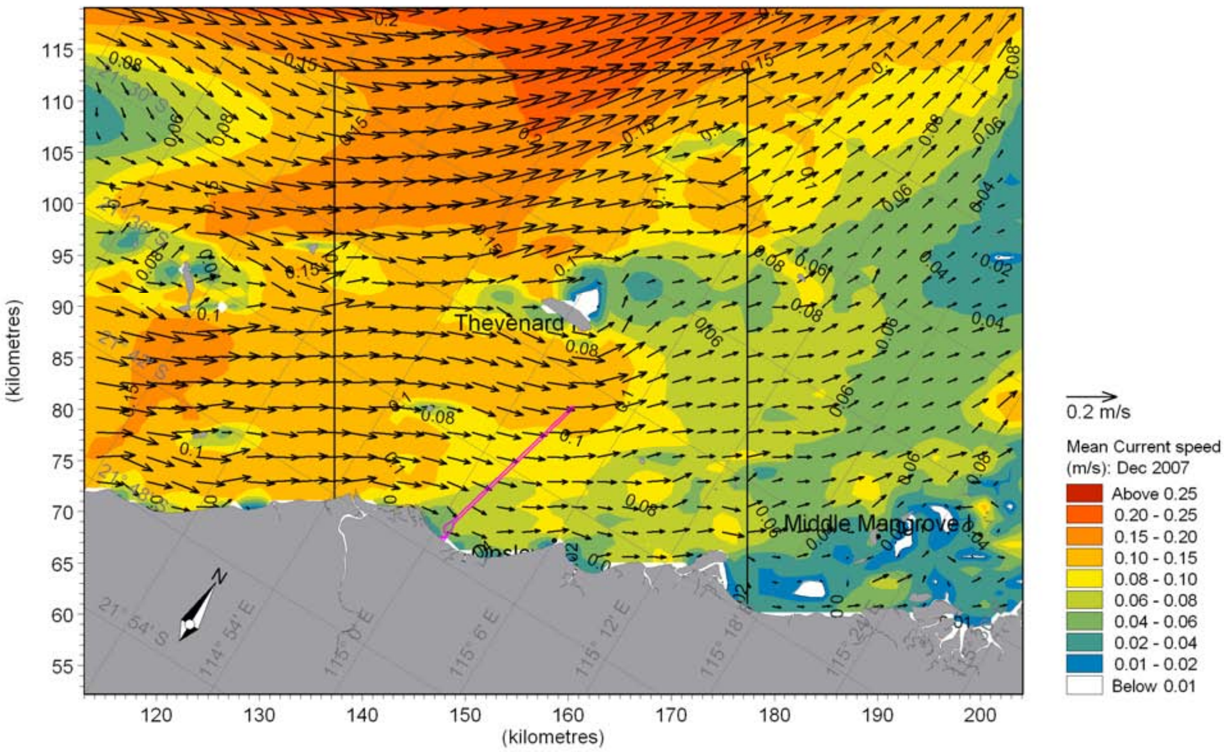


Figure FF.32 Simulated average net currents during December 2007 driven by winds from hourly MesoLAPS

FF.4.2 Intra and inter-annual Variability

Both intra- and inter-annual variability in the climatic conditions, e.g. driven by the El Nino – La Nina cycle, can impact the wind patterns and the resulting net currents at the site. The scenario modelling approach is generally not sensitive to this. As long as the resulting climatic conditions lie within the bounds covered by the climatic scenarios, the resulting impacts can be considered to be covered by the envelope of impact zones derived through the scenario modelling.

To ascertain whether the effects of inter-annual variability on the net currents are adequately covered by the present climatic scenarios, time series of net currents have been derived through modelling for years covering both El Nino and La Nina effects. Per recommendations from Dr. Mills, 1999-2000 have been included as these years had a positive Southern Oscillation Index (SOI) corresponding to a La Nina period. 2002-2003 were included as representative of an El Nino period with predominantly negative SOI index.

Net currents for a variety of locations throughout the area of interest have been derived and analysed. Time series have been shown here for 2 locations at either end of the proposed navigation channel at the "Jetty" and "Channel" shown in Figure FF.33. The modelling has been carried out for both Onslow and MesoLAPS winds when available. Monthly statistics are further illustrated for AWAC-01 and ADCP-01 in the following section.

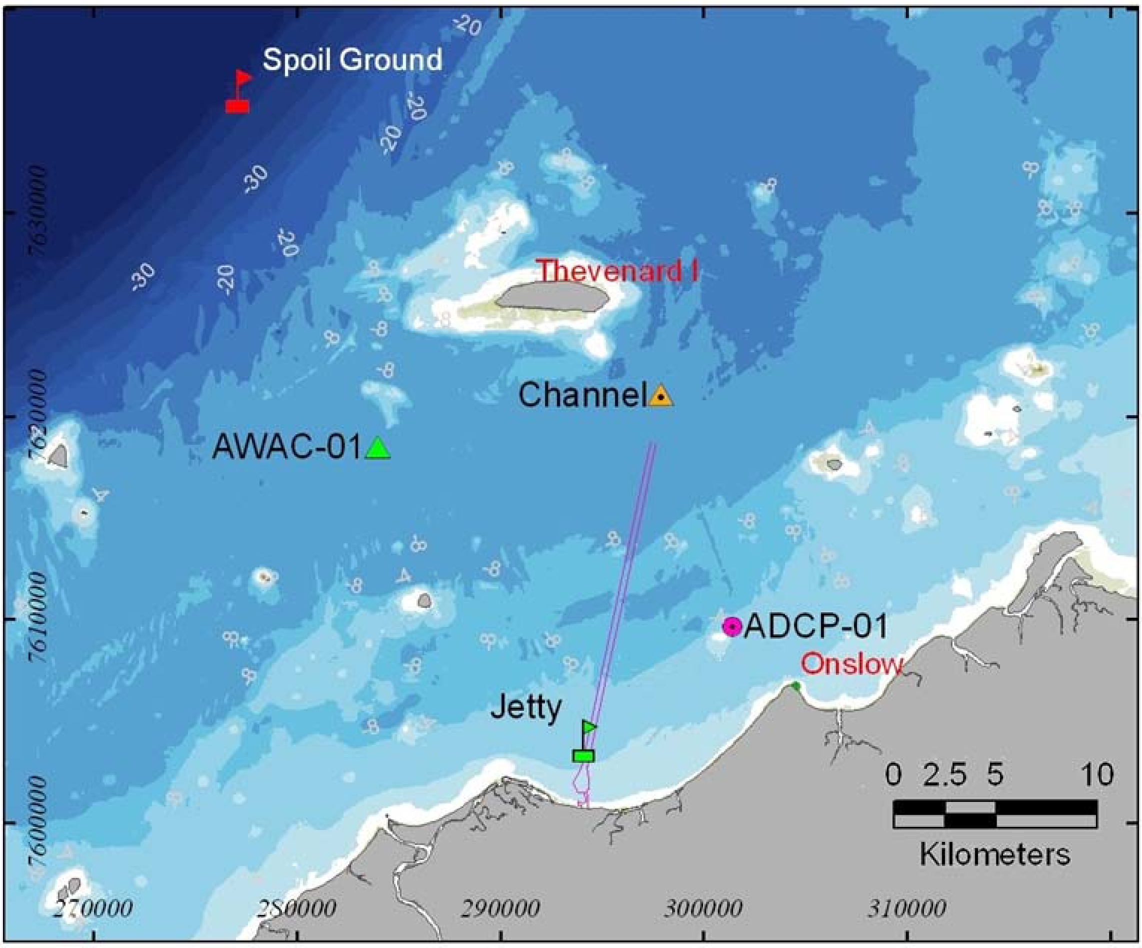


Figure FF.33 Locations of current extraction points (corresponding to locations with measurements) for which the net currents have been derived and compared to the net currents from the climatic scenarios.

FF.4.2.1 Net Currents for "Jetty"

The "jetty" location, see Figure FF.33, represents a relatively shallow, nearshore location. The simulated net currents during the assessment periods are illustrated in Figure FF.34. The following general observations are made:

- At this nearshore location, the Onslow wind driven net currents are generally stronger during summer and transitional conditions. MesoLAPS driven net currents are slightly stronger during winter conditions.
- Net currents during summer conditions are the strongest and most persistent, although winter net currents are fairly strong. Peak net currents during the transitional months rarely reach 0.1 m/s, about half the magnitudes reached during the summer and winter conditions.

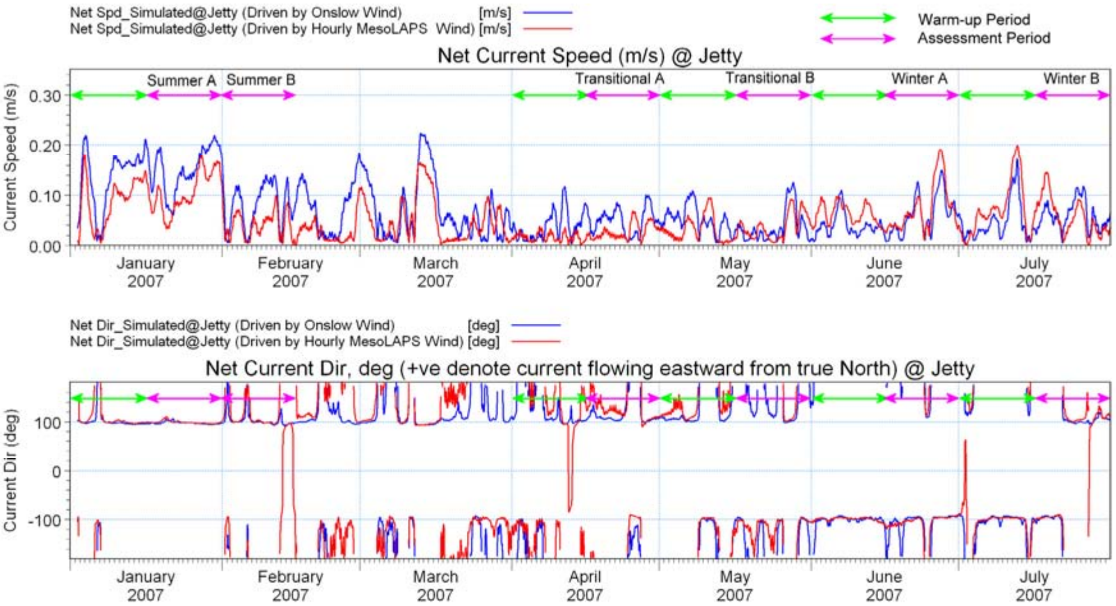


Figure FF.34 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red). The assessment periods used for the impact assessment are illustrated at the top of the plot.

Model derived net currents are illustrated in Figure FF.35 to Figure FF.43 for selected years, including the years with positive and negative SOIs. The following general observations are made:

- Except for short duration peaks typically related to cyclones (such as e.g. the spike generated by Cyclone Vance in March 1999), both summer and winter net currents generally fall below the net currents in the "strong" assessment periods.
- Consistencies of the net currents are generally also well captured by the assessment periods with a larger degree of consistently higher net flows during summer than during winter.
- Both the positive and negative SOI periods are captured within the climatic scenarios with respect to the peaks and consistency of the net flows.

Overall, it is considered that the variability and consistency of the net currents at the nearshore "jetty" location are captured within the climatic scenarios.

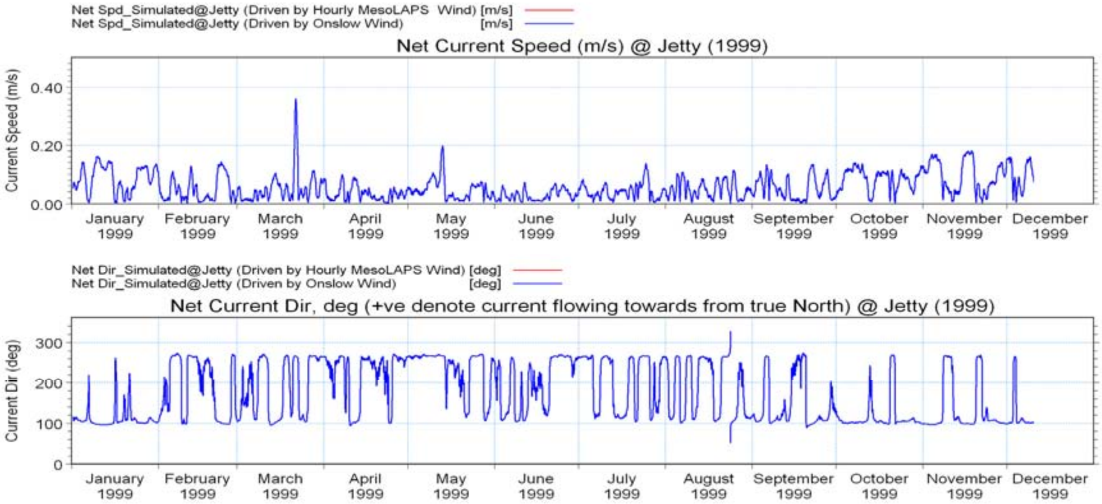


Figure FF.35 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS winds for 1999.

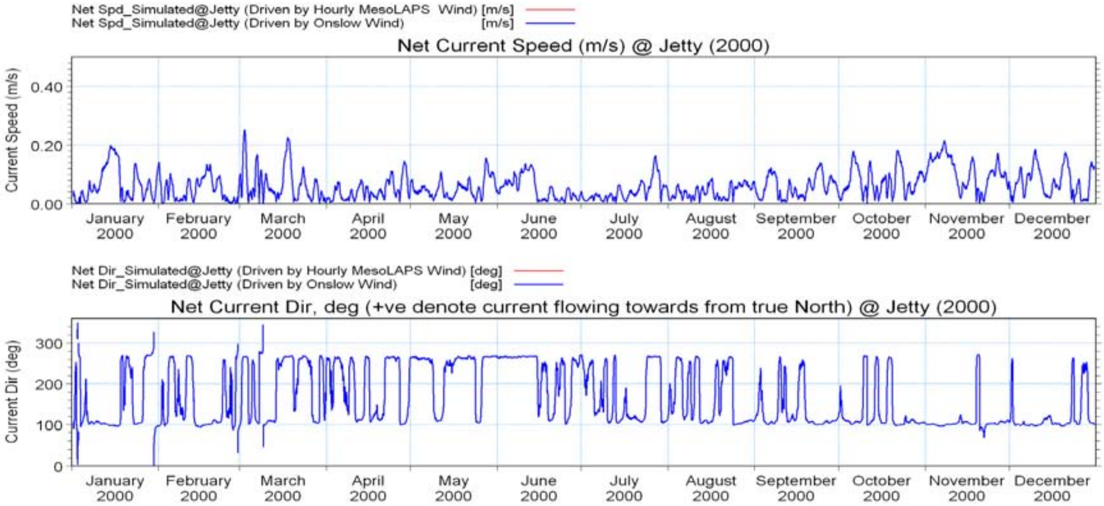


Figure FF.36 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS winds for 2000.

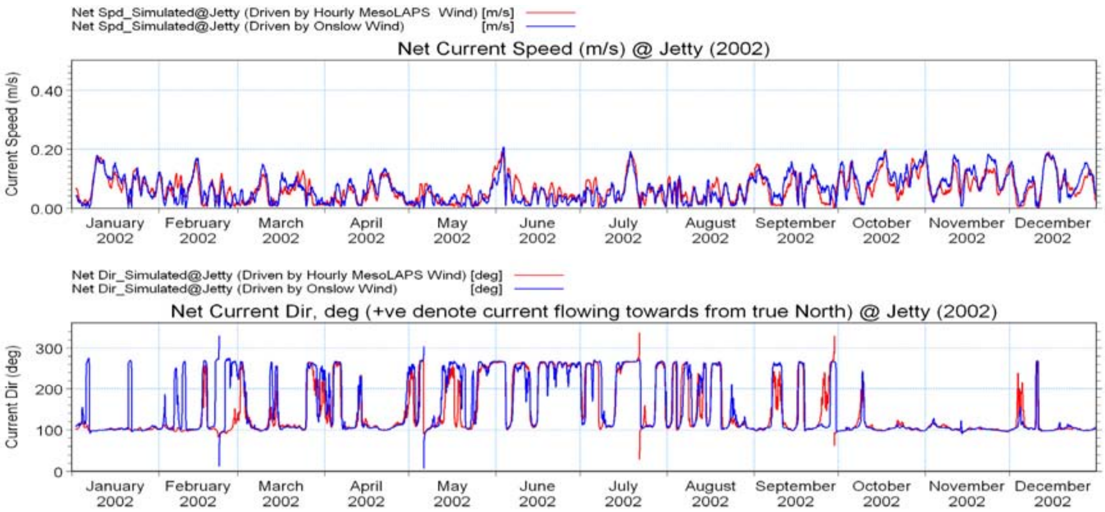


Figure FF.37 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2002.

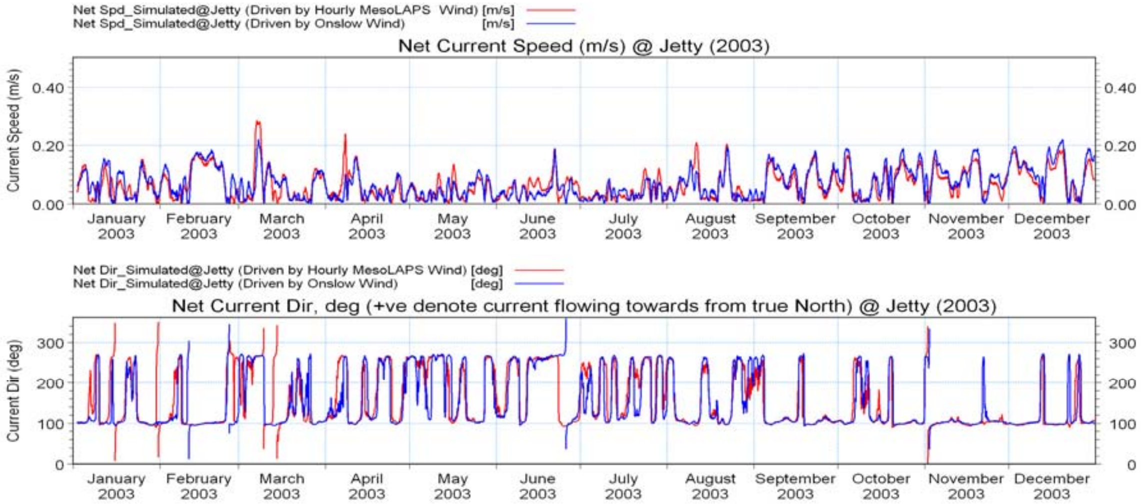


Figure FF.38 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2003.

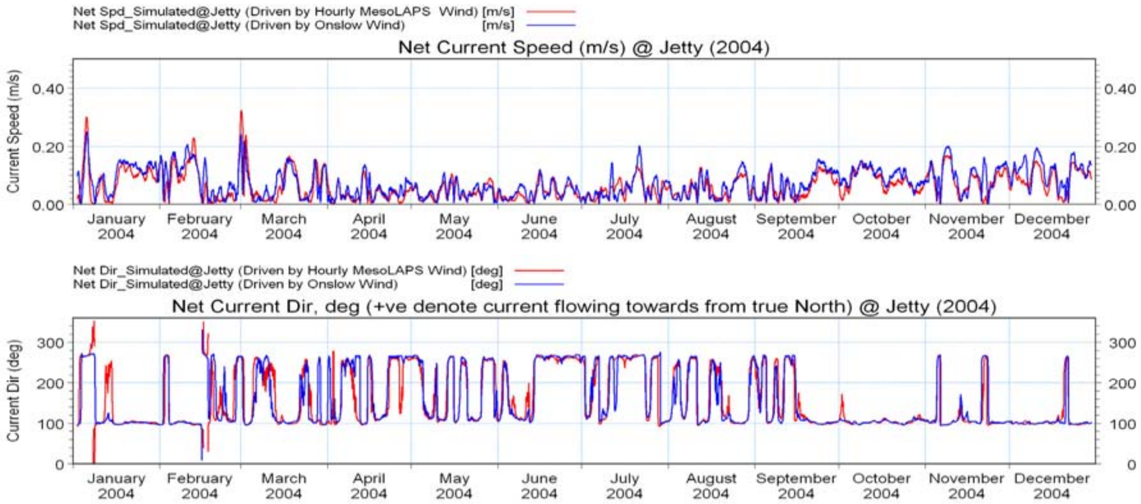


Figure FF.39 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2004.

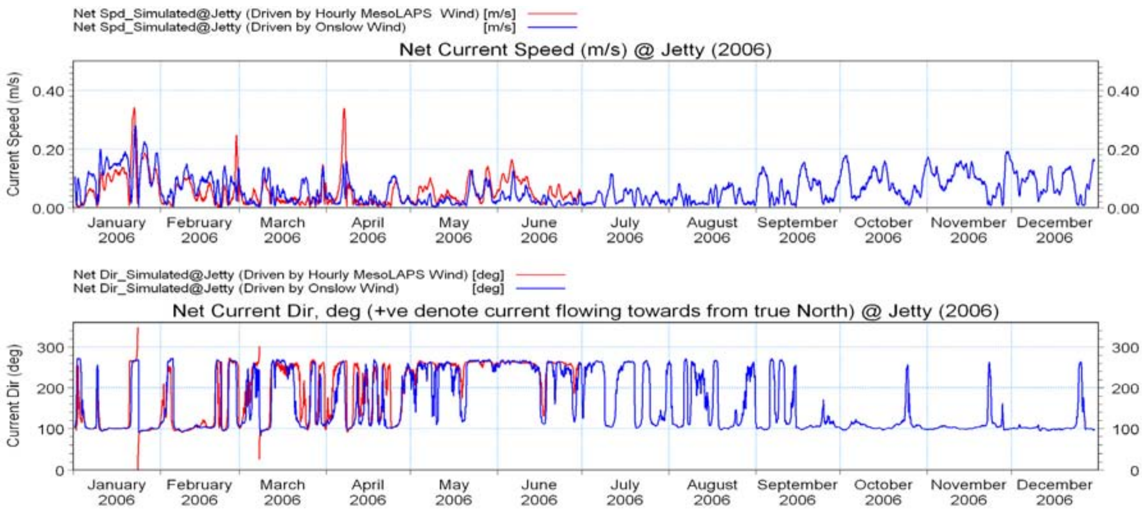


Figure FF.40 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2006.

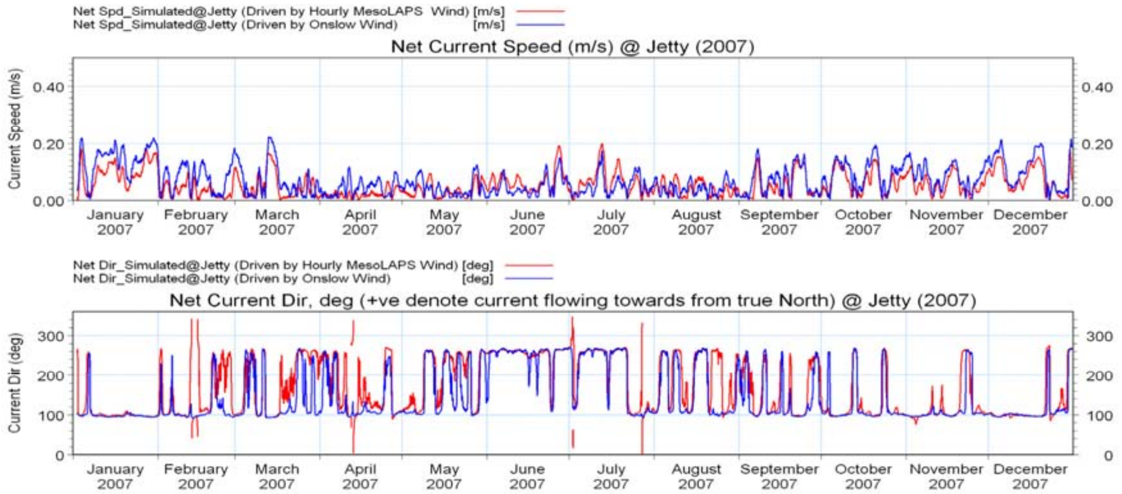


Figure FF.41 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2007.

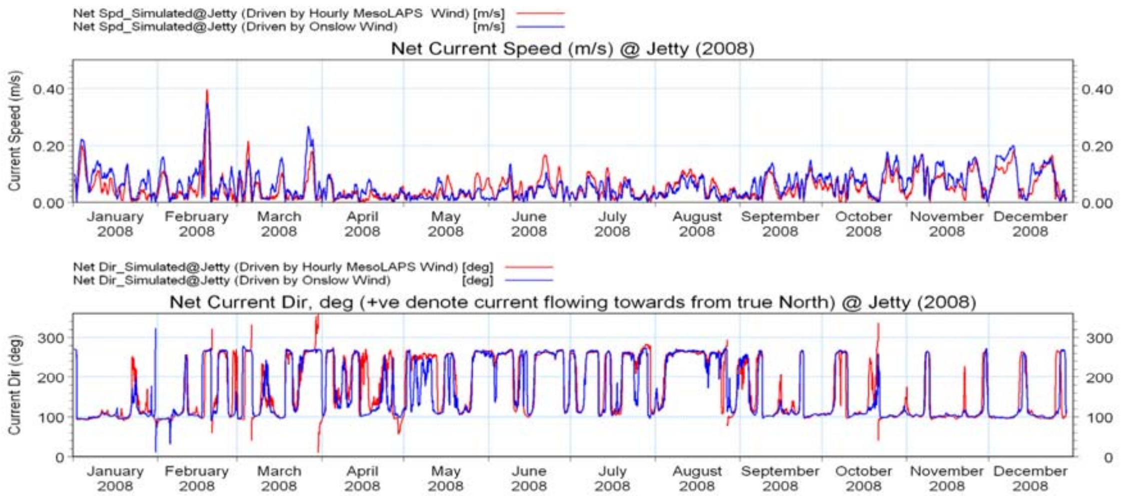


Figure FF.42 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2008.

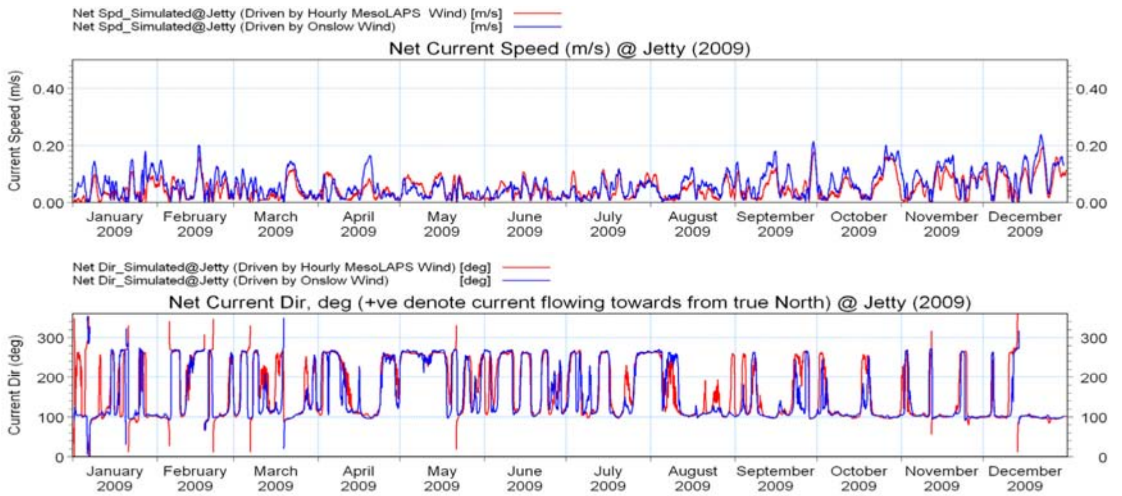


Figure FF.43 Net currents at the Jetty location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2009.

FF.4.2.2 Net Currents for "Channel" Location

The "Channel" location, see Figure FF.33, represents conditions at the outer part of the proposed channel. The simulated net currents during the assessment periods are illustrated in Figure FF.44. The following general observations are made:

- The wind driven net currents at the outer end of the proposed navigation channel are about 25% stronger than at the "jetty" location closer to shore during both summer and winter conditions.
- The Onslow and MesoLAPS wind driven net currents are fairly similar during summer and transitional conditions, while MesoLAPS driven net currents are much stronger winter conditions due to the much stronger easterly winds in the MesoLAPS records compared to the OMS measurements.

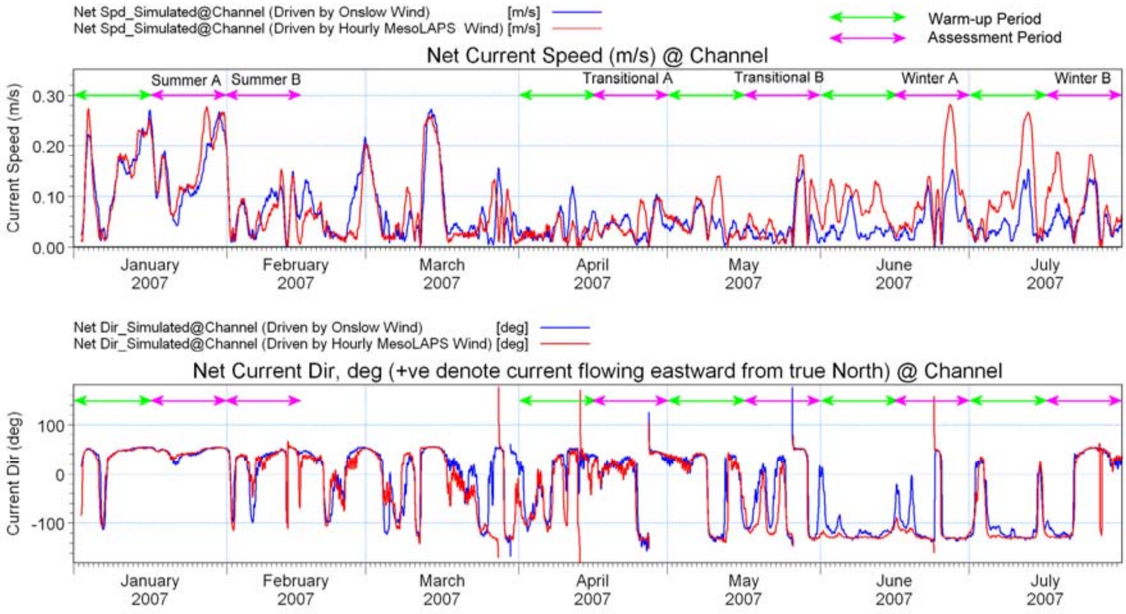


Figure FF.44 Net currents at the "Channel" location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red). The assessment periods used for the impact assessment are illustrated at the top of the plot.

Model derived net currents are illustrated in Figure FF.45 to Figure FF.53 for 9 years, including the years with positive and negative SOIs. The general observations made for the "jetty" location are also valid for the "Channel" location.

- Except for short duration spikes in net currents associated with tropical storms or cyclones (when dredging would be stopped), both summer and winter net currents generally fall below the net currents in the "strong" assessment periods.
- The consistencies of the net currents are generally also well captured by the assessment periods.
- Both the positive and negative SOI periods are captured within the climatic scenarios with respect to the peaks and consistency of the net flows.

Overall, it is considered that the variability and consistency of the net currents at the "Channel" location at the off-shore limit of the navigation channel are captured within the climatic scenarios.

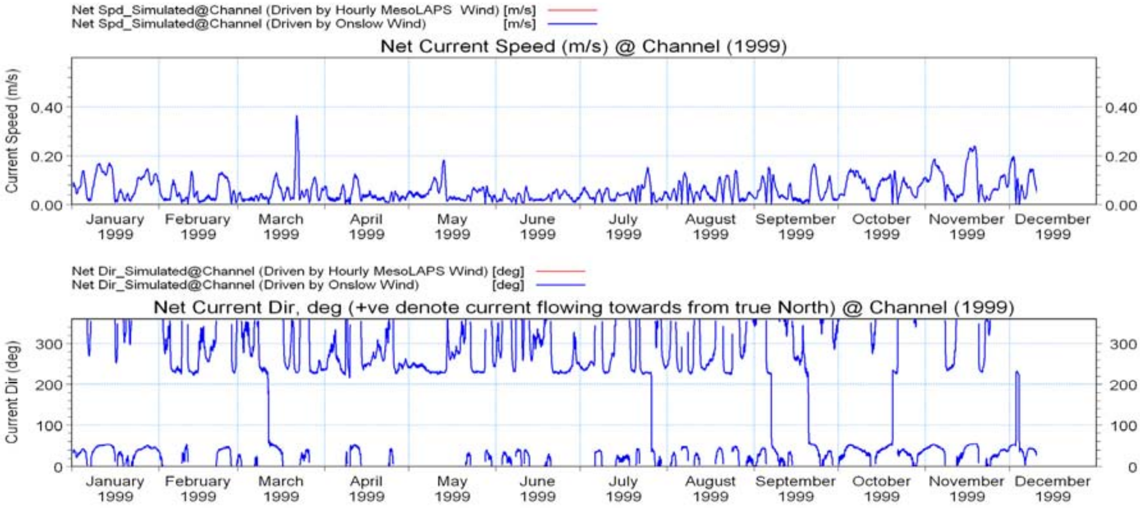


Figure FF.45 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS winds for 1999.

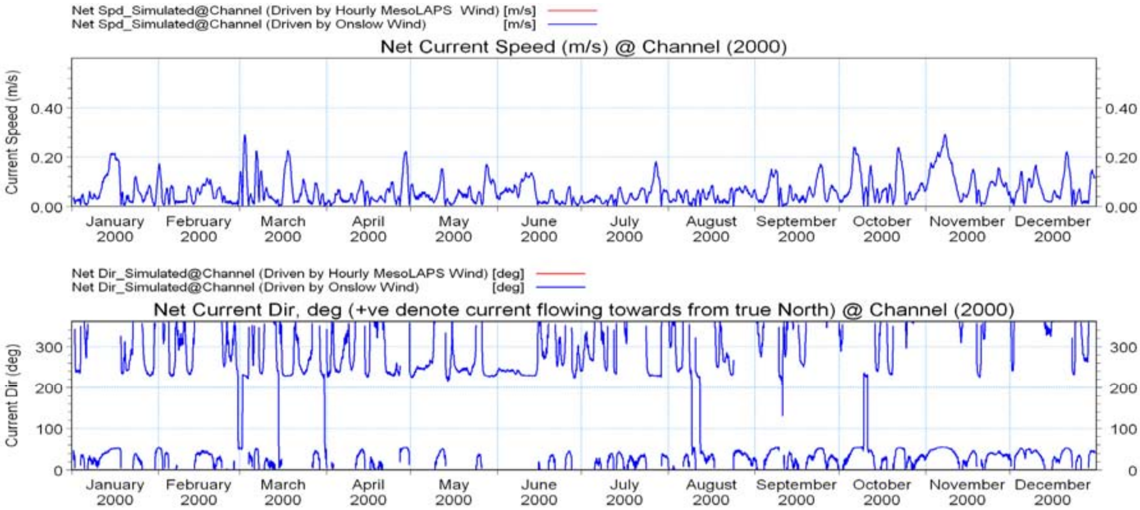


Figure FF.46 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS winds for 1999.

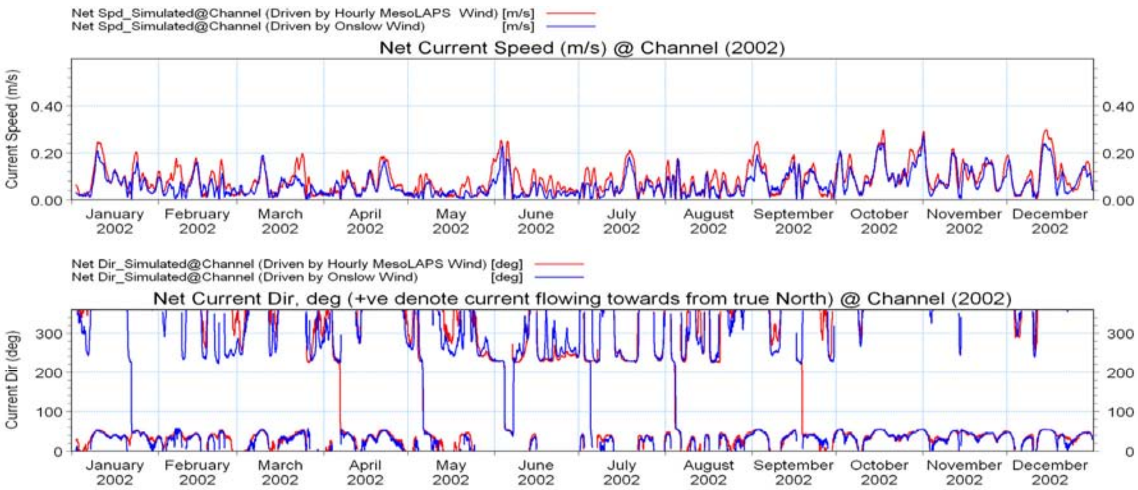


Figure FF.47 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2002.

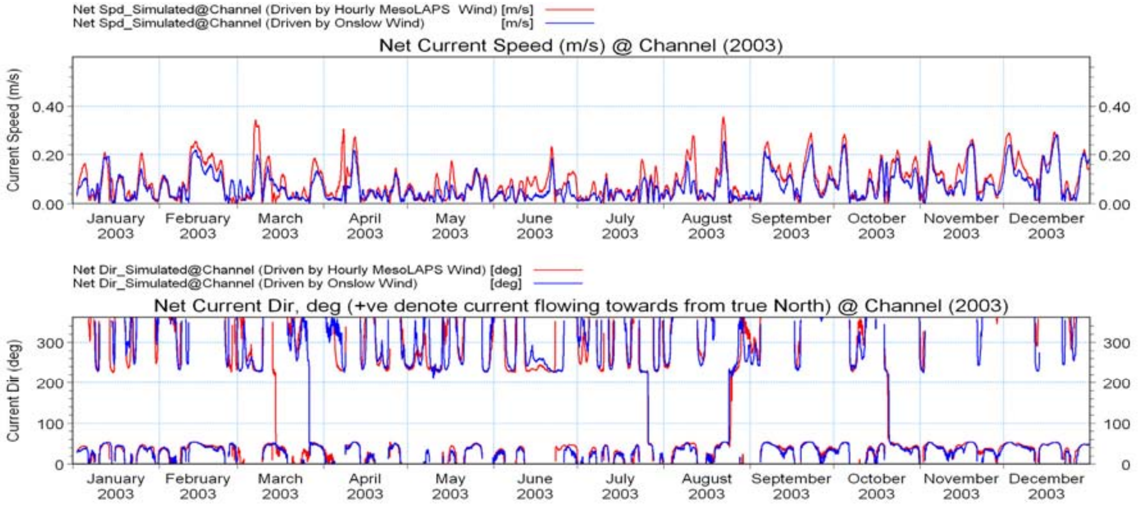


Figure FF.48 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2003.

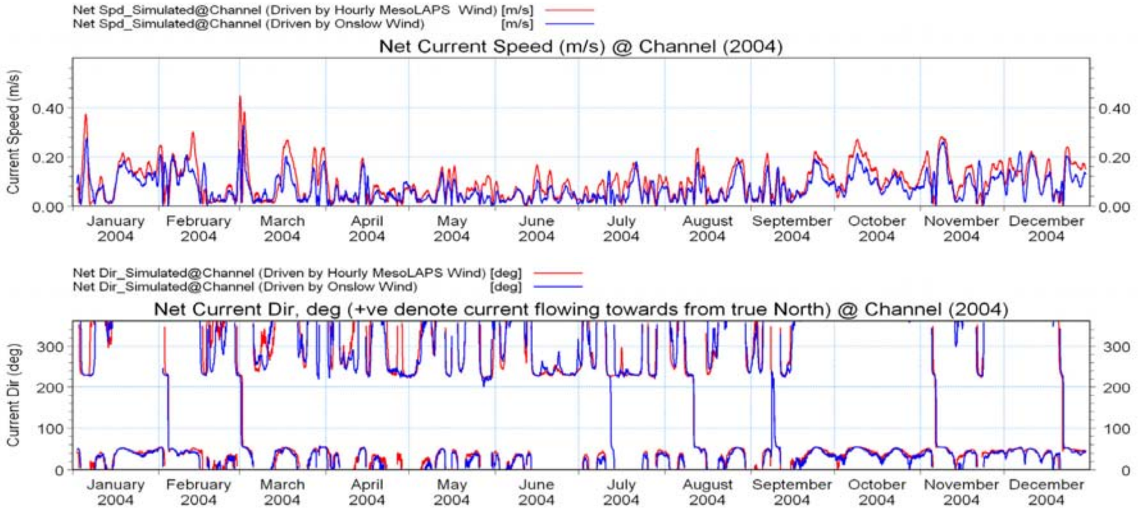


Figure FF.49 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2004.

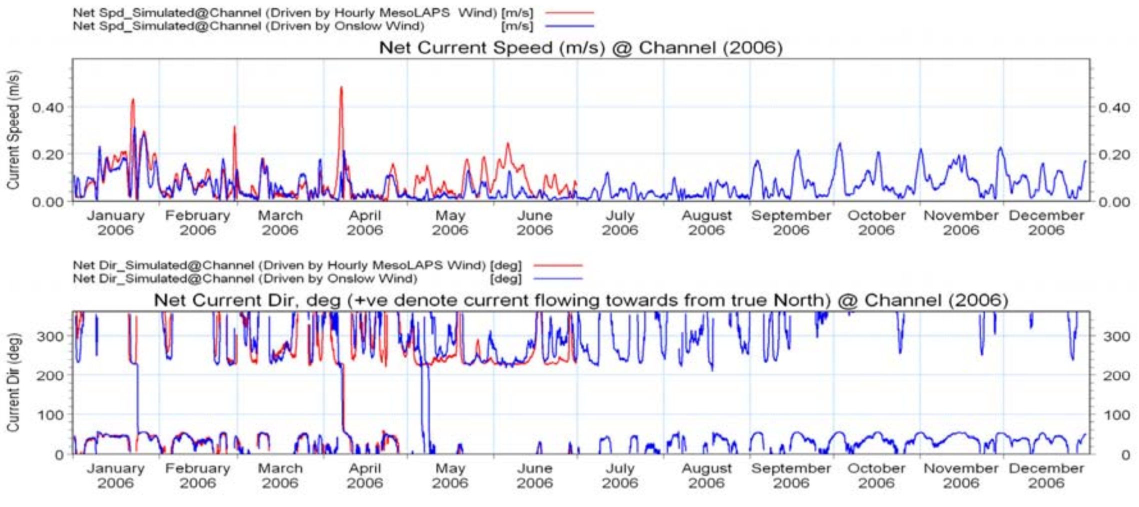


Figure FF.50 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2006.

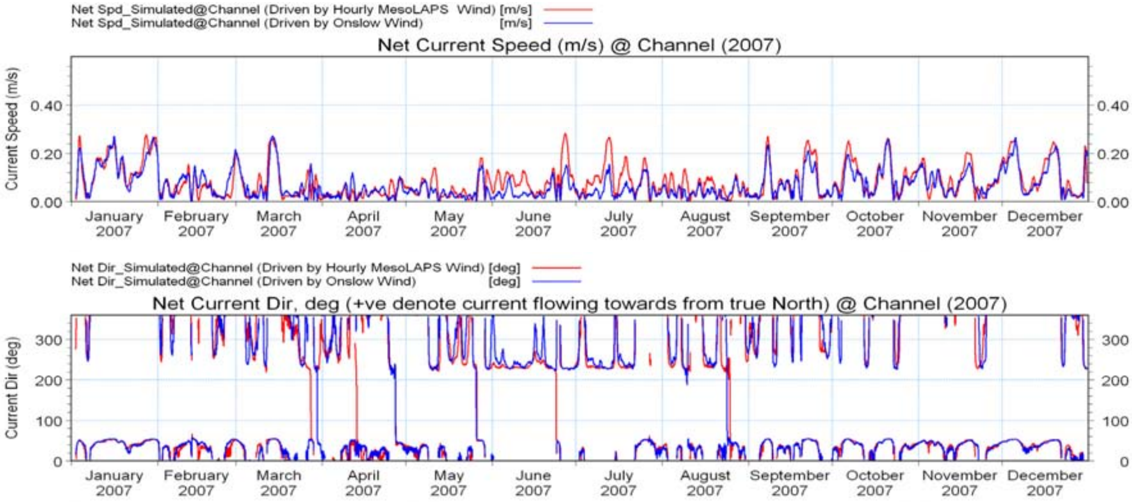


Figure FF.51 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2007.

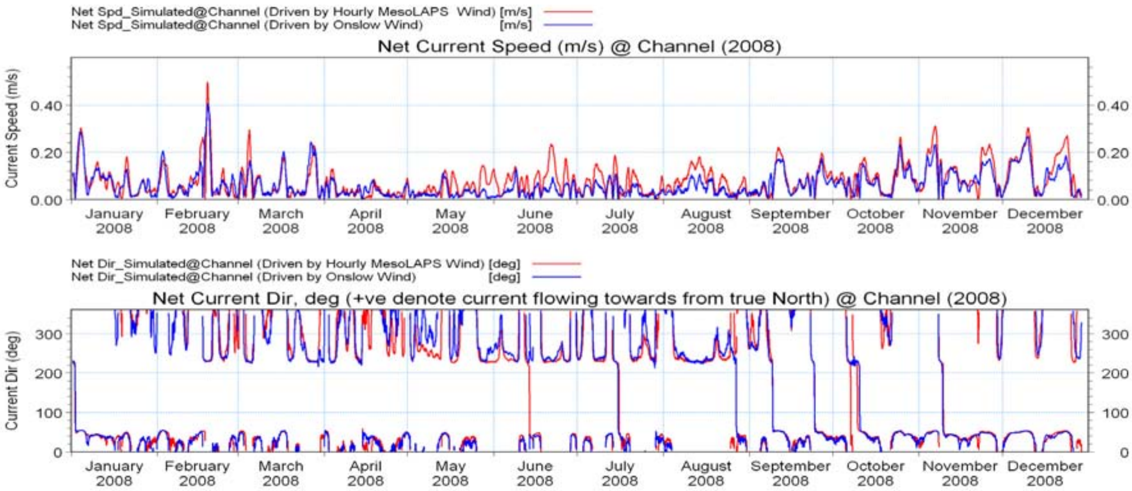


Figure FF.52 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2008.

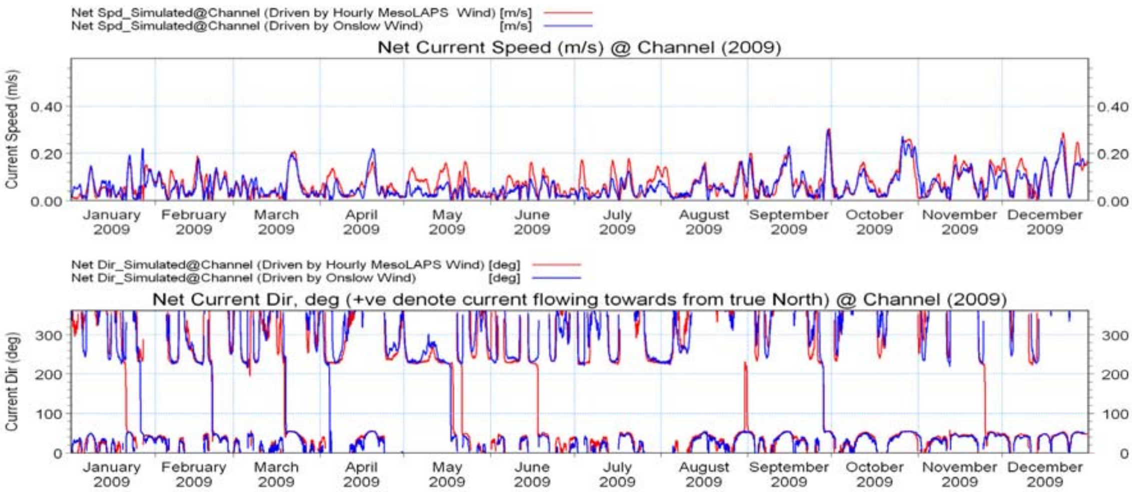


Figure FF.53 Net currents at the Channel location, see Figure FF.33, derived from the models driven by OMS (blue) and MesoLAPS winds (red) for 2009.

FF.4.3 Monthly Averages of Net Currents

Monthly averages of the net currents for the 9 simulated years are illustrated in Figure FF.54 to Figure FF.61 for 4 extraction location for Onslow and MesoLAPS winds.

The following is observed:

- For all locations, the maximum monthly average net easterly (summer) currents are reached during January 2007, which is the chosen "strong" summer scenario. This is valid for both Onslow and MesoLAPS driven net currents.
- For all locations, the maximum monthly average net westerly (winter) currents are reached during June 2007, which is the chosen "strong" winter scenario. This is valid for both Onslow and MesoLAPS driven net currents.
- In the nearshore area ("jetty" location), MesoLAPS driven net currents are on average lower during summer and higher during winter.
- At the off-shore end of the proposed navigation channel at the "Channel" location, the MesoLAPS driven net currents are significantly stronger than the OMS driven currents during winter conditions, and similar magnitude or slightly stronger during summer conditions.
- Whereas the El Nino and La Nina oscillations may shift the "normal" seasonal patterns, the generated net currents are considered to be well captured within the maximum bounds defined by the "strong" summer and winter months of 2007.

In line with previous findings, the net currents are relatively closely correlated to the wind fields. As the climatic scenarios initially were chosen to include periods of strong and consistent winds, it is not surprising to find that these periods generally encompass the range of conditions expected to be encountered under non-cyclonic conditions.

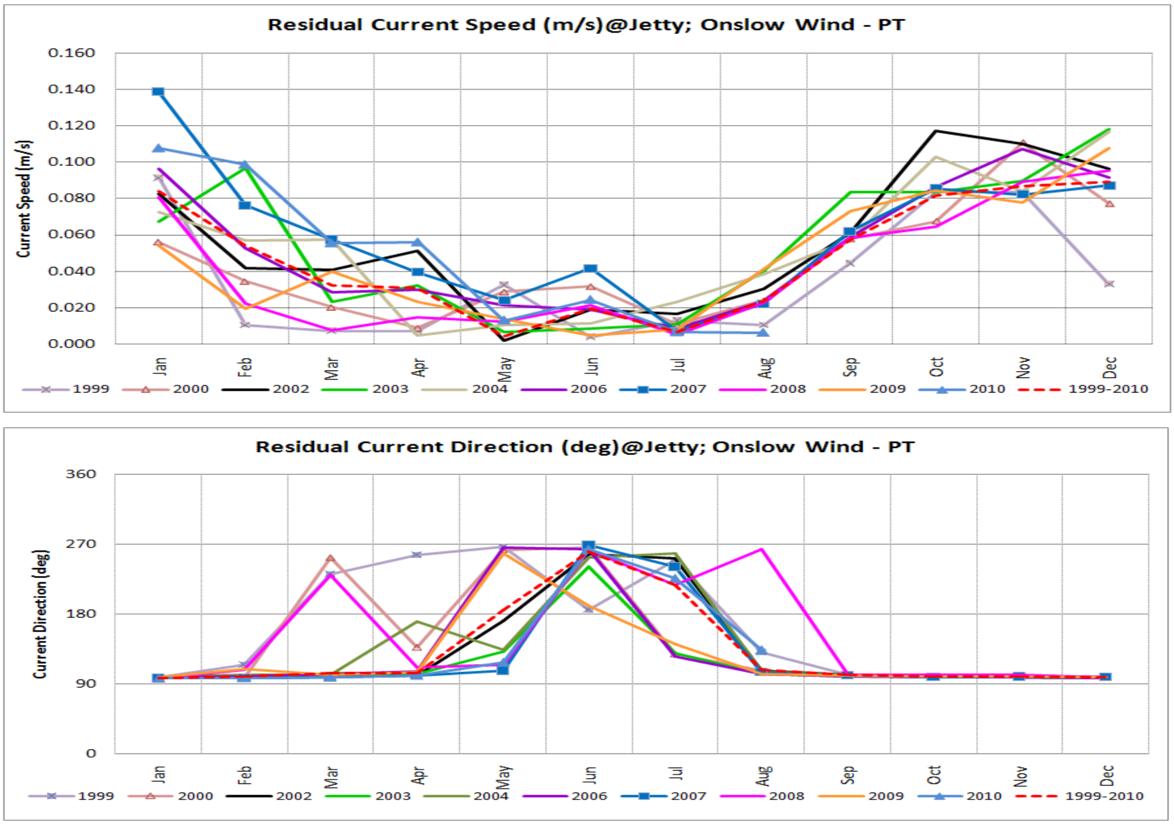


Figure FF.54 Net monthly current speeds (top) and directions (bottom) derived through vector addition at the "Jetty" location, see Figure FF.33, for Onslow winds.

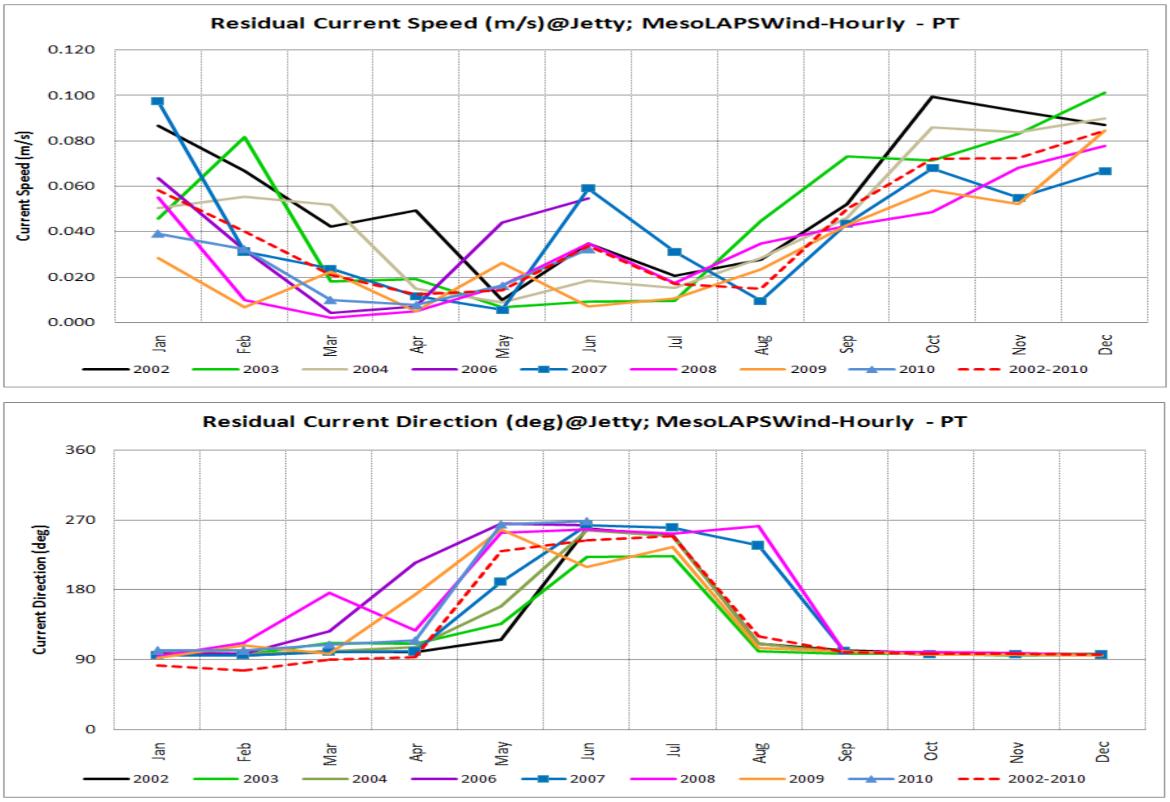
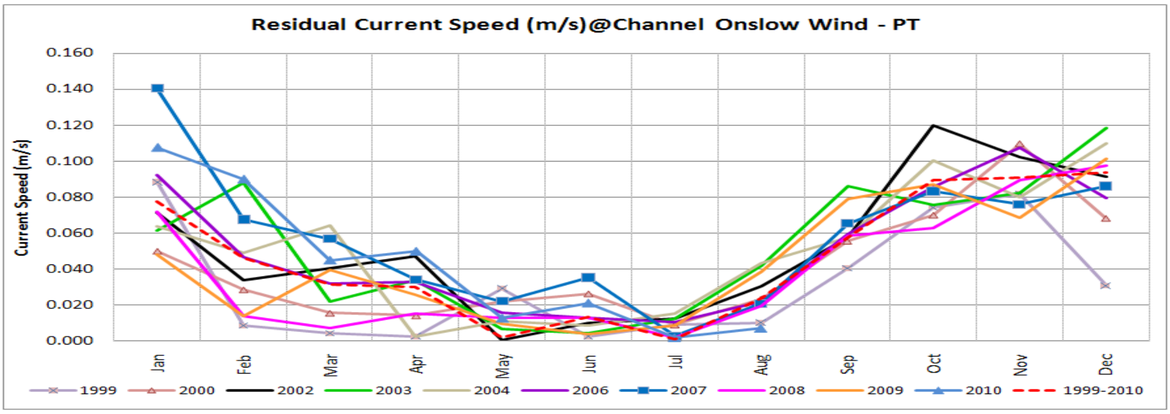


Figure FF.55 Net monthly current speeds (top) and directions (bottom) derived through vector addition at the "Jetty" location, see Figure FF.33, for MesoLAPS winds.



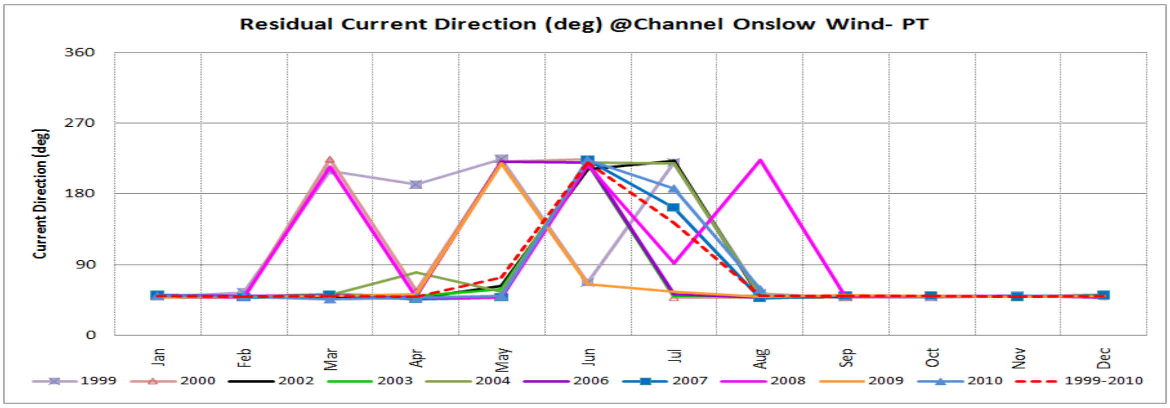
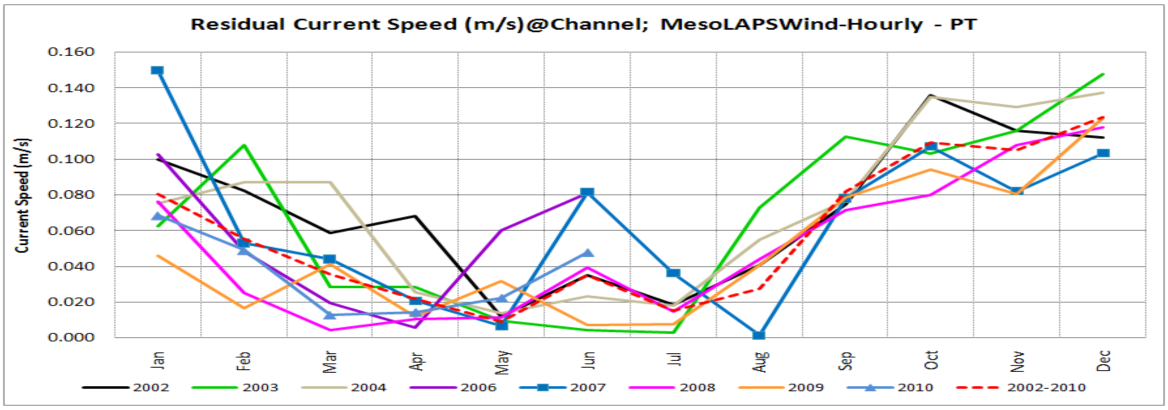


Figure FF.56 Net monthly current speeds (top) and directions (bottom) derived through vector addition at the "Channel" location, see Figure FF.33, for Onslow winds.



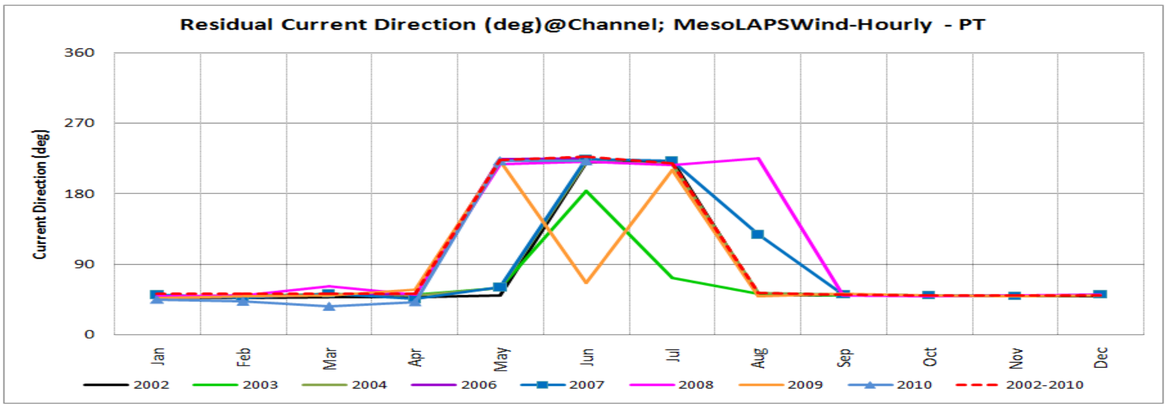


Figure FF.57 Net monthly current speeds (top) and directions (bottom) derived through vector addition at the "Channel" location, see Figure FF.33, for MesoLAPS winds.

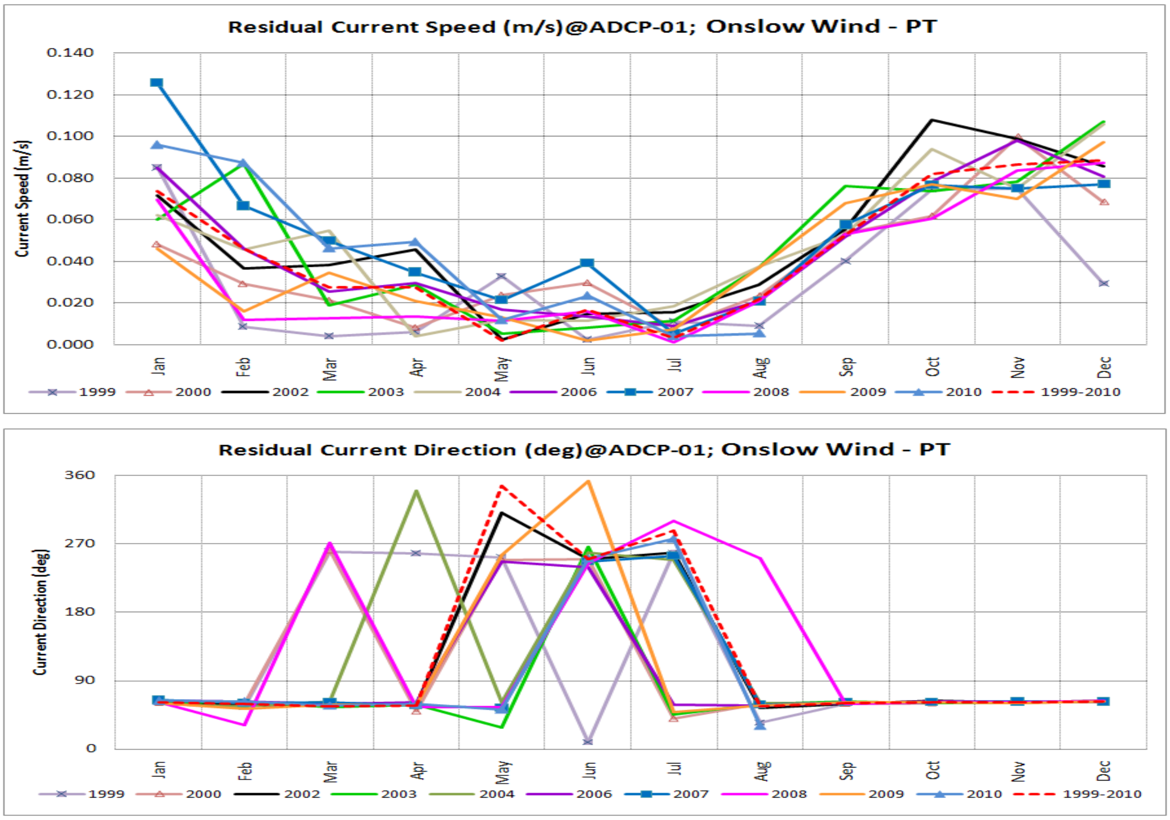


Figure FF.58 Net monthly current speeds (top) and directions (bottom) derived through vector addition at the "ADCP-01" location, see Figure FF.33, for Onslow winds.

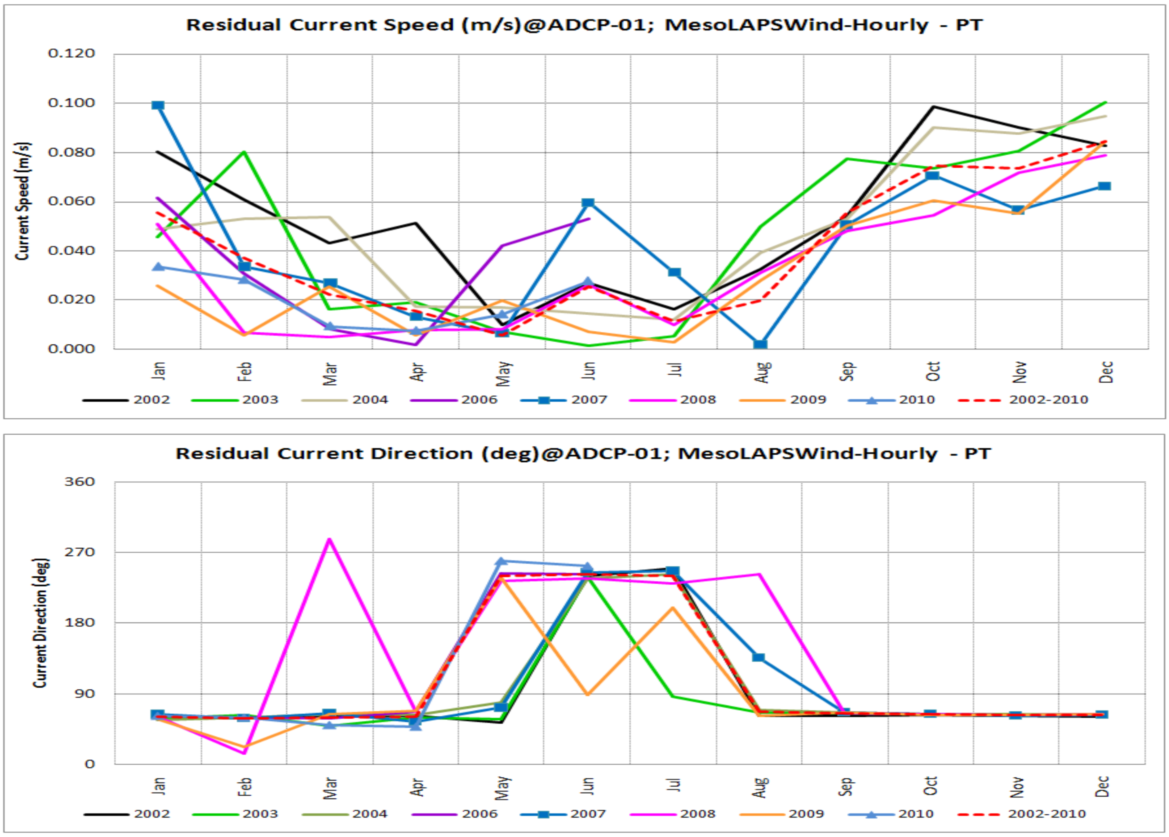


Figure FF.59 Net monthly current speeds (top) and directions (bottom) derived through vector addition at the "ADCP-01" location, see Figure FF.33, for MesoLAPS winds.

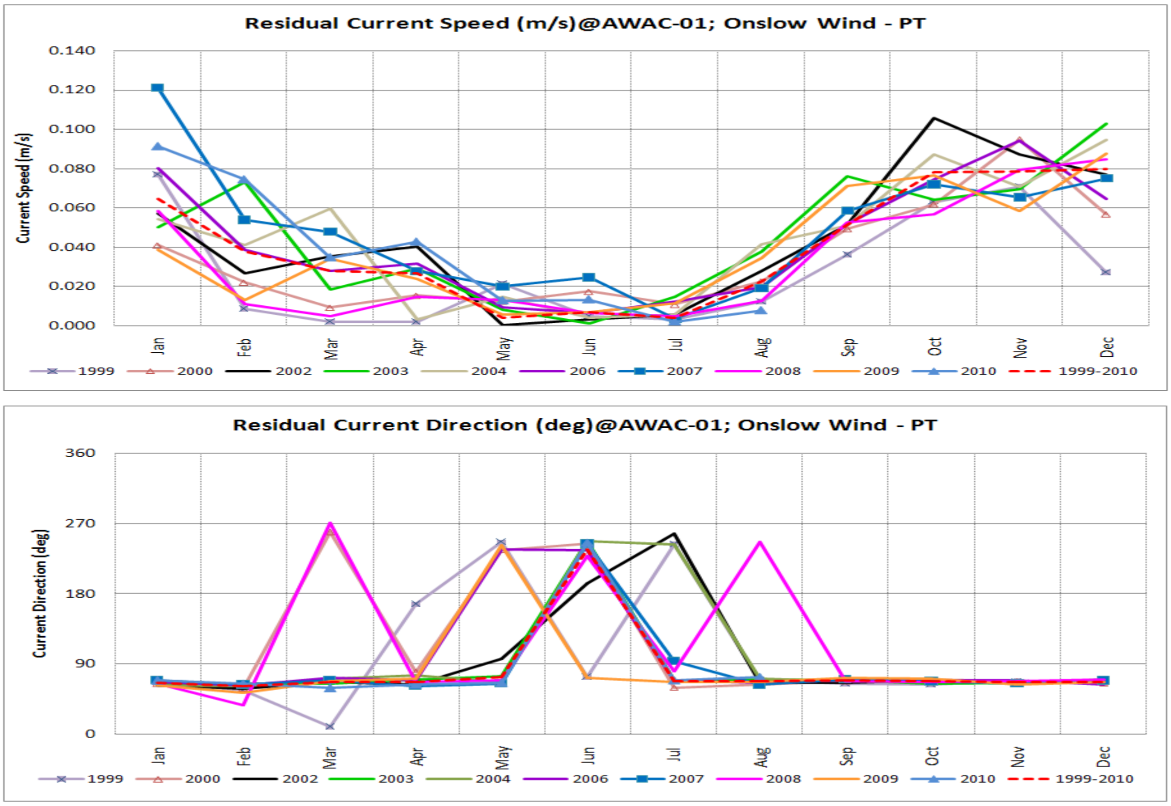


Figure FF.60 Net monthly current speeds (top) and directions (bottom) derived through vector addition at the "AWAC-01" location, see Figure FF.33, for Onslow winds.

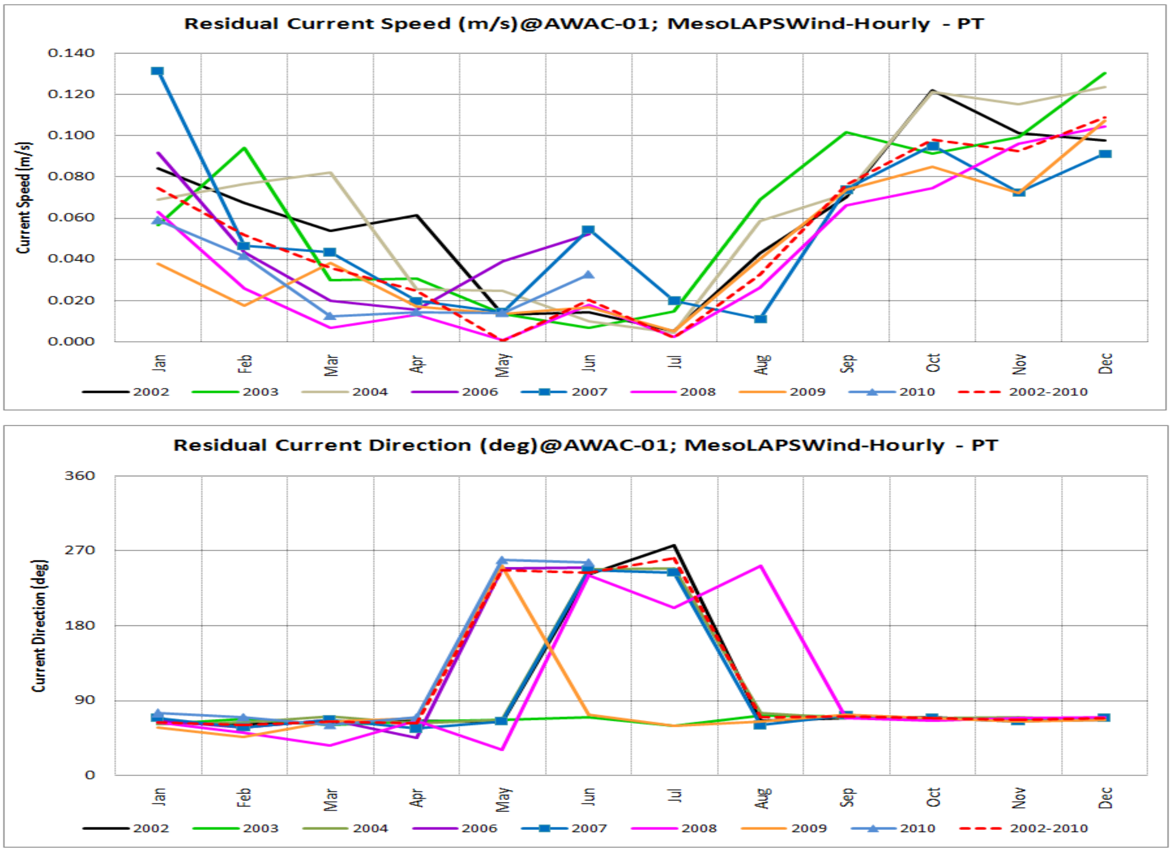


Figure FF.61 Net monthly current speeds (top) and directions (bottom) derived through vector addition at the "AWAC-01" location, see Figure FF.33, for MesoLAPS winds.

FF.5 Summary and Conclusions

The selection of climatic scenarios is one of the key components for dredge plume modelling. For Wheatstone, where the transport away from the site is dominated by variable wind driven currents, the climatic scenarios are of particular importance. The climatic scenarios must target a range of conditions to provide “realistic” worst case conditions throughout the potential impact area. This includes both mild weather conditions which will cause lower dispersion with resulting higher concentrations and sedimentation rates in the near field area and stronger winds which will tend to disperse the plume more rapidly and reduce near-field impacts, but drive the plume further away from the dredge area and thereby extend the zone of impact and define the zone of influence.

Waves, which are important for the settling and resuspension of sediments, are included in the models based on the same winds that drive the net currents.

Significant intra- and inter-annual variability exists in the climatic conditions at the site. To represent this, three seasons have been defined, and two climatic periods defined for each season. With the use of two different wind fields to drive the model, this in effect leads to six periods with two different wind fields, i.e. a total of twelve different climatic drivers.

A comprehensive assessment of both winds and net current fields has been carried out to assess whether the adopted climatic scenarios can be considered reasonably conservative. The assessment showed that the chosen “strong” winter and summer conditions comprise the strongest monthly averages of net wind and current fields. The transitional periods include weak and variable winds and net currents to cover the potential local build-up of sediments during periods of neap tide.

A particular strength of the scenario modelling approach adopted for the Wheatstone EIA is the independence of the timing of the climatic conditions as all climatic scenarios are combined with all defined dredge scenarios to develop total envelopes of the impact zones. Whereas the inter-annual variability may shift the seasonal currents, it was found that the overall ranges of net current speeds and consistency were well covered by the periods adopted for the climatic scenarios.

Whereas the limited number of climatic scenarios do not cover all variations of winds and resulting net currents that will be experienced during the dredging period, it is concluded that the range of both summer, winter and transitional (calmer) conditions are well covered and provide a reasonably conservative estimate of the impact zones when applied through the scenario modelling approach.

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Appendix H1

Baseline Soil Quality and Landforms Assessment

Final Report

Baseline Soil Quality and Landforms Assessment

13 JANUARY 2011

Prepared for

Chevron Australia Pty Ltd

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Abbreviations

Abbreviation	Description
AHD	Australian Height Datum
ALS	Australian Laboratory Services
ANC	Acid Neutralising Capacity
ANZECC	Australian and New Zealand Environment and Conservation Council
ASS	Acid Sulfate Soil
BSQ	Baseline Soil Quality
CSIRO	Commonwealth Scientific and Research Organisation
DEC	Department of Environment and Conservation
DEWHA	Department of Environment, Water, Heritage and the Arts
Domgas	Domestic Gas
EIL	Ecological Investigation Level
EPA	Environment Protection Authority
ERMP	Environmental Review and Management Programme
GSWA	Geological Survey of Western Australia
HIL	Health Investigation Levels
LNG	Liquefied Natural Gas
MBO	Monosulfidic Black Ooze
MOF	Marine Offloading Facility
MTPA	Million Tonnes Per Annum
NATA	National Association of Testing Authorities
NHMRC	National Health and Medical Research Council
NEPM	National Environment Protection Measure
PASS	Potential Acid Sulfate Soil
SAP	Sampling and Analysis Plan
SIC	Shared Infrastructure Corridor
SD	Standard Deviation
TPA	Titratable Peroxide Acidity
TSA	Titratable Sulfidic Acidity
URS	URS Australia Pty Ltd
WA	Western Australia

Executive Summary

URS Australia Pty Ltd (URS) was commissioned by Chevron Australia Pty Ltd to undertake a baseline soil quality and landforms assessment for the proposed Wheatstone Project which includes Ashburton North and surrounds, the Shared Infrastructure Corridor, Domgas Pipeline and the Accommodation Village (collectively known as the Terrestrial Assessment area).

The following report details the works completed for Ashburton North and surrounds, the Shared Infrastructure Corridor (SIC study area) the Domgas Pipeline (Domgas study area), Accommodation Village (Camp study area) and the Construction Area (Construction study area, which includes Borrow Area 2). This assessment was completed, in part, as a desktop study comprising a review of land systems and landforms at a regional scale, followed by a site specific assessment of landforms and baseline soil quality (including potential acid sulfate soils [PASS]), completed between March and October 2009. The assessment also included a review of subsequent intrusive geotechnical and PASS investigations undertaken by Coffey (2010) and Golder (2010), which further aided in the assessment of PASS across the Terrestrial Assessment area.

A series of seven land systems were defined within the Terrestrial Assessment area and include the Littoral, Dune, Onslow, Giralia, Stuart and Uaroo land systems. Ashburton North and surrounds and the Construction study area is generally comprised of the Littoral land system which is dominated by landforms including intertidal creeks, mangrove swamps and supratidal salt flats on the north eastern boundary and samphire flats and claypans along the north western boundary.

Alluvial/colluvial plains and clayey plains, generally dominate the remainder of the Terrestrial Assessment area. The alluvial/colluvial plains are characterised by low swales and slopes with soils comprising dark reddish brown sands and sandy loams along the northern boundary of the SIC study area and the Construction study area.

Linear inland dunes, comprising of parallel dunes, trending north-south, are intermittently encountered along the northern boundary of the SIC study area and Domgas study area and throughout the Construction study area.

As part of the Ashburton North and surrounds investigation, a total of 18 soil bore and nine hand auger locations were investigated to a depth ranging between 0.3 and 4.6 metres below ground level (mbgl). Analytical testing for a suite of heavy metals, and for the soil's potential acid generating capacity, was completed on 38 and 44 primary samples, respectively on representative soil profiles identified across Ashburton North and surrounds.

Ten hand auger locations ranging in depths from 1.5 to 1.6 mbgl were completed along the SIC study area. In total, 37 primary samples were collected during the intrusive investigation of which 12 were submitted for analysis.

A review of available geotechnical and PASS investigation reports, completed as part of the Wheatstone Project, was also undertaken to further aid in the vertical and horizontal delineation of PASS across the Terrestrial Assessment area, and in the determination of the potential acid generating capacity of this material. This information was then used to help derive the PASS map and the approximate thickness and depth of PASS across the Terrestrial Assessment area.

Executive Summary

As this investigations primary objective is to identify baseline soil quality, and because there has been no land disturbance or industrial activity of the Terrestrial Assessment area, assessment of soil data against threshold levels is not required. However, as a means of comparison and to also provide an assessment of whether naturally occurring compounds (metals) may pose a risk to human health, a comparison against relevant Western Australian (WA) guidelines has been made.

Analytical results reported elevated metal concentrations against adopted assessment criteria for Ecological Investigation Levels (EIL) (Department of Environment and Conservation [DEC], 2003) for arsenic, chromium, manganese and nickel, in the north western to north eastern section of Ashburton North and surrounds. Reported analytical results were all below the adopted Health Investigation Levels (HIL).

Comparison of the these results against an assessment of heavy metals completed by Oceanica (2005) and URS (2008) along the Pilbara coastline of similar deltaic systems, also reported elevated concentrations of arsenic, chromium and nickel. The elevated metals encountered are comparable suggesting that the high background levels are likely a result of the weathering of terrestrial origin.

The results of the field and analytical investigations, the geotechnical bore (Coffey, 2009) and Golder (2010a, 2010b and 2010c) review indicates that PASS is present at shallow depths ranging between 0.25 mbgl and 5.25 mbgl. Corresponding elevations indicate PASS was typically encountered below 3 mAHD ranging between 1.52 and -3.0 mAHD (mean 0.60 mAHD) and was typically intercepted at or below the watertable (assuming some change in elevation due to tidal fluctuations).

PASS thickness ranges between 0.2 and 3.5 m, predominantly along the north and north eastern extent of the Terrestrial Assessment area and the samphire flats to the west of the longitudinal dune network. However PASS has also been identified further south along the supratidal salt flats where the SIC study area boundary is located.

PASS was also identified at depths typically below 2.5 mbgl (and below 1.5 mAHD), on the southern part of Borrow Area 2 located to the east of the longitudinal dunes, which is bound by the supratidal salt flats. To a lesser extent, PASS was identified intermittently on the adjacent Borrow Area 3, located to the east of Borrow Area 2, where PASS was typically identified in low lying claypan areas.

Corresponding soil profiles were typically characterised as dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND, with trace organics. Mottling was identified in both clayey and sandy profiles, ranging in colour from yellow and orange, evidence of oxidation considered to be typical of a fluctuating water table.

Uncharacteristically however, soils characterised as Ashburton Red Beds (Coffey,2009), in this case comprising red brown SAND to silty clayey GRAVEL, exhibited low net acidity concentrations in 10% of the samples submitted for analysis in Borrow Area 4.

The acid neutralising capacity (ANC) of the Terrestrial Assessment area is generally high, however is typically absent in soil profiles identified as PASS. Soils with the highest ANC throughout Ashburton North and surrounds generally comprised of sands and sand clays with shell, limestone and/or sandstone interbedded throughout. ANC of the SIC study area was significantly lower with highest buffering capacity detected in the red clayey sands.

A PASS map was produced identifying areas reported below the DEC trigger value of 0.03% sulfur (%S) and as low, moderate and high potential to generate acidity for the Terrestrial Assessment area. Based on the results of the PASS assessment, PASS of high acid generating potential is typically located in the north and north eastern extent of the Terrestrial Assessment area of the intertidal flats, the samphire flats and clayey plains along the north western boundary, along the southern boundary of Borrow Area 2 (below 3 mbgl), and below alluvial colluvial plains where shallow marine/organic deposits were identified.

Given the variable nature of the acid generating potential of material encountered, it is typical to encounter PASS of moderate acid generating potential interspersed in pockets in areas identified as high potential. This is noted along the north western boundary of the Terrestrial Assessment area and the southern part of the Borrow Area 2.

The area to the north north west of the Terrestrial Assessment area, closest to the Indian Ocean, has been classified as low potential for encountering PASS based on soil types encountered at depth, and inferred landforms, which are considered indicative of PASS.

The supratidal salt flats are considered to be of low acid generating potential where PASS material was typically encountered at shallow depths (<1 mbgl) with a thickness of less than 1.0mbgl. Clayey pockets dotting the SIC study area have been classified as low acid generating potential, given that low %S have been detected as far south as the Construction study area.

The northern limits of Borrow Area 4 is considered to be of low acid generating potential based on analytical tests which identified net acidity in exceedance of the adopted DEC guideline criteria in 10% of soil samples characterised as Ashburton Reds.

Borrow Area 1, the majority of Borrow Area 3 and 4, the Domgas study area, and the majority of the SIC study area has been reported to be below the DEC trigger value of 0.03%S, given the nature of the landforms, field screening and analytical results and based on soil types encountered.

Introduction

Chevron Australia Pty Ltd (Chevron) proposes to construct and operate a multi-train liquefied natural gas (LNG) plant and a domestic gas (Domgas) plant 12 km south west of Onslow on the Pilbara Coast. The LNG and Domgas plants will initially process gas from fields located approximately 200 km offshore from Onslow in the West Carnarvon Basin and future yet-to-be determined gas fields. The project is referred to as the Wheatstone Project and Ashburton North and is the proposed site for the LNG and Domgas plants. The Project will require the installation of gas gathering, export and processing facilities in Commonwealth and State Waters and on land. The LNG plant will have a maximum capacity of 25 Million Tonnes Per Annum (MTPA) of LNG.

The Wheatstone Project has been referred to the State Environmental Protection Authority (EPA) and the Commonwealth Department of Environment, Water, Heritage and the Arts (DEWHA). The investigations outlined in this report have been conducted to support the environmental impact assessment process.

URS Australia Pty Ltd (URS) was commissioned by Chevron Australia Pty Ltd to undertake a baseline soil quality (BSQ) and landforms assessment for the proposed Wheatstone Project which includes Ashburton North and surrounds, the Shared Infrastructure Corridor (SIC), Domgas Pipeline and Accommodation Village (collectively known as the Terrestrial Assessment area).

This report presents results from the desktop and intrusive works completed for Ashburton North and surrounds, the SIC and the Domgas study areas, and a desktop review of landforms and soils for the Camp and Construction study area.

1.1 Objectives

The objective of the programme was to provide sufficient information for an Environmental Review and Management Programme (ERMP) level of assessment, in accordance with the *Guidelines for Preparing a Public Environmental Review/ Environmental Review and Management Programme* (Environmental Protection Authority [EPA, 2009]) as requested for the Wheatstone Project, by the Western Australian (WA) EPA.

Specifically, the objectives of the desk top reviews and field works were to:

- Complete a regional review and a site specific assessment of the soils and landforms identified for Ashburton North and surrounds, the SIC and Domgas study area.
- Complete a regional review and desktop assessment of the soils and landforms of the Camp and Construction study area.
- Identify baseline metal concentrations of the surface and subsurface profile within Ashburton North and surrounds and the SIC study area.
- Identify generalised limitations of soils encountered for use in rehabilitation.
- Assess the general extent of PASS and the acid generating potential of such soils in general accordance with the definitions set out by Ahern *et al* (1998) and DEC Acid Sulfate Soils (ASS) Guidelines Series (updated May 2009).

The objectives outlined above, and works completed to date, are in accordance with the, Environmental Scoping Document.

1.2 Scope of Works

To meet the above objectives, the following scopes of works were completed:

- A desktop review of published and available data including geotechnical logs in areas of interest, topographic maps, PASS maps, geological and environmental maps and completed surveys of the Terrestrial Assessment area as they become available.
- An assessment of aerial photography (for coarse landform assessment) and available soils investigations and associated geochemical data covering the Terrestrial Assessment area and the surrounding Onslow region.
- A sampling and analysis programme (**Appendix A** of Appendix HI Draft Environmental Impact Statement [EIS]/ Environmental Review and Management Programme [ERMP] [Chevron, 2010]), detailing the field methodologies, procedures and laboratory analyses completed for the assessment of landforms and BSQ of the Terrestrial Assessment area.
- *In situ* field tests to assess PASS and soil stability including field pH (pH_f), field peroxide pH (pH_{fox}), a calcareous reaction test (effervescence or fizz test) and field dispersion testing of the surface and subsurface profile at sample locations.
- Analytical testing of existing and potential acidity of the soil using Chromium method in accordance with the Department of Environment and Conservation (DEC) Identification and Investigation of Acid Sulfate Soils (2009a) and the Guidelines for Sampling and Analysis of Lowland Acid Sulfate Soils in Queensland 1998 (Ahern *et al*. 1998).
- Analytical testing for a suite of metals including aluminium (Al), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), copper (Cu), iron (Fe), lead (Pb), mercury (Hg), manganese (Mn), nickel (Ni), vanadium (V) and zinc (Zn).
- Laboratory testing of selected soil samples at a National Association of Testing Authorities (NATA) accredited laboratory Analytical Laboratory Services of Perth (ALS).
- Production of this interpretative report which presents the soils and landforms identified within the Terrestrial Assessment area, including baseline soil quality and characterisation of the potential to encounter PASS, to meet the requirements of the '*ASS Guidelines Series'* (2004) as adopted by the DEC (updated May 2009).

Environmental Setting

2.1 Location

The Wheatstone Project is located within the Pilbara Region of Western Australia approximately 1400 km north of Perth, and 12 km south west of Onslow. The Wheatstone Project components include Ashburton North and surrounds, the Shared Infrastructure Corridor, hereafter referred to as SIC, the Accommodation Village, the Domgas Pipeline and the Construction Area.

Ashburton North and surrounds is located along the coastal boundary of the Wheatstone Project and is bound by the Indian Ocean to the north, the Ashburton River to the west, and Hooley Creek to the east (**Figure 1)**.

The SIC commences along the south eastern boundary of Ashburton North and generally proceeds in a south easterly direction where it meets Onslow Road approximately 12 km from Ashburton North. The Accommodation Village is located approximately mid point along the SIC over an area of approximately 460 ha. The Domgas Pipeline follows the route of the SIC before running parallel to Onslow Road for a further 53 km in a south east direction.

The Construction Area is located over an area of approximately 838 ha and incorporates land that may be disturbed for construction roads and Borrow Areas.

2.2 Topography

The topography of the Wheatstone Project consists of undulating dunal systems (including longitudinal, coastal and fringing dunes), alluvial/colluvial plains, and low lying coastal systems (including supratidal flats, samphire/salt flats, claypans, tidal creeks, intertidal flats and mangroves).

The greatest ‘spot’ heights of the Terrestrial Assessment area range between approximately 5 and 21 mAHD (Landgate, 2007) and are associated with the longitudinal coastal and fringing dunes. Similarly, areas of low relief are associated with the supratidal flats, claypans, tidal creeks, intertidal flats and mangroves which are generally below 5 mAHD.

2.3 Geology and Stratigraphy

A geological mapping programme undertaken by the Geological Survey of Western Australia (1975) produced a 1:250,000-scale map series and geological descriptions in Bulletin 133. These geological data and interpretations were substantially updated by publications by Iasky and Mory (1999) and Iasky *et.al* (2003). The following interpretation was adapted from the URS (2009) desktop assessment of this information.

The Palaeozoic-Recent Northern Carnarvon Basin is a large, mainly offshore basin on the northwest shelf of Australia developed during four successive periods of extension and thermal subsidence. The Wheatstone Project is located on the Peedamullah Shelf within the Northern Carnarvon Basin.

The main deposition centres of the Northern Carnarvon Basin host up to 12 km of sedimentary infill. Triassic to Early Cretaceous deposition is dominantly siliclastic deltaic to marine, whereas slope and shelfal marls and carbonates dominate the Mid-Cretaceous to Cainozoic section.

2 Environmental Setting

The carbonate-rich sediments were deposited as a series of northwest propagating wedges as the region continued to cool and subside resulting in the deep burial of the underlying Mesozoic source.

The geology and stratigraphy beneath the Wheatstone Project is presented in **Table 2-1** below, as interpreted from the Jade 1 petroleum exploration well for the Department of Industry and Resources, Western Australia (Information Request for Jade 1, 1993). The Jade 1 petroleum exploration well was located within the Terrestrial Assessment area and is considered representative of the geology of the region. The geological core log is attached as **Appendix B** of Appendix HI Draft ERMP/EIS [Chevron, 2010]).

Table 2-1 Interpreted Stratigraphy

Formation		Age	Lithology
Superficial Formations Dune Sands		Recent/Quaternary	Gravelly sand, calcareous sandstone and sand variably lithified and consolidated.
Superficial Formations Ashburton River Delta Alluvium		Recent/Quaternary	Poorly consolidated claystones and minor limestone.
----------Unconformity----------			
Trealla Limestone		Tertiary	Interbedded limestones and claystones with siltstone, sand and limestone at the base.
----------Unconformity----------			
Winning Group	Gearle Siltstone	Early-Cretaceous	Argillaceous siltstone, grading to a silty claystone; commonly pyritic, glauconitic and micaceous.
	Windalia Radiolarite	Early-Cretaceous	Radiolariean siltstone.
	Muderong Shale	Early-Cretaceous	Argillaceous siltstone with thin lenses of siltstone and fine sandstone.
	Mardie Greensand Member	Early-Cretaceous	Glauconite-rich sandstones and minor interbedded claystone, silica cemented.
	Birdrong Sandstone	Early-Cretaceous	Glauconitic sandstone with minor interbedded claystone.
Mungaroo Formation		Triassic	Quartzose sandstones, siltstones and shale.

The superficial sediments of quaternary age are generally 4.5 to 25.0 m in thickness and are dominated by unconsolidated sediments comprising intertidal flats and mangrove swamps (calcareous clay, silt and sand) beaches and coastal dunes (reddish-brown to yellow quartz sand) and residual sand plains and alluvium associates within the Ashburton River System (Geological Survey of Western Australia (GSWA), 1982) (**Figure 2**).

2.4 Hydrogeology

Within the Northern Carnarvon Basin, unconfined aquifers are known to be formed by alluvial palaeochannel successions associated with ancient watercourses beneath reaches of most of the major rivers (URS, 2009). Unconfined aquifers are also known to form as alluvial successions beneath the wide coastal river valleys and deltas associated with the drainage basins formed by the Yannarie, Ashburton, Cane, Robe and Fortescue Rivers. Local minor aquifers may potentially be present below dune beach sands.

Groundwater is also hosted in confined aquifers in the deeper Carnarvon Basin successions. Confined aquifers underlying the Wheatstone Project are known to be formed by the Trealla Limestone (semi-confined by the superficial formations), and Birdrong Sandstone (confined by the Gearle Siltstone and Muderong Shale) (Wills and Dogramaci, 2000).

The Birdrong Sandstone is the most significant regional confined aquifer in the Carnarvon Basin and is intersected by both artesian and sub-artesian water supply bores. Historically, it has been used to supply predominantly brackish (1,000 to 12,000 mg/L TDS) groundwater to pastoral and salt industries.

2.5 Hydrology

The Ashburton River is considered to be one of the major rivers of the Pilbara Region with a catchment area of approximately 78 777 km^2. Stream flow is typically ephemeral, occurring in response to significant local and regional rainfall events.

Runoff is generated in the upper reaches of the catchment due to greater topographic relief of the low rugged ranges (URS, 2009). Downstream on the coastal plain, the Ashburton River fans out into a deltaic system made up of wide and braided flow paths before discharging into the Indian Ocean. The delta contains tidal creeks and pools, which are frequently inundated by the sea in the lower reaches. Major flows occur in the Ashburton River every one to three years. River flows predominantly occur during the cyclone seasonal and are typically short-lived.

The Wheatstone Project is on a local-scale catchment divide between the Hooley Creek Catchment, Southwest Catchment (southwest of the proposed Wheatstone LNG plant) and the Ashburton River, each of which are hosted by the coastal delta area of the Ashburton River, termed the Ashburton River Delta. The Wheatstone Project is located in the tidal zone and is exposed to rainfall and storm surge associated with cyclones.

2.6 Landforms

At a regional scale, the Wheatstone Project is part of the Western Region soil-landscape covering about half of the total area of Western Australia. The boundaries of the Western Region extend from the Indian Ocean to the edge of the Sandy Desert and Central Southern Regions and comprise of landforms including undulating plateaux, plains, hills and ranges and coastal plains

The Western Region has been divided into 10 soil-landscape provinces. The majority of the Wheatstone Project is located within the Exmouth soil-landscape Province, while the south eastern boundary of the Wheatstone Project, along the Domgas study area, is located within the Ashburton Province. These boundaries are based on Jennings and Mabbutt (1977).

The Exmouth Province occupies about 25,100 km^2 with landforms generally comprising of alluvial plains or sand plains with coastal flats and dunes (and some ranges and stony plains) on sedimentary rocks. The Ashburton Province is located to the south east of the Exmouth Province and occupies about 188,375 km^2. The Ashburton Province is comprised of a mosaic of hilly terrain and stony plains, with rugged ranges, hills, ridges and plateaux are found on the sedimentary rocks.

2.7 Soils

Soils are varied over the Western Region as a result of a wide range of parent materials and climatic conditions encountered. Major soils encountered within the Western Region have been defined by the Soils Group of Western Australia (Schoknecht, 2002). As reported by Tille (2006) and as defined by Schoknecht (2002), soils of the Exmouth Province generally comprise of Red deep sands and Red deep sandy duplexes and Red sandy earths dominating the broad, sandy surfaced plains and dune landscape.

Component zones associated with Exmouth Province include the Yannery Plains and Onslow Plains. Sandplains and alluvial plains (and some floodplains) of the Yannery Plains comprise red deep sands with red/brown non-cracking clays and red deep sandy duplexes with some hard cracking clays. These soils have been identified in the north-west coast between the Ashburton and Lyndon rivers.

Coastal mudflats (with some sandplains and coastal dunes) of the Onslow Plains comprise tidal soils with Calcareous deeps sands and some red deep sands, red/brown non-cracking clays and salt lake soils. These soils are located in the north-west coast between Cape Preston and the Exmouth Gulf.

Soils of the Ashburton Province generally comprise of Stony soils dominating the hilly terrain, and Red shallow loams, Red brown non-cracking clays, Red loamy earths and Red deep sandy duplexes of the stony plains.

2.8 Acid Sulfate Soils

Acid sulfate soils are naturally occurring soils, sediments and peats that contain iron sulfides, predominantly in the form of pyrite materials. These soils are most commonly found in low-lying land bordering the coast, estuarine and saline wetlands in soils comprising of Holocene marine muds and sands in protected low-energy environments.

Acid sulfate soils are formed when seawater or sulfate-rich water mixes with land sediments containing iron oxides and organic matter in a waterlogged situation, in the absence of oxygen.

In an undisturbed anoxic state, these materials remain benign, and do not pose a significant risk to human health or the environment and are referred to as PASS. However, the disturbance of PASS, and its exposure to oxygen, leads to the production of acidic conditions which have the potential to cause significant environmental and economic impacts including fish kills and loss of biodiversity in waterways; contamination of groundwater by acid, leaching of arsenic and heavy metals and corrosion of concrete and steel infrastructure by acidic water.

The probability of encountering acid-generating material in the region ranges from " low" to "high", according to acid sulfate soils risk mapping completed by the DEC (2009). The high probability areas are generally located in low lying areas of 0 to 3 m above Australian Height Datum (AHD) including Holocene intertidal flats, supratidal salt flats and mangrove swamps. Low probability areas are generally associated with deposits of coastal dune, beaches and longitudinal dunes (**Figure 3**). Probable layers of organic and marine deposits are located at shallow depths, and low probability areas and associated with the coastal dunes and Red earths.

2.9 Contaminated Soils

Based upon the information derived from the publicly accessed DEC Contaminated Sites Database (accessed May 2009), which references the underdeveloped nature of the area; and the fact there are no known historical contaminating land use practices within the footprint of the Terrestrial Assessment area , it is considered unlikely.

A review of recent aerial photography indicates that land use to the east of the Terrestrial Assessment area is used for solar salt manufacturing. Onslow Salt Pty Ltd (Onslow Salt) is licenced under the Environmental Protection Act 1986-Licence. The premises are classified as solar salt manufacturing (category 14) and bulk material loading and unloading (category 58) under the Environmental Protection Regulations 1987. While there are likely to be sections of the Onslow Salt operations that have the potential to contaminate (such as petroleum hydrocarbon storage and use, plant/machinery workshops, waste disposal etc) these areas of the Onslow Salt operations are located to the north east of the salt ponds. Therefore due to the distance from the Terrestrial Assessment area these operations are considered unlikely to have an adverse impact on the Terrestrial Assessment area.

A search of the DEC Contaminated Sites Databases indicates there is no known contamination history reported for these operations.

2.10 Vegetation

The majority of the Wheatstone Project lies within the Cape Yannarie Coastal Plain of the Cape Range subregion of the Carnarvon Botanical District (Beard, 1975) and to a lesser extent, the Onslow Coastal Plain of the Roebourne subregion of the Fortescue Botanical District (Beard, 1975) located along the Domgas study area.

The Cape Yannarie Coastal Plain generally comprise mangrove dominant vegetation along the coastal parts of the Wheatstone Project, including *Avicennia marina* as the principal species and some *Rhizophora stylosa* (Biota, 2009 and Outback Ecology Services [OES], 2010*).* Behind the tidal creeks and mangrove swamps are bare saline mud flats or intertidal flats, which sometimes floods with spring tides. This zone is generally devoid of any vegetation, although some samphire communities occur locally (*Tecticornia* species).

Inland of the tidal mud flats area (supratidal salt flats) is a zone mapped as shrub steppe on sandhills with numerous small claypans. The shrub steppe is typically dominated by *Triodia* species (*T. epactia/pungens*) with *Acacia bivenosa, A. synchronicia, A. tetragonophylla* and *A. xiphophylla* the most common shrub species present.

Vegetation of the Onslow Coastal Plain is dominated by *Acacia victoriae, A. xiphophylla* in shrubland *and Acacia pyrifolia* in open shrubland with *Triodia pungens, T. basedowii* in open hummock grassland and mixed grassland.

2.11 Conservation Reserves

The Cane River Conservation Park (C-Class Reserve) is located approximately 100 km south of Onslow and 4.5 km to the east of the eastern end of the Domgas study area. The National Reserves System Co-operative Program, however, is proposing to include extensions to the Cane River Conservation Park to include the Mt Minnie Pastoral Lease, Ashburton (110 921ha), and part of the Nanutarra Pastoral Lease, Ashburton (70 030 ha). This may occur in 2015, and once implemented, the eastern 44 km section of the Domgas study area will be located within the Park.

Some of the conservation values of the Cane River Conservation Park include (DEC 2009c):

- Landforms and vegetation types of particular interest not found in other conservation reserves in the Pilbara.
- Contrasting granite outcrops and sandstone ranges including the Parry Range and Mt Minnie.

According to the DEC (2009c), “conservation parks are managed for their scenic, cultural and biological values, to conserve wildlife and the landscape, for scientific study and to preserve features of archaeological, historical or scientific interest”. It has been identified by the DEC that conservation parks require ongoing management to protect biodiversity values, control weeds and feral animals, manage fire and to provide for visitor access and facilities.

Land Systems of the Terrestrial Assessment Area

Land systems mapping for the Terrestrial Assessment area, have been adapted from Payne *et al.* (1988) and van Vreeswyk *et al.* (2004). Land systems are comprised of repeating patterns of topography, soils, and vegetation (Christian and Stewart 1953)

A series of seven land systems have been identified within the boundaries of the Terrestrial Assessment area and include the Onslow, Littoral, Dune, Minderoo, Giralia, Stuart and Uaroo land systems (**Figure 4)**.

The land systems are described as follows:

- The Onslow land system comprises sandplains, dunes and clay plans supporting soft spinifex grasslands and minor tussock grasslands.
- The Littoral land system comprises coastal mudflats with mangroves on seaward fringes, samphire flats, sandy islands, coastal dunes and beaches.
- The Dune land system comprises dune fields supporting soft spinifex grasslands and depositional surfaces such as sand dunes and swales.
- The Minderoo land system comprises alluvial plains supporting tall shrublands and tussock grasslands and sandy plains supporting hummock grasslands.
- The Giralia land system comprises linear (parallel) dunes up to 30 m in height, sandy, broad non-saline and calcrete plains supporting hard spinifex pastures.
- The Stuart land system comprises gently undulating plains, minor hills and broad lower plains supporting hard and soft spinifex and stony chenopod.
- The Uaroo land system comprises low hills, low stony rises and pebbly, sandy and calcrete plains supporting hummock grasslands of soft and hard Spinifex.

These land systems and associated geomorphologic characteristics within the Terrestrial Assessment area are presented in **Table 3.1** as adapted from Payne *et al* (1988).

URS

Table 3-1 Land Systems and Associated Geomorphology Occurring Within the Terrestrial Assessment Area

Land System	Associated Geomorphology	Components of the Terrestrial Assessment area Occurring In This Land System	Approximate Coverage of Land System Within The Terrestrial Assessment Area	
			Area (ha)	% of Total
Onslow	Depositional surfaces include sandy plains, with non saline clay plains subject to sheet flow, narrow drainage zones and minor depression. Coastal fringes of low sand plains interspersed with slightly lower saline samphire flats and minor claypans, coastal dunes and beaches of relief of up to 20m in height.	Ashburton North and surrounds, Shared Infrastructure Corridor, Accommodation Village, Construction Area and northern extent of Domgas Pipeline.	**1779**	**47**
Littoral	Depositional surfaces include saline coastal flats such as estuarine and littoral surfaces, with extensive bare saline mudflats that are subject to infrequent tidal inundation and slightly higher elevated samphire flats. Intense dissection patterns are identified where mangrove seaward fringes and tidal creeks are present. Minor linear dunes and sand plains of relief up to 6m in height are also present.	Ashburton North and surrounds, Construction Area and north western extent of Shared Infrastructure Corridor.	**1138**	**30**
Dune	Depositional surfaces include dune fields which comprise of sand dunes of relief of up to 1 m in height, and swales with no organised drainage. Minor claypans, swamps and depressions are also identified.	Ashburton North and surrounds and minor representation along the Shared infrastructure Corridor and Construction Area.	**275**	**7**
Minderoo	Depositional surfaces include alluvial plains which comprise of old floodplains associated with the Ashburton River and plains formed by sheet flood and deflation with no organised drainage. Sand plains, of relief of up to 20m in height, claypans, swamps and depressions are also identified.	Southern extent of the Accommodation Village and Construction Area.	**116**	**3**
Giralia	Depositional surfaces include sandy plains formed by sheet flood and wind action, broad non-saline plains with thin sand cover and linear dunes trending N-S with no organised drainage but through flow areas receiving more concentrated sheet flow than adjacent plains.	Northern extent of the Domgas Pipeline and Construction Area.	**140**	**3**
Stuart	Erosional surfaces include gently undulating plains and minor hills, broad lower plains. Relief up to 25m.	South eastern extent of Domgas Pipeline.	**71**	**2**
Uaroo	Depositional surfaces include sandy and non-saline sandy plains approximately 10km in extent, with little organised drainage. Pebbly surfaced plains and plains with calcrete at very shallow depth and minor low stony hills and rises. Relief is mostly less than 5m in height although isolated sills can be up to 30m.	Broad section of the central part of the Domgas Pipeline	**291**	**8**

4

Landforms and Soils of Ashburton North and Surrounds

The following landform units and soil profiles were derived from the completion of the desktop assessment of Ashburton North and surrounds and of the field programme undertaken between March to June 2009.

Landforms typically encountered within the boundary of Ashburton North and surrounds are shown in **Figure 5-1** and include:

- Tidal Creeks, Intertidal Flats and Mangrove Swamp.
- Supratidal Salt Flat.
- Samphire Flats.
- Claypans and Clay Plains
- Alluvial/Colluvial Plains.
- Fringing and Coastal Dunes.
- Longitudinal Dunes and Interdunal Swales.
- Mainland Remnant Dunes.

Landforms and soils typically encountered within the Ashburton North and surrounds study area is presented below:

4.1 Tidal Creeks, Intertidal Flats and Mangrove Swamp

The landform units identified as the tidal creeks, intertidal flats and mangrove swamp (**Plates 4-1 to 4-4**) form a major bio-physical system along the north western boundary of Ashburton North and surrounds as part of the Ashburton River delta, and to a lesser extent, near Hooley Creek. These landform units are generally associated with the Littoral land system.

Together, these landform units are characterised by sinuous tidal creeks and intertidal mud/sand flats characterised by surficial salt scalding and significant surface and shallow subsurface shell deposition. Relatively high tidal ranges lead to regular flooding of the shallow sloping shores.

A number of palaeochannels have been identified within Ashburton North and surrounds, with the most significant for this landform unit being adjacent to Hooley Creek, migrating inland along the western boundary of the longitudinal dunal network (Damara, 2009). The creeks associated with this landform unit, typically form a wide mouth which narrows and becomes shallow upstream via a sinuous channel, becoming dendritic toward the supratidal salt flats. Damara (2009) reported that water flow through the tidal creeks provides the major exchange of sediment between the nearshore marine and terrestrial areas.

Shallow soils of the low lying intertidal flats, tidal creek and mangrove swamp consists mainly of neutral and alkaline (saline) red brown surface soils grading dark brown to light brown, grey sandy clays, clays and fine to coarse grained silty sands. Carbonate concentrations are moderate (reflecting shelly material in the sediments) and the concentration of organic material is variable, but generally high.

At shallow depths, the accumulation of sediment beneath the mangrove swamp (due to trapping and baffling by vegetation) has resulted in strongly reducing conditions, poorly- to moderately-sorted silts and clays, with generally high concentrations of organic material. These clayey subsurface soils have the potential to generate acidity, with a thickness reported up to 1.0m..

4 Landforms and Soils of Ashburton North and Surrounds

Vegetation varies between densely vegetated mangrove swamp along the creek banks, to sparse spinifex grasses and algal mats in areas completely devoid of vegetation. Mangroves form a fringe along the tidal creeks, reducing in density with distance from the edge of the creeks.

Intertidal flat and mangrove swamp deposits generally consist of the following:

- SAND: fine to medium grained, red brown with some clay, trace of gravel, trace shell fragments.
- Sandy CLAY: medium plasticity, brown, some occasional black mottling with depth, sand is fine grained.
- CLAY: high plasticity, dark brown, occasional black mottling.
- Silty SAND/SAND: silty, fine to coarse grained, brown, moderately sorted, quartz sand, minor feldspar.

Figure 6 illustrates a generalised cross-section (B-B^1) of the soils intercepted at shallow depths (3 mbgl) extending across from the fringing dune network to the west along the intertidal flats to the east. PASS was detected as a shallow lens of marine/organic deposits up to 0.95m thick.

Plate 4-1 Hooley Creek-Tidal Creek

Plate 4-2 Salt Scalding of Intertidal Mud Flat

Plate 4-3 Tidal Creek with Mangroves

Plate 4-4 Intertidal Flats

4.2 Supratidal Salt Flat

The supratidal salt flats are typically encountered in the Littoral land system, and are located up gradient of Hooley Creek to the north west, and are characterised by surficial salt crusting, the result of intense evaporation due to a dry evaporative environment that undergoes infrequent inundation.

The supratidal flats are dominated by low gradient, and mostly featureless, bare open mud/algal flats (**Plate 4-5**) that generally occur above the spring high water mark and hence are rarely inundated by marine waters, except in the event of cyclonic storm surge. A thin veneer of decomposing black organic gel-like matter, indicative of iron monosulfides, was observed beneath the ground surface where algal mats had colonised along the edges, as a result of recent flooding associated with heavy rainfall.

These iron monosulfides, or as they are typically described, mono-sulfidic black ooze (MBO) can occur in the protected upper reaches of tributaries of PASS environments (e.g. intertidal flats) where organic matter (e.g. algal mats) contribute large amounts of decaying organic debris.

MBO materials are subaqueous or waterlogged mineral or organic materials that contain mainly oxidisable monosulfides rather than pyritic sulfides. They usually have a field pH of 4 or more but may become acid (pH <4) when disturbed due to hydrolysis of ferrous iron. When disturbed and mixed with water, the iron monosulfide can react within minutes to completely consume dissolved oxygen causing the degradation of water quality.

In the natural environment of Ashburton North and surrounds, it is anticipated that the presence of carbonates of calcium, magnesium and sodium in soils where MBO materials are present, will neutralise the acidity as it forms, through the sequence of natural processes.

Shallow soils/sediments comprise of alkaline (saline) red brown clayey sand, grading to slightly acidic light brown sandy clay of variable plasticity with depth. Surface carbonate concentrations are generally high, and concentrations of organic matter are generally low.

Soils associated with the supratidal salt flats generally consist of the following:

- Clayey SAND: fine to medium grained, red brown, some black mottling.
- Clayey SAND: fine to medium grained, light brown, clay is low plasticity.
- Sandy CLAY: low to medium plasticity, light brown/cream, sand is fine grained.

4.3 Samphire Flats

The samphire flats are also predominantly encountered within the Littoral land system and are generally located along the west and north (**Plate 4-6**) of the Terrestrial Assessment area.

The surface of the samphire flats are generally salt encrusted with a thin lens of variably decomposed black organic matter beneath the soil surface. This high nutrient environment, together with the activity of algae and micro-organisms, generates reducing conditions, which results in the formation of black MBO. MBO is discussed in greater detail above in **Section 4.2.**

The samphire flats are typically characterised by salt tolerant vegetation which ranges between very scattered to moderately dense salt tolerant Samphire species, and low shrublands.

Shallow soils generally consist of neutral to acidic red-brown sandy clay and plastic clays grading brown to grey as shallow groundwater is intercepted.

Soils associated with the samphire flat generally consist of the following:

- Sandy CLAY/CLAY: variable plasticity, red/brown with grey mottling. Sand is fine to medium sands with shell fragments clay.
- CLAY: Moderate to high plasticity, brown /grey/yellow mottled.

Plate 4-5 Salt Encrusted Supratidal Flat

Plate 4-6 Samphire Flat with Samphire

4.4 Claypans and Clay Plains

There are numerous localised areas of claypan dominated terrain (**Plates 4-7 and 4-8**), ranging in size from 100-200 m^2 to 1 500 m^2 within Ashburton North and surrounds. These isolated claypans form a discontinuous network within the boundaries of the alluvial/colluvial landform units adjacent the longitudinal dune network.

Sinuous bare claypans, flanked by samphire flats, were identified south east of the north western extent of the Terrestrial Assessment area and fringing the islands associated with the mainland remnant dunes along the eastern boundary (**Figure 5-1**). Claypan dominated terrain typically consists of neutral plastic clays overlying variably cemented calcareous material.

The claypans are generally defined as bare (devoid of vegetation), regularly inundated or irregularly inundated (both of which support soft spinifex *sp.* and salt tolerant plants) (Biota, 2009).

Claypan dominated terrain typically consists of neutral to alkaline plastic clays with variably cemented carbonate material.

Soils associated with claypan generally comprise of:

- CLAY: high plasticity, red brown
- Silty sandy CLAY/silty CLAY: low plasticity, very fine to medium grained sand, red brown.
- Sandy CLAY: medium plasticity, sand is fine to medium grained, red/brown.
- Silty SAND: red brown grading with limestone fragments and bands.

Plate 4-7 Discontinuous Claypan Pocket

Plate 4-8 Sinuous Bare Claypan

4.5 Alluvial/Colluvial Plains

Alluvial sediments of the low lying alluvial/colluvial plains (**Plate 4-9 and 4-10**) are closely associated with the lateral migration of clay-pan and dune deposits. Subtle changes in surface material and depositional characteristics are highlighted by the highly variable surface soils. The alluvial/colluvial plains of Ashburton North and surrounds are typically encountered adjacent to the longitudinal dunes and claypans of the Dune land system, and on the southern boundary of the fringing and coastal dunes of the Onslow land system.

Vegetation typically encountered included hummock grasslands such as soft Spinifex species and some hard Spinifex species with sparse low shrubs such as *Acacia.*

Shallow soils are highly variable grading between poorly sorted alkaline red earth silt, and sand and gravel with both cracking and non cracking clay soils, overlying the shallow sandstone bedrock formation.

Recent marine deposits, characterised as moderate to high plasticity brown to grey clay, were intercepted at shallow depth (~2.0 mbgl), where the plains fringed the intertidal flats of the mangrove/tidal creek landform unit along the north eastern extent of Ashburton North and surrounds.

Soils associated with the alluvial/colluvial plains generally consist of the following:

- CLAY: moderate plasticity, brown to grey with yellow mottles.
- Clayey SAND: fine to medium grained, red brown, some black mottling at surface.
- Gravelly SAND: sub angular to angular gravel to 20mm, fine to medium grained, red/brown.
- Silty SAND: grading fine to medium grained, red brown.
- Silty CLAY: high plasticity, mottled, minor quartz present, red/brown.
- Sandy clayey GRAVEL: fine to coarse grained gravels, brown to red brown and grey black.
- Gravelly sandy CLAY: medium plasticity, angular sandstone, gravels 5 to 10mm, red/brown.
- SAND: grading fine to coarse grained, brown to red brown.
- Sandy CLAY/sandy silty CLAY: firm, sand very fine grained, red/brown and light brown.
- SANDSTONE: moderately to very well cemented, fine to coarse grained sands, pale brown, high shell content and fossils.

Plate 4-9 Colluvial/Alluvial Plain

Plate 4-10 Colluvial/Alluvial Plain with Spinifex

4.6 Fringing and Coastal Dunes

The fringing dune landform unit (**Plate 4-11 and 4-12**), which comprise of beach and low dune ridges of variable stability, generally commence from the northern boundary (ocean) and extend in a southerly direction for approximately 200 m. The low dune ridges are typically formed from the deposition of wind blown sands and through sand supplied by storm surges, and are generally located above the high water mark.

4 Landforms and Soils of Ashburton North and Surrounds

Coastal dunes (**Plate 4-13 and 4-14**), in the order of 6 to 7 m in height were identified in the field, and with slopes of 20 to 35 degrees, were identified along the northern and western part of Ashburton North and surrounds, adjacent to the fringing dunes.

Soils along the coastal fringe mainly consist of neutral to alkaline sands and shell fragments overlying carbonate sandstone. Along the northern extent of Ashburton North and surrounds, the interception of marine deposits comprising of low plasticity grey clay, at shallow depths of around 0.8 mbgl of up to 0.95 m thick and identified as PASS, suggest the presence of an underlying chenier (a continuous ridge of beach material built upon marine deposits) and hence the potential for the presence of potentially acid generating material at shallow depths.

This is further supported by Damara (2009) who reported that a more recently formed pavement of marine origin commonly sits above the Red deep sand and is exposed at the Ashburton River Delta and fringing beaches. The pavement has a variety of lithified geomorphic features associated with fluvio deltaic and nearshore marine processes and includes the landforms of mid delta environments: channel gorges, topographic rises and basins.

Vegetation of the low dune ridges of the fringing dune landform unit, typically support hummock grasses with isolated to scattered shrubs while the beaches are generally devoid of vegetation. The coastal dunes also support hummock grasses, and are moderately vegetated with shrubs of 1 to 2 m in height.

Soils associated with the fringing and coastal dunes generally comprise the following:

- SAND/silty SAND: fine to medium grained, poor to well sorted, red brown, with shell fragments.
- Sandy CLAY/gravelly CLAY: low to moderate plasticity, red brown, fine to medium grained.
- CLAY: Medium to high plasticity, cream/brown to grey, yellow mottles.
- Calcareous SANDSTONE: moderately to well cemented, fine to medium grained quartz, some small shell fragments, cream/white.

Figure 6 illustrates a generalised cross-section ($C\text{-}C^1$) of the soils intercepted at shallow depths (3 mbgl) extending across the alluvial/colluvial plains and coastal dunes located adjacent the Ashburton River delta along the western boundary of the Terrestrial Assessment area. No PASS was identified along this cross section.

Plate 4-11 Fringing Dunes-Beach

Plate 4-12 Fringing Dune-Low Ridges

Plate 4-13 Coastal Dune

Plate 4-14 Coastal Dune with Spinifex

4.7 Longitudinal Dunes and Interdunal Swales

Longitudinal dunes and interdunal swales (**Plate 4-15 to 4-18**) were typically encountered within the central part of Ashburton North and surrounds, orientated generally in a north-south direction. The dunes, which range in height from 5 to 21 mAHD, display network patterns with a high level of variability along the length of the dune. These landforms are generally associated with the Dune land system.

The majority of the contemporary surface of the longitudinal dunes is a function of degradation and sand mobilisation over time. The longitudinal dunes have generally formed from residual sand, alluvial, colluvial and claypan deposits that were eroded and redeposited as dunes. The interdunal areas of the longitudinal dune network are generally either stable or vegetated, or form deflation zones and claypans which have probably been reworked historically by colluvial and aeolian processes. Longitudinal dunes and interdunal swales typically support hummock grasslands with low to mid-height shrubs of up to 1 m in height.

Soils associated with the longitudinal dunes and interdunal swales generally comprise the following:

- SAND: fine to medium grained, poorly sorted, light brown to red brown.

- Silty sandy GRAVEL: weathered limestone, angular gravels of 20-30 mm, some shell partially cemented.
- Silty SAND: fine to medium grained, moderately sorted, red brown, some shell.
- Sand/Calcareous SANDSTONE: fine to medium grained quartz, variable lithified, some shell fragments brown grey to pale brown.

Figure 6 illustrates a generalised cross-section (A-A[1]) of soils intercepted at shallow depths (3 mbgl) along the longitudinal dune and interdunal swale landform unit located centrally of Ashburton North and surrounds.

Plate 4-15 Longitudinal Dunes in Distance

Plate 4-16 Interdunal Swales

Plate 4-17 Inland Dune

Plate 4-18 Interdunal Swale

4.8 Mainland Remnant Dunefield

Mainland remnant dunes of the Dune land system were identified along the eastern boundary of Ashburton North and surrounds on islands isolated by the supratidal salt flats and fringing claypan dominated terrain.

These features are remnants of an ancient dunefield landscape and now remain isolated by the supratidal salt flats following a small marine transgression/regression. Hence, the majority of the remnants contain a physical framework typical of the ancient dunefield landscape, in particular, longitudinal dunes and interdunal swales and claypans.

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These soils are of similar composition as the soils of the longitudinal dunes and interdunal swales based on the typical framework associated with these landform units.

Landforms and Soils of the SIC, Camp, Construction and Domgas Study Areas

A desktop review was completed of soils and landforms along the SIC, Camp, Construction and the Domgas study area. The desktop review, was predominantly based on works completed by Biota Environmental Sciences (Biota), (undertaken in April 2009) and of OES, (undertaken in May 2010). Use of aerial photography and land system mapping (as adapted from Payne *et al.* [1988] and van Vreeswyk *et al.* [2004]) were also used to aid in the identification of typical landforms of the area in question. Methodology used in the desktop review of available literature is presented in **Appendix A** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

A landforms assessment of the SIC and Domgas study area was completed between 19 and 23 October 2009. Heritage surveys had not been completed for the Camp study area at the time of writing, and therefore a desktop review of this area has only been completed to date.

The following section summarises these initial findings.

5.1 Landform Units of the Shared Infrastructure Corridor Study Area

Land systems identified within the boundaries of the SIC study area include the Onslow, Littoral and Dune land systems with the dominant system being the Onslow land system. The Littoral land system is represented along the north east boundary of the SIC study area and the Dune land system at the southern end, adjacent Onslow Road.

Landforms typically encountered within the boundary of the SIC study area are shown in **Figure 5-2** and include the following:

- Alluvial/Colluvial Plains.
- Supratidal Salt Flats.
- Saline Flats.
- Longitudinal Dunes and Interdunal Swales.
- Claypans and Clay Plains
- Samphire Flats.

The dominant landform unit of the SIC study area comprise of broad scoping alluvial/colluvial plains (**Plate 5-1**) interspersed with continuous and discontinuous pockets of claypan depressions and clay plain. The alluvial/colluvial surfaces generally comprise of undulating sand plains up to 3km in extent with micro-relief of up to 2 m in height and support hummock grasslands.

As with the alluvial/colluvial plains of Ashburton North and surrounds, subtle changes in surface material and depositional characteristics (drainage lines and sheet apparent).are highlighted by the highly variable surface soils.

Soils of the alluvial/colluvial plains of the SIC study area typically comprise of the following:

- Clayey SAND/Clayey SAND: fine to medium grained, low plasticity, red brown, surface soils are loose, minor gravels are cemented (calcrete).
- Silty SAND: very fine grained, light brown, surface soils are loose.

Samphire flats (**Plate 5-2**) were commonly encountered adjacent the low lying claypan areas. Unlike the more coastal samphire flats of Ashburton North and surrounds, these areas are not subject to as frequent flooding other than during heavy rainfall events. Groundwater was only intercepted at one soil bore location at 2.29mbgl and there was no evidence of PASS or MBO, unlike the more reactive soils reported for Ashburton North and surrounds. It should be noted, however, that there is still a potential for the interception of PASS material at depths below where groundwater is intercepted, based on an assessment of samphire flats across the Terrestrial Assessment area.

Soils of the samphire flats along the SIC study area typically comprise of the following:

- Clayey SAND/sandy CLAY: fine grained sands, low to medium plasticity clays, red brown, moderately tight.
- CLAY/clayey SAND: Sub rounded sandstone gravels (3 mm - 10 mm diameter) fine grained, brown, low plasticity.
- Limestone: (at 26 mbgl) Calsilutite creamy white, clay to claystone infill variable, fresh, few fractures, hard, few vugs, grades into more days and conglomeritic, sandy patches and fractures frequent.

Plate 5-1 Alluvial/ Colluvial with adjacent Longitudinal dunes

Plate 5-2 Samphire Flats

Plate 5-3 Supratidal Salt Flat

Plate 5-4 Saline Flat

The supratidal salt flats (**Plate 5-3**) were typically encountered along the northern boundary of the SIC study area and are part of the supratidal unit adjacent to Hooley Creek, along the north eastern extent of Ashburton North and surrounds. This landform unit is typically similar in composition to that described for Ashburton North and surrounds.

The shallow soils encountered along this area include:

- Sandy CLAY: medium plasticity, fine to medium grained, red brown, alkaline
- Sandy CLAY: moderate plasticity, fine to medium grained, organic matter, grey with some yellow mottling, reactive. These soils are considered PASS.

Small dentric tributaries, associated with the supratidal salt flats of Ashburton North and surrounds, called saline flats, were identified along the north eastern boundary of the SIC study area and again adjacent to Onslow Road. These tributaries are typically devoid of vegetation and are rarely inundated by marine waters unless in the event of cyclonic conditions which may result in storm surge and heavy rainfall. The saline flats are typically dominated by low gradient, and mostly featureless, bare open mud flats (**Plate 5-4**) with a salt encrusted surface.

Soils of the saline flat runoff areas encountered along the SIC study area will be of similar composition as those reported closer to the coast, although with less marine/organic deposits. It is considered that PASS will be encountered where groundwater is intercepted (~2-3 m bgl) although these are very minor in extent.

The claypans (and clayey plains as described by Biota [2009]), range in shape from circular, oval to irregularly shaped and in degree of connectivity with tidal areas. The claypans are typically bare to sparsely vegetated sealed (hardened crust) surfaces with steep marginal slopes of up to 3 m in height adjacent to alluvial/colluvial plains (**Plates 5-5** and **5-6**).

Soils encountered within the claypans typically comprise of the following:

- Silty SAND: fine to medium grained, red brown, minor gravels, sub angular
- Sandy CLAY/Clayey SAND: fine to medium grained sands, low to moderate plasticity clays, tight, red brown.

Plate 5-5 Sparsely Vegetated Claypan

Plate 5-6 Bare Claypan

A network of relatively low longitudinal dunes and interdunal swales were encountered throughout the boundary of the SIC study area ranging in height from 5 m to 10 m. Typically, these dunes were orientated in a north south direction and are of similar composition to the network identified within Ashburton North and surrounds. This landform unit typically supports hummock grasslands and small shrubs while the interdunal swales typically support tall shrubs.

Surface soils encountered within the longitudinal dunes of the SIC study area include:

- SAND: fine to medium grained, poorly sorted, light brown to red brown.
- Silty SAND: fine to medium grained, moderately sorted, red brown, some shell.

5.2 Landform Units of the Camp Study Area

Land systems identified within the boundaries of the Camp study area and surrounds include the Onslow, Dune and Minderoo land systems. The dominant land system is the Onslow land system while the Dune and Minderoo land systems are mainly present along the southern most boundary of the Camp study area.

It is anticipated that landform units located within the boundaries of the Camp study area, which are shown in **Figure 5-2**, include the following:

- Alluvial/Colluvial Plains.
- Claypans and Clay Plains
- Longitudinal Dunes and Interdunal Swales.
- Samphire Flats.

The dominant landform unit comprises alluvial/colluvial plains and are typically similar in formation as those encountered along the SIC study area. Soils typically comprise dark reddish brown sands and sandy loams while a nominal number of bare and vegetated claypans were identified along the south western boundary of the Camp study area. Samphire flats and longitudinal dunes and interdunal swales were identified in the south western boundary of the Camp study area.

Based on the DEC (2009) Ass Risk Map and a desktop assessment, the area has been mapped as moderate to no known risk for PASS. The moderate to low areas generally coinciding with areas associated with samphire flats.

5.3 Landform Units of the Construction Study Area

Land systems identified within the boundaries of the Construction study area are dominated by the Littoral and Onslow landsystems and to a lesser extent the Dune, Minderoo and Girala land systems.

Landforms typically encountered within the boundary of the Construction study area are shown in **Figure 5-1 and Figure 5-2** and include the following:

- Supratidal Salt Flats.
- Mainland Remnants
- Claypans and Clay Plains
- Alluvial/Colluvial Plains.

- Longitudinal Dunes and Interdunal Swales.
- Samphire Flats.
- Saline Flats (Drainage Line).

The northern part of the Construction study area is bound by Borrow Area 3 to the east and Ashburton North and surrounds to the west by typically bare to sparsely vegetated (Tecticornia spp.) supratidal salt flats. The supratidal salt flats dominate the north eastern boundary of the terrestrial study area typically comprising low gradient, and mostly featureless, bare open mud/algal flats.

It is anticipated that the features identified on Borrow Area 3, which is located along the north eastern boundary of the Construction study area, are remnants of an ancient dunefield landscape, as identified for the minor islands located within Ashburton North and surrounds, and now remain isolated by the supratidal salt flats following a small marine transgression/regression. Hence, the majority of the remnants contain a physical framework typical of the ancient dunefield landscape, in particular, longitudinal dunes and interdunal swales and claypans.

Where the Construction study area extends south towards the SIC study area, the landscape is typically dominated by alluvial/colluvial plains and claypans (bare and partially vegetated) scattered throughout the Construction study area ranging in size, and with degree of connectivity with tidal areas (connected and seasonally inundated or isolated).

Similarly, broad clayey plains were present throughout the Construction study area ranging in size and connectivity as heavy clay plains in low-lying areas, adjacent to the SIC study area, to broad ranging plains of up to 2-3km in length as identified south of Ashburton North and surrounds. Permeability of the clayey soil types, which ranged between red brown, high plasticity clay to red brown, low plasticity, very fine to medium grained silty sandy clay, will potentially impact the degree of water holding potential (lending some to hold water for several weeks, while others of similar sized were dry).

The degree of vegetative cover on the claypans was varied, but most were fringed by a narrow band of ephemeral grasses, sedges and herbs. It is considered that the claypans will become ‘less saline’ with proximity from the coastline (the northern boundary of the Terrestrial Study area) (OES, 2010). The clayey plains typically support tussock grasses, tall shrublands and various Spinifex species (hard and soft)

The alluvial/colluvial plains dominate the southern boundaries of the Construction study area and are comprised of flat to gently undulating sandy inland plains which were broadly dominated by soft Spinifex and hummock grasses (OES, 2010). This is typical of alluvial/colluvial plains identified throughout the Terrestrial Study area as discussed in detail in **Section 4.5**.

Inland longitudinal dunes and swales were encountered throughout the southern component of the Construction study area, where it runs adjacent with the SIC and Camp study area, and to a lesser extent south of Borrow Area 3 and to the south of Ashburton North and surrounds. Unlike the dune systems located within Ashburton north and surrounds, these linear dune systems are typically of lower relief (of approximate heights of 5 m to 10 m) trending north south and range in length to up to approximately 100m in length.

The soils associated with the longitudinal dunes and interdunal swales include light brown to red brown, fine to medium grained sand, to a red brown, fine to medium grained silty sand. OES (2010) reported that dominant vegetation species of the consolidated red sand dunes included hummock grasses and *Triodia* spp. The narrow swales typically featured scattered tall shrubs of the dominant species from the dunes along with higher density of Acacia.

Samphire flats are present intermittently across the Construction study area, although are most dominant along the construction road located to the west of Ashburton North and surrounds and along the western boundary of the Construction study area located south of Ashburton North and surrounds. The samphire flats are typically characterised by salt tolerant vegetation which ranges between very scattered to moderately dense salt tolerant Samphire species, and low shrublands. Typically, shallow soils encountered within the samphire flats comprise of neutral to acidic red-brown sandy clay and plastic clays grading brown to grey as shallow groundwater is intercepted.

Small dentric tributaries called saline flats which are associated with the supratidal salt flats of Ashburton North and surrounds extend south across the Construction study area north and south of the SIC study area. The saline flats are typically devoid of vegetation and are rarely inundated by marine waters unless in the event of cyclonic conditions which may result in storm surge and heavy rainfall. The saline flats are typically dominated by low gradient, and mostly featureless, bare open mud flats with a salt encrusted surface in areas.

Based on the DEC (2009) ASS Risk Map (Figure 3) and the landform assessment, the Construction study area is considered moderate risk typically along the northern boundary where the supratidal salt flats and samphire flats are encountered and low to no risk for PASS along the southern boundaries.

5.4 Landform Units of the Domgas Study Area

The dominant land system identified within the boundary of the Domgas study area is the Uaroo land system. The Onslow and Giralia land systems are generally located towards the northern boundary while the Stuart land system is present at the southern most boundaries.

Landforms typically encountered within the boundary of the Domgas study area are shown in **Figure 5-3 to 5-5** and include the following:

- Alluvial/Colluvial Plains.
- Claypans and Clay Plains
- Longitudinal Dunes and Interdunal Swales
- Drainage Areas.
- Stony Hills.

Alluvial/colluvial plains (**Plate 5-7**) dominate the landscape along the Domgas study area, commencing along the northern boundary of the Domgas study area, adjacent to Onslow Road extending the length of the Domgas study area. The alluvial/colluvial plains along the northern boundary are characterised by low swales and slopes with soils comprising dark reddish brown sands and sandy loams.

Toward the central and eastern boundaries of the Domgas study area, the alluvial/colluvial plains become broad and flat (**Plate 5-8**) with gradients of 1 in 1000, with micro-relief. They are generally moderately vegetated with Spinifex and low to high shrubs ranging in height between 1 and 2m.

Claypans are intermittently encountered along the northern boundary of the Domgas study area and are typically flat, rounded, depressed surfaces up to 300 m wide; the soils associated with the claypans are reddish brown clay soils with occasional seasonal cracking.

Plate 5-7 Undulating Alluvial/Colluvial Plain

Plate 5-8 Broad Flat Alluvial/Colluvial Plain

Linear inland dunes were identified along the northern to central extent of the Domgas study area comprising of parallel dunes, trending north-south, with the most significant approximately 3km in length and 60 to 80 m wide. Soils are loose dark red sandy soils.

A number of unchannelled drainage areas (**Plate 5-8**) are located centrally of the Domgas study area and west of the Stuart land system. These drainage areas (or floodways) range from flat to a gentle east to west inclination. These areas may receive sheet flow during high rainfall events and range from sparsely to moderately vegetated small to tall shrub (up to 2m in height). Soils of the unchannelled drainage areas comprise of dark reddish brown soils, with loamy surface horizons becoming more clayey with depth.

Plate 5-9 Drainage Areas

Plate 5-10 Stony Hills

A number of low stony hills (**Plate 5-9**), up to 100 to 200 m in width, and rock outcrops are present along the eastern boundary of the Domgas study area, where the Stuart land system commences. The stony hills are characterised by isolated hill tracts and convex slopes. Rock outcrops (intrusion of quartz) were observed with a maximum height of 10m. The stony surfaced outcrops and hills are generally support hummock grasses and occasional tall shrubs.

Adjacent to the stony hills and for the remainder of the Domgas study area, the landscape comprise of broad clayey plains with a stony soil surface. These areas are generally moderately vegetated with hummock grasses. The soils of these are generally red gravelly surface sands sand grading to clay with depth.

Based on the DEC (2009) ASS Risk Map and the landform assessment, the Domgas study area is considered low to no risk for PASS.

5.5 Landform Significance of the Terrestrial Assessment Area

In summary, eleven major landform units have been described within the Terrestrial Assessment area. An assessment of landform significance for the Terrestrial Assessment area was undertaken and was based on the identification of landforms comprising of conservation values significant for the Pilbara Region as discussed in **Section 2.11**. Based on these conservation values, no current landforms of significance were identified within the Terrestrial Assessment area.

Table 5-1 outlines the area of each identified landform that is present in the Terrestrial Assessment area.

5 Landforms and Soils of the SIC, Camp, Construction and Domgas Study Areas

Table 5-1 Landform Unit Significance and Component Occurring in the Terrestrial Assessment Area

Landform Unit	Landforms of Significance	Approximate Area of Landform within Terrestrial Assessment Area (ha)	Components of the Terrestrial Assessment Area (Occurring In This Landform)
Tidal Creeks, Intertidal Flats and Mangrove Swamp	None	326	Ashburton North and surrounds
Supratidal Salt Flat	None	300	Ashburton North and surrounds and Construction study area up gradient of Hooley Creek to the north west, extending as far south to the SIC study area
Saline Flat	None	6	South eastern boundary of SIC adjoining the supratidal salt flats and Construction study area
Samphire Flats	None	439	The west and north of Ashburton North and surrounds and the SIC, Camp and Construction study areas
Claypans and Plains	None	320	Ashburton North and surrounds and within the SIC, Camp and Construction study area. Areas. Claypans are intermittently encountered along the northern boundary of the Domgas study area and as plains where the Stuart landsystem is encountered.
Alluvial/Colluvial Plains	None	798	Throughout the Terrestrial Assessment area, although particularly dominant as broad, flat to gradually undulating throughout the Domgas and Construction study areas
Fringing and Coastal Dunes	None	100	Ashburton North and surrounds
Longitudinal Dunes and Interdunal Swales	None	387	Longitudinal dunes and interdunal swales were typically encountered within the central part of Ashburton North and surrounds and to a lesser extent along the SIC, Construction and Domgas study areas,
Mainland Remnant Dunes	None	141	Ashburton North and surrounds and Construction study area
Stony Hills	None	1	Domgas study area
Drainage Areas	None	13	Domgas study area

5.6 Soils of the Terrestrial Assessment Area

In summary, there are three major identifiable soil groups/types encountered of the shallow soil profile for the Terrestrial Assessment area, and have been summarised below. It should be noted that at the time of writing, intrusive works had not been completed for the Domgas study area and therefore the following summary does not include soil units associated with the stony hills and the drainage areas of the Domgas study area.

Further, while intrusive works were not undertaken for the Construction study area, it is considered that landforms encountered within this study area were typical of landforms encountered within Ashburton North and surrounds and the SIC study area and hence the soil groups/types discussed below are therefore considered generally representative of soils encountered within the Construction study area.

- Red earths: Otherwise known as ‘Ashburton Red Beds’ (Coffey, 2009).
  - These soils include fine to coarse grained, red to red brown SAND/silty SAND with minor clay content, quartz and minor feldspar. These soils are typically encountered within landform units associated with longitudinal dunes and interdunal swales, alluvial/colluvial plains and the fringing and coastal dunes
  - These soils include low to medium plasticity, fine to medium grained, red to red brown clayey SAND/sandy CLAY, with variable shell content. These soils are typically encountered within the landform units associated with the supratidal salt flat, samphire flats, claypans, alluvial/colluvial plains
- Marine/organic deposits: These soils were typically characterised as low to high plasticity CLAY to clayey SAND/SAND, low to high plasticity, brown to dark grey; fine to medium grained, mottling may range from yellow and orange, firm to very soft. These soils are considered to be of marine/organic origin and are generally located within landform units associated with the intertidal flats, tidal creek and mangrove swamp and the samphire flats, saline and supratidal salt flats.
- Calcareous sands/rock: These soils/rock were typically characterised as moderately to very well cemented, fine to coarse grained sands to well cemented rock, pale brown to cream/white, high shell content calcareous SAND/SANDSTONE. This soils/rock were typically located at shallow depths underlying landform units associated with the alluvial/colluvial plains, fringing and coastal dunes and the longitudinal dunes and interdunal swales.

BSQ and PASS Investigation Methodology

6.1 Introduction and Rationale

The following section summarises the field and analytical methodologies completed as part of the BSQ and PASS investigation for Ashburton North and surrounds and the SIC study area. The complete sampling and analysis plan (SAP) and field methodology used in the investigation is attached as **Appendix A** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

Relevant regulatory guidelines require a PASS investigation to complete two samples per hectare to meet relevant guidelines (DEC, 2009b). Given the size of Ashburton North and surrounds and the SIC study area, soil sampling locations were selected based on geological/geomorphological units identified in the desktop assessment of the area. The sampling locations and density was thereby reduced to a total of 37 locations within Ashburton North and surrounds and the SIC study area and is considered representative of these units.

As no construction details were available prior to the completion of these works and based on the proviso that PASS of high to moderate risk is typically encountered within three metres of the natural soil surface (DEC, 2009), the field intrusive works were aimed at investigating to this depth. Where suspect material was identified at depth, and where sample retention was adequate, the investigation depth was increased accordingly.

The DEC (2009b) required sample collection rate of 0.25 m vertical intervals was reduced to 0.5 m vertical intervals (or less if changes in soil units were reported). The laboratory schedule was further reduced to approximately two samples per location. The rationale for diverting from the DEC guidelines was based on the input of significant data characterising the various geological/geomorphological units identified within Ashburton North and surrounds and the results of field pH tests (which is further discussed in this Section).

Based on a desktop assessment of the SIC study area, and known information derived from the works completed for Ashburton North and surrounds, the testing frequency was reduced to one sample per borehole for the SIC study area.

A soil erosion assessment was undertaken of soils and landforms encountered within the Terrestrial Assessment area for soil erodibility and dispersion. The criteria used to determine soil erodibility included soil types and landform units encountered. Water and wind erosion hazards were identified as the primary erosion hazards and an assessment of these criteria was completed for the identified erosion hazards.

Field dispersion tests were undertaken in the field on recovered samples for the classification of soils based on behaviour of soil aggregates, when immersed in distilled water, and their coherence in water (Emerson Class Test). Testing was generally undertaken on soils with suitable soil aggregates where a percentage of clay was present. Although sands and gravels are usually unsuitable for the test, slaking was noted for these soils where tested. The field methodology used for field dispersion testing is presented in **Appendix A** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

Soil field tests for pH_f, pH_{fox} and effervescence ‘fizz’ test, and field dispersion tests, were completed on recovered soil samples with the objective of obtaining a preliminary understanding of the soils existing and potential chemical composition. Soil field tests for pH_f, pH_{fox} and an effervescence ‘fizz’ test, were undertaken on the recovered soil cores for each of soil bores completed as part of the investigation at 0.25 m intervals. The results of field tests are presented in **Appendix D** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

6.1.1 Ashburton North and Surrounds

A total of 18 environmental soil bores were drilled at a variety of locations for Ashburton North and surrounds to a maximum depth of 4.6 mbgl using diamond core rotary method between the 27 March and 29 April 2009 (**Figure 7**) (**Table 6.1**). Soil bore logs are presented in **Appendix C** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

A further nine hand auger locations were completed at shallow depths ranging between 0.4 and 1.2 mbgl, between 27 March and 29 April 2009, and 7 July and 9 July 2009. The depth of the hand auger investigation was controlled by depth to groundwater (interception of groundwater resulted in core loss) or the interception of cemented carbonate material resulting in refusal.

Six of the hand auger locations (E034, E038, E040, E041, E042 and E045) were identified as potential areas for PASS during the desktop phase of the investigation. The identified locations, or areas identified as ‘high risk’ PASS locations based on desktop investigation, were selected based on typical PASS geomorphology profiles using aerial photography (e.g. low lying [below 5 mAHD]) and/or generally waterlogged and the presence of salt tolerant plant species). The remaining three hand auger locations were selected as access to these sites had been restricted for drill rigs due to rainfall events (E036, E037 and E039).

Two of the hand auger locations (E040 and E042) were augered, sampled and analysed during the hand augering programme completed between 27 March and 29 April 2009, and were re-sampled during the hand augering programme completed between 7 July and 9 July 2009. The objective of the duplicate sampling was to illustrate that results could be reproduced, and hence were representative of the Ashburton North and surrounds, at both a field and laboratory level of investigation.

In total, 148 primary samples were collected during the intrusive investigation of which 30 were submitted to ALS laboratory on 15 May 2009 and eight were submitted on 28 July 2009 for analysis of heavy metals including aluminium (Al), arsenic (As), barium (Ba), beryllium (Be), cadmium (Cd), chromium (Cr), cobalt (Co), Copper (Cu), iron (Fe), lead (Pb), mercury (Hg), manganese (Mn), nickel (Ni), vanadium (Va) and zinc (Zn) as part of the BSQ assessment. This suite of 13 heavy metals is considered the standard contaminant assessment suite as recognised by the DEC, with the additional inclusion of iron.

A total of 35 samples were also submitted for the assessment of PASS and ANC using the Chromium suite method on the 15 May 2009 and nine samples were submitted on 28 July 2009.

The total number of samples selected for PASS and ANC testing generally reflects an analytical regime of one sample per shallow borehole. The selection of samples was primarily based on field test results and the soil profiles intercepted, although representation of landform units, typical of the Ashburton North and surrounds, was also considered.

6 BSQ and PASS Investigation Methodology

6.1.2 Shared Infrastructure Corridor Study Area

Ten hand auger locations (E046, E047, E048 and E052 and SS01, SS03-SS07) were undertaken between the 19 and 21 October 2009 (Figure 6) as presented in **Table 6.1** and illustrated on **Figure 7**. Soil bore logs are presented in **Appendix C** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]). The hand auger investigation was driven by depth to groundwater (interception of groundwater resulted in coreloss) or the interception of cemented carbonate material (refusal) and ranged in depths from 1.5 to 1.6 mbgl.

In total, 37 primary samples were collected during the intrusive investigation of which 12 were submitted to ALS laboratory on the 24 November 2009.

The total number of samples selected for PASS and ANC testing generally reflects an analytical regime of one sample per shallow borehole. The selection of samples was primarily based on field test results and the soil profiles intercepted, although representation of landform units, typical of the SIC study area, was also considered.

Table 6-1 Summary of Environmental Bore Completion

Soil Bore Location[1]	Soil Sample ID	Coordinates		Start Date	Completion Date	Total Depth of Environmental Investigation[2]	Static Water Level[3]
		Northing	Easting			mbgl	mbgl
Ashburton North and Surrounds-Environmental Soil Bores							
E002	MB2B	291156	7595091	30/03/2009	30/03/2009	3.0	3.79
E003	MB3A	291105	7595517	30/03/2009	30/03/2009	3.0	4.38
E004	MB4A	291243	7595540	27/03/2009	27/03/2009	3.0	5.93
E005	MB5A	291482	7596954	2/04/2009	2/04/2009	3.2	3.08
E006	MB6A	292538	7598296	5/04/2009	5/04/2009	3.5	1.10
E007	MB7A	292711	7598613	5/04/2009	5/04/2009	3.2	2.12
E008	MB8A	293243	7599460	5/04/2009	5/04/2009	3.0	5.02
E009	MB9A	243256	7599398	5/04/2009	5/04/2009	3.0	4.66
E010	MB10A	293462	7599684	14/04/2009	14/04/2009	3.0	2.29
E011	MB11A	294113	7600691	12/04/2009	12/04/2009	3.1	0.66
E012	MB12A	294958	7600445	21/04/2009	21/04/2009	3.0	0.79
E013	MB13A	295014	7600692	10/04/2009	10/04/2009	3.7	1.0
E015	MB15A	290894	7596347	8/04/2009	8/04/2009	3.0	3.84
E016	MB16A	290313	7596335	4/04/2009	4/04/2009	3.0	3.63
E017	MB17A	290022	7596324	2/04/2009	2/04/2009	4.6	1.07
E018	MB18A	293920	7600287	15/04/2009	15/04/2009	3.0	2.69
E019	MB19A	293685	7600754	29/04/2009	29/04/2009	3.0	2.12
E021	MB21	293984	7600707	21/04/2009	21/04/2009	3.0	1.00
Ashburton North and Surrounds-Environmental Hand Auger Locations							
E034	EB034	294515	7600206	25/04/2009	25/04/2009	1.1	0.47

[1] URS prefix MB was superseded by Chevron's global use of the prefix E000 for environmental bores at the conclusion of the BSQ and ASS investigation, and therefore laboratory certificates refer to soil samples with the prefixes MB (for monitoring bore).
[2] Refer to URS (2009) Appendix C of Report Baseline Soil Quality and Landforms Assessment (Draft) 28 September 2009 WHST-STU-ET-RPT-0068_Rev D.
[3] Refers to Summary of Groundwater and Environmental Monitoring Bore Installation Sheet (URS, 2009a) Hydrogeological Impact Assessment of Wheatstone Plant Area, Infrastructure Corridor and Accommodation Site (Draft) 42907100 , work in progress (last amended date 15 September 2009) Attached as **Appendix A** of Appendix H Draft EIS/ ERM [Chevron, 2010]). Hand Auger depths were based on field logs of URS (2009) Appendix C of Report Baseline Soil Quality and Landforms Assessment (Draft) 28 September 2009 WHST-STU-ET-RPT-0068_Rev D

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Soil Bore Location[1]	Soil Sample ID	Coordinates		Start Date	Completion Date	Total Depth of Environmental Investigation[2]	Static Water Level[3]
E036	E036	294083	7598997	09/07/2009	09/07/2009	0.4	Not intercepted
E037	E037	294330	7598059	09/07/2009	09/07/2009	0.4	Not intercepted
E038	E038	294922	7597474	09/07/2009	09/07/2009	1.0	0.2
E039	E039	294095	7596917	09/07/2009	09/07/2009	0.4	Not intercepted
E040 and E040A	EB040	292978	7599709	25/04/2009 & 07/07/2009	25/04/2009 & 07/07/2009	1.1	0.35 and 0.45
E041	E041	291958	7598163	08/07/2009	08/08/2009	1.0	0.45
E042 and E042A	EB042	290855	7599136	26/04/2009 & 07/07/2009	26/04/2009 & 07/07/2009	1.2 and 1.1	0.5 and 0.45
E045	E045	290687	7597631	07/07/2009	07/07/2009	1.0	Not intercepted
Shared Infrastructure Corridor-Environmental Hand Auger Locations							
E046	E046	293200	7593710	21/10/2009	21/10/2009	1.4	Not intercepted
E047	E047	294209	7592312	20/10/2009	20/10/2009	1.6	2.39[4]
E048	E048	296277	7591591	20/10/2009	20/10/2009	1.6	Not intercepted
E052	E052	300284	7590246	19/10/2009	19/10/2009	1.5	Not intercepted
SS01	SS01	297786	7591155	19/10/2009	19/10/2009	1.25	Not intercepted
SS03	SS03	295408	7591961	20/10/2009	20/10/2009	1.5	Not intercepted
SS04	SS04	293688	7592610	21/10/2009	21/10/2009	1.6	Not intercepted
SS05	SS05	293353	7592933	21/10/2009	21/10/2009	1.6	Not intercepted
SS06	SS06	293078	7594338	21/10/2009	21/10/2009	1.6	0.7
SS07	SS07	293117	7595500	21/10/2009	21/10/2009	1.6	0.7

6.1.3 Additional Data Review

A review of geotechnical and PASS investigation reports made available to URS, completed as part of the Wheatstone Project, was undertaken to further aid in the vertical and horizontal delineation of PASS across the Terrestrial Assessment area, and in the determination of the potential acid generating capacity of this material. This information was then utilised to refine the PASS map (discussed in Section 8) and the approximate thickness and depth of PASS (Figures 12 and 13) across the Terrestrial Assessment area.

The following reports were reviewed as part of this process:

Coffey (2010) Factual Interpretative Report-Onshore Geotechnical Investigation

A review of geotechnical bore logs and core photos was undertaken as presented in the Coffey *Final Interpretive Report – Onshore Geotechnical Investigation, Ashburton North Site (Rev B 23rd April 10) WS1-0000-GEO-RPT-COF-000-00028-000).*

.This consisted of a review of 73 geotechnical and hydrogeological bores logs and 34 core photos (where bore logs were not available) ranging between 10 and 60 mbgl.

[4] As reported in the corresponding Phase 2 geotechnical logs (attached as **Appendix F**).

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Golder (2010a) Potential Acid Sulfate Soil Investigation Final Factual Report

A review of the Golder Associates Pty Ltd (Golder) F*inal Factual Report: Potential Acid Sulfate Soils Investigation dated 15 October 2010 (Ref 097642446-015-R-Rev0)* was completed. The Golder (2010a) report details the fieldwork completed between November 2009 and April 2010 and presents the results of field and laboratory testing across the Terrestrial Assessment area, including Borrow Areas 1, 2 and 3.

In total, 226 locations were sampled by advancing boreholes and test-pit excavations. Field screening tests of 3,839 samples were undertaken at a 0.25m vertical interval. Each soil sample was assigned a risk indicator of low, medium or high, based on the following field screening criteria:

- pH_{fox} of <3.
- Change in pH (ΔpH, as pHf–pHfox) of > 3.
- Strong or extreme oxidation reaction.

Samples with zero or one indicator were assigned low PASS risk; with two indicators a medium PASS risk; and with all three indicators they were classified with a high PASS risk ranking. Field screening tests on samples collected during this investigation resulted in 445 samples interpreted as high risk for PASS. Samples recording a high risk of PASS were selected for laboratory analysis at a maximum density of 1 sample for every 50 cm sampled. On this basis a total of 264 primary samples were analysed using the Suspended Peroxide Oxidation Combined Acidity and Sulfur (SPOCAS).

Golder (2010b) Potential Acid Sulfate Soil Investigation -Borrow Area

A review of the Golder *Potential Acid Sulfate Soils-Borrow Area report, dated November 2010 (Ref 097642446-023-R-Rev0)* was completed. The Golder (2010b) report summaries the findings of the PASS investigation for Borrow Areas 1, 2 and 3, initially presented in Golder (2010a), and the findings of the additional PASS investigation undertaken at Borrow Area 4 in October 2010. To avoid repetition, a summary of Golder (2010a) has not been undertaken in this report..

In summary, a total of 18 test pits were excavated for Borrow Area 4. Field screening of 219 samples was undertaken at a vertical interval of 0.25 m. Each soil sample was assigned a risk indicate based on the field screening criteria described above (Golder, 2010a) as a primary indicator of risk.

A secondary assignment of risk was included for Borrow Area 4 based on the position of the sample within the vertical profile i.e. samples exhibiting high risk characteristics at an R.L of 1.5 mAHD or less were excluded from analysis. This additional risk characterisation is based on information provided to Golder (2010b) by Chevron that excavation of Borrow material would not exceed 1.5 mAHD.

As such, samples with a low or medium interpreted PASS risk rating (generally found above the water table and above RL 1.5 m AHD) were then submitted for SPOCAS analysis so that each lithology from each test pit could be analysed to determine the vertical extent of any PASS layer present.

On this basis, a total of 44 samples were analysed using the SPOCAS method for Borrow Area 4. Chromium reducible sulphur analysis was also undertaken on a selection of samples across the borrow areas that had exceeded the adopted action criteria of 0.03%S for the purpose of comparing different analytical methodologies.

Golder (2010c) Technical Memo: Preliminary Geotechnical Information-Domgas Study Area

A review of information provided in the technical memorandum for the PASS investigation completed along the southern part of the Domgas study area (Golder, 2010c) was completed.

A total of 44 test pits were excavated along 70 km of the southern side of Onslow Road, between Twitchen Road and the Dampier Bunbury Natural Gas Pipeline.

Field screening of 204 samples was undertaken at a vertical interval of 0.25m. Each soil sample was assigned a risk indicate based on the field screening criteria described above (Golder, 2010a). On this basis, it was not necessary to submit any samples for analysis.

6.2 Test Methodology

The following section discusses the tests undertaken during the field and/or based on field test results.

6.2.1 Erodibility Assessment

An erodibility assessment was undertaken for landform units of the Terrestrial Assessment area based on soil types and landform units encountered during the field investigation. The assessment was undertaken in general accordance with van Gool *et al* (2005) which provide standard methods for attributing and evaluating conventional land capabilities. Water and wind erosion hazards were identified as the primary erosion hazards associated with the Terrestrial Assessment area.

Wind erosion refers to the inherent susceptibility of the land to the loss of soil as a result of wind movement. The susceptibility of a soil to wind erosion has been assessed from a simple matrix of surface texture and surface condition. The five categories of wind erosion hazard relate to the level of disturbance needed to bring soils to a loss and consequently erodible condition. Category V includes soils that are highly susceptible because they have a loose and consequently erodible condition while Categories I to V have decreasing susceptibility. These soils are less fragile and require some disturbance by machinery to loosen the soil.

Water erosion is the inherent susceptibility of the land to the loss of soil as a result of water movement across the surface, where the susceptibility of landform units to water erosion is based on soil erodibility and slope. Water erosion is highly variable depending on seasonal and climatic factors. For example, a high rainfall event immediately after summer can result in ‘first flush’ of sediment into nearby water ways of the receiving environment.

Susceptibility of landform units are the rating based on a low, moderate, high, very high and extreme ranking outlined in van Gool *et al* (2005)

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The field test methodologies used in the assessment of landform susceptibility and soil erodibility are described in detail in **Appendix A** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

6.2.2 Dispersion Tests

Dispersive soils, or sodic soils, collapse or disperse to form dissolved slurry when in contact with fresh water (rain). These soils are highly prone to erosion often leading to tunnel and gully erosion. Unlike other forms of erosion, dispersion result from an imbalance in soil chemistry (Emerson, 1991).Construction activities may increase the risk of the exposure of soils which exhibit dispersive characteristics and therefore result in the erosion of these soils

During construction, the runoff from areas of disturbed dispersive soils, which tend to have high clay content, may appear cloudy when entering water bodies. It is very difficult to remove this clay from freshwater without the addition of chemicals (e.g. gypsum). If this runoff enters local waterways has the potential to reduce light levels and decrease water quality (Department of Agriculture, 1998).

The identification of dispersive soils is important when identifying potential soils for use in rehabilitation. Many factors affect the success or failure of attempts to stabilise and rehabilitate at closure. Major erosion is often associated with unstable materials prone to tunnelling, such as dispersive spoils. The presence of these materials commonly has the potential to result in the creation of relatively unsafe landforms with widespread tunnels immediately below the soil surface, development of large gullies when tunnels collapse, and instability of rock drains.

Further, soil aggregates that slake and disperse readily indicate a weak structure that is easily degraded by raindrop impact or mechanical disturbance. This degradation has the potential to reduce infiltration and permeability in loamy and clayey soils, and impede root development and seedling emergence by increasing soil density.

Soil dispersion potential is measured as the Emerson Class number (a simple semi-quantitative dispersion test), which considers soil consistency, depth, and in some cases established soil electro-chemical data. Weathered parent rock substrates can also show dispersive tendencies. Dispersive soils usually contain significant amounts of clay, with at least moderate levels of chemically exchangeable sodium, if they are not buffered by salinity.

The Emerson Aggregate Test assesses how aggregates break down in water and classifies a soil into eight categories. The Emerson Aggregate Test is a simple way of identifying four significant soil groups with respect to their behaviours:

- Soils which are spontaneously dispersive to varying degrees (Class1 and Class 2). Class 1 soils are highly unstable and invariably sodic to highly sodic.
- Soils which are potentially dispersive if remoulded when wet (Class 3).
- Soils which slake but are non-dispersive (Classes 4, 5 and 6).
- Soils which have a high inherent stability (Class 7 and 8).

6.2.3 pH_f and pH_{fox} Tests

Field pH (pH_f) and field peroxide (pH_{fox}) tests were conducted on recovered soil samples at an interval of 0.25 m depth interval in order to assess the potential of the soil to generate acidity. Results of the field tests were conducted in accordance with the *Laboratory Methods Guidelines Acid Sulfate Soils (Version 2.1-June 2004) (Ahern et al, 1998).*

Field pH (pH_f) and field peroxide (pH_{fox}) tests were conducted on recovered soil samples using deionised water and a 30% hydrogen peroxide solution. The pH values were measured using a Hanna pHEP® meter which was calibrated prior to field testing using buffer solutions of pH4 and pH7 +/- 0.01 units.

The complete field methodology used for the completion of these tests is presented in **Appendix A** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

6.2.4 Carbonate 'Fizz' Test

The carbonate 'fizz' test is used to determine the presence of carbonates in soil. The test is normally conducted on samples suspected of containing carbonates such as fine shell, crushed coral or soluble carbonates presence within the soil profile. The field test was conducted in accordance with the *Laboratory Methods Guidelines Acid Sulfate Soils (Version 2.1-June 2004) (Ahern et al, 1998).*

This test is simply an indicator for the presence of carbonate material and detailed analytical tests are required to determine the actual carbonate material available to neutralise *in situ* potential acid generating conditions.

The tests were conducted on recovered soil samples using hydrochloric acid (HCl) solution. Observations were noted as to whether the sample 'fizzed' as 2-3 drops of HCl was applied.

The complete field methodology used for this test is presented in **Appendix A** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

6.3 Assessment Guidelines

6.3.1 Heavy Metals

The Terrestrial Assessment area has had no previous anthropogenic activities that may have adversely altered soil quality; therefore, as the results obtained are considered representative of background concentrations, a comparison against criteria based on future land uses can be useful.

Given the present underdeveloped nature of the Terrestrial Assessment area, soil analytical results were compared with Ecological Investigation Levels (EIL's) as presented in the draft Western Australia DEC (2003) *Contaminated Sites Series Guidelines-Assessment Levels for Soil, Sediment and Water,* which are based on the EIL's provided in the Australian and New Zealand Guidelines for the Assessment and Management of Contaminated Sites (ANZECC/NHMRC, 1992). The EIL's are generally protective of environmentally sensitive receptors such as mangrove habitats and/or the intertidal environment as located within Ashburton North and surrounds of the Terrestrial Assessment area.

As the proposed future use of Terrestrial Assessment area will result in an operational site, the analytical test results can also be compared to Health Investigation Levels (HIL's), which are primarily based on the Health-based Soil Investigation Levels presented in the National Environmental Protection Measure (NEPM) (NEPC, 1999). Analytical results will be compared against HIL-F trigger values based on the known use of the Terrestrial Assessment area as an industrial site for the process and production of LNG.

An initial comparison of metal concentrations was undertaken utilising studies completed for North west coast deltaic systems of the Pilbara Region (i.e. Oceanica [2005] and URS [2008])

6.4 PASS

The assessment criteria adopted for PASS in Western Australia are the 'Texture Based ASS Action Criteria' developed by Ahern *et al* (1998) and are presented in **Table 6-2.** The criteria act as a guide to determine whether soils will generally require treatment and/or management, based on **Net Acidity** (net acidity = S_{cr} +TAA) as sulfur (% S) or equivalent acidity (mol H^+/tonne).

As clay content tends to influence a soils natural buffering capacity, the action criteria are grouped into three broad texture categories. Classification of the soils encountered during the investigation ranged from medium to fine grained. Based on this generalised classification, and assuming a disturbance of soil (through excavation during the construction of the Terrestrial Infrastructure) of greater than 1 000 tonnes, the selected 'action criteria' for **Net Acidity** is 0.03 %S or the equivalent acidity of 18.7 mol H^+/tonne (as highlighted in **Table 6-2**).

Table 6-2 Texture Based ASS Action Criteria Matrix

Type of Material		NET ACIDITY ACTION CRITERIA			
		1-1000 tonnes disturbed		>1000 tonnes disturbed	
Texture range McDonald *et al* (1990)	**Approximate Clay Content (%)**	**Equivalent sulfur (%S)**	**Equivalent acidity (mol H^+/tonne)**	**Equivalent sulfur (%S)**	**Equivalent acidity (mol H^+/tonne)**
Coarse Texture sands to loamy sands	<5%	0.03	18.7	**0.03**	**18.7**
Medium Texture Sandy loams to light clays	5-40%	0.06	37.4	**0.03**	**18.7**
Fine Texture Medium to heavy clays and silty clays	>40%	0.1	64.8	**0.03**	**18.7**

Source: 'Ahern *et al.* 1998. Action Criteria' Based on ASS Analysis for Three Texture Categories

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6.4.1 Adopted Laboratory Methodology

The analytical method selected for the analysis of PASS, the Chromium suite, was undertaken in accordance with laboratory methodologies outlined in Ahern *et al* (2004) and is the preferred analytical method adopted by the DEC (DEC, 2009b). The Chromium suite method provides an analytical determination of inorganic sulfur (e.g. iron sulfides) and is not subject to interferences from sulfur, either in organic matter or as sulfate minerals.

A brief description of the NATA accredited laboratory analytical method selected is as follows:

- **EA033: Chromium Suite for Acid Sulfate Soils**: This method covers the determination of Chromium Reducible Sulfur (S_{CR}); pH_{KCl}; titratable actual acidity (TAA) and acid neutralising capacity by back titration (ANC). The above determinations are reported as % sulfur (S) or the equivalent acidity (mol H^+/tonne) with the exception of ANC which is reported as kg $CaCO_3$/t.

The above determinations can be defined further as the following:

- S_{cr}: A measure of total reduced inorganic sulfide and a measure of a soils potential to generate acidity.
- pH_{KCl}: The determination of pH in a solution of potassium chloride.
- TAA: A measure of total existing acidity. The soluble and exchangeable acidity already present in a soil, often a consequence of previous oxidation of sulfides.
- ANC: A soils inherent ability to buffer acidity and resist the lowering of the pH.

BSQ and PASS Investigation Results

7.1 Erosion Assessment

The results of the soil erosion assessment is summarised below:

7.1.1 Erodibility Assessment Results

A field landform susceptibility and soil erosion assessment has been completed for the various landform units and associated soil types found within the Terrestrial Assessment area.

The assessment identified three landform units, the fringing and coastal dunes, the longitudinal dunes and the mainland remnant dunes, which have a very high to extreme potential for wind and a high potential for water erosion when disturbed. Results of the assessment are presented in **Table 7.1** and the complete soil erodibility results are presented in **Appendix D** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

Table 7-1 Erodibility Potential for Landform Units of the Terrestrial Assessment Area

Landform Type	Water Erosion Potential[5] (VL, L,M,H, VH, E)	Wind Erosion Potential Class I-V (VL, L,M,H, VH, E)	Assessment Area
Intertidal flats, mangrove communities and tidal creeks [6]	L to M	L	North west of Ashburton North and surrounds and Construction study area
Alluvial / Colluvial	L	L	Ashburton North and surrounds, SIC, Camp, Domgas and Construction study area
Claypans	M	L	Ashburton North and surrounds, SIC, Camp and Construction study area
Fringing and Coastal Dunes	H	VH to E	Ashburton North and surrounds
Drainage Area[6]	L	L	Domgas study area
Stony Hills[6]	L	L	Domgas study area
Longitudinal Dunes and Interdunal Swales	H	VH to E	Ashburton North and surrounds, SIC, Camp Domgas and Construction study area
Mainland Remnant Dunes[6]	H	VH to E	Ashburton North and surrounds and Construction study area
Samphire Flat	L	L to M	Ashburton North and surrounds, SIC, Camp and Construction study area
Supratidal Salt Flat	M	L	Ashburton North and surrounds, SIC and Construction study area
Saline Flats[6]	M	L	SIC study area and Construction study area.

[5] Erosion potential assessed against *Land evaluation Standards for Land Resource Mapping Third Edition* Dennis van Gool, Peter Tille and Geoff Moore December 2005
[6] Based on desktop assessment of landform erodibility only

7.1.2 Soil Dispersion Results

Field dispersion tests were conducted on surface and subsurface clayey soil samples for Ashburton North and surrounds and the SIC study area, with the objective of determining soil sodicity across appropriate soil types. A summary of the field test results undertaken during the investigation are presented in **Table 7-2** where clay was intercepted, while the complete field test results are presented in **Appendix D** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

Based on the results of the field dispersion tests, red brown clay and/or clayey soils identified within the Ashburton North and surrounds and the SIC study area generally slake (slightly) but are non dispersive (Class 4, 5 or 6).

Brown to grey CLAY identified within Ashburton North and surrounds was generally identified as potentially dispersive (Class 3). These soils were not identified as dispersive within the SIC study area.

It should be noted that Emerson testing does not account for high salinity (hyper saline) materials, particularly those of marine origin, and may report a false positive (i.e. non-dispersive soils). If the salt content of a material is very high, then spontaneous dispersion may not occur, even when immersed in excess deionised water.

Overall, the field test suggests that it is unlikely that there is potential for significant erosion, and hence impacts on the environment are considered to be low. However, soils with dispersive tendencies should not be used for rehabilitation, which includes the grey yellow mottled clays of the alluvial/colluvial plains and the brown clays contained within the tidal creeks, mangrove swamps and intertidal flats (refer to **Table 7-2** below).

Table 7-2 Field Dispersion Field Test Results (Clayey Soil)

Landform Unit	Lithological Description	Emerson Class
Longitudinal Dunes and Interdunal Swales	clayey SAND (5% clay), occasional gravel, red/brown	Class 4, 5 or 6
Alluvial/Colluvial Plains	sandy CLAY, red/brown	Class 4, 5 or 6
	CLAY, grey with yellow mottles	Class 3
	sandy CLAY, red/brown	Class 4,5 or 6
	clayey SAND, occasional well cemented Sandstone	Class 4, 5 or 6
	clayey SAND, red/brown	Class 4, 5 or 6
	CLAY, medium to high plasticity, cream/brown	Class 4, 5 or 6
	heavy CLAY, grey, occasional yellow mottles	Class 4, 5 or 6
Tidal Creek, Mangrove Swamp & Intertidal Flat	CLAY, brown, medium plasticity	Class 3
Supratidal Salt Flats	clayey SAND, red brown, fine grained	Class 4, 5 or 6
	clayey SAND, red brown, fine to medium grained	Class 4, 5 or 6
	sandy CLAY, medium plasticity, red brown	Class 4, 5 or 6
	sandy CLAY, mod plasticity, grey some yellow mottling	Class 4, 5 or 6
	Sandy CLAY, mod plasticity, red brown yellow mottling	Class 4, 5 or 6
Samphire Flats	CLAY, moderate to high plasticity, grey red mottles	Class 4, 5 or 6
	CLAY, low to moderate plasticity, grey	Class 4, 5 or 6

Landform Unit	Lithological Description	Emerson Class
	Clayey SAND, low plasticity, red brown	Class 4, 5 or 6
	sandy CLAY, red low plasticity	Class 4, 5 or 6
Claypan	sandy CLAY, moderate plasticity, red brown	Class 4, 5 or 6
	CLAY, red brown high plasticity	Class 4, 5 or 6
	Clayey SAND, low to medium plasticity, red brown	Class 4, 5 or 6
	silty sandy CLAY, red brown low plasticity	Class 4, 5 or 6
	silty CLAY, red brown, low plasticity	Class 4, 5 or 6

7.2 Heavy Metal Assessment

The following section provides a general summary of the analytical testing completed to determine the BSQ for Ashburton North and surrounds and the SIC study area, and a discussion of the results against adopted assessment criteria

Soil analytical results for a suite of heavy metals, including Al, As, Ba, Be, Cd, Cr, Co, Cu, Fe, Hg, Pb, Mn, Ni, Va, Zn. are presented in **Appendix D** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]), highlighting samples that exceed the adopted EIL and HIL-F trigger values

7.2.1 Ashburton North and Surrounds-Analytical Results

The distribution of metals encountered within Ashburton North and surrounds are presented on **Figure 8-1** and **8-2** and summarised below:

- Reported metal concentrations for all analytes did not exceed HIL-F trigger values for the samples analysed.
- Arsenic concentrations exceeded the EIL trigger value of 20 mg/kg at five locations ranging between 20 mg/kg (E041_0.9-1.0) and 93 mg/kg (E018_2.5). Exceedances were located within the north western to north eastern extent of Ashburton North and surrounds.
- Chromium concentrations exceeded the EIL trigger value of 50 mg/kg at eight locations ranging between 52 mg/kg (E007_0.0) and 108 mg/kg (E018_2.5). These were located within the central to north west to north eastern section of Ashburton North and surrounds.
- Manganese concentrations exceeded the EIL trigger value of 500 mg/kg at two locations (569 mg/kg [E007_0.0] and 1380 mg/kg [E017_1.5-1.75]) within the central part of Ashburton North and surrounds.
- Low manganese concentrations were reported in soils generally associated with PASS or reported generally lower pH values than of the surrounding environment. These included E006__1.0 (66 mg/kg), E011_1.0 (56 mg/kg), E018_2.5 (80 mg/kg), E018_3.0 (55 mg/kg), E019_1.75 (98 mg/kg), E034_0.75-0.85 (95 mg/kg), E040_0.75-0.85 (28 mg/kg) and E040A_1.0-1.1 (26 mg/kg).
- Nickel concentrations exceeded the EIL trigger value of 60 mg/kg at one location, reporting a concentration of 61 mg/kg (E018_3.0) in the north east of Ashburton North and surrounds.

7 BSQ and PASS Investigation Results

Discussion

No results were reported in exceedance of the adopted HIL-F guideline criteria and hence no risk to human health, with relation to metals, is anticipated.

Elevated arsenic, chromium, manganese and nickel concentrations were detected above the adopted environmental investigation level (EIL) trigger values within the north western and north eastern extent of Ashburton North and surrounds.

Comparison of these results against an assessment of heavy metals completed by Oceanica (2005) and URS (2008) along the Pilbara coastline of similar deltaic systems also reported elevated concentrations of arsenic, chromium and nickel. The elevated metals encountered are comparable suggesting that the high background levels are likely a result of the weathering of terrestrial origin.

These concentrations are therefore considered representative of background conditions given the absence of human induced disturbance within the Terrestrial Assessment area, the distance from the Onslow Salt operations and based on a comparison with other North West coast deltaic systems within the Pilbara Region.

7.2.2 SIC Study Area-Analytical Results

The distribution of metals encountered within the SIC study area are presented on **Figure 8-3** and summarised below:

- Reported metal concentrations for all analytes did not exceed HIL-F trigger values.
- Chromium concentrations exceeded the EIL trigger value of 50 mg/kg at seven locations ranging between 50 mg/kg (E048_0.0-0-0.1) and 70 mg/kg (SS01_0.5-0.6). These exceedances were identified throughout the SIC study area.
- Manganese concentration exceeded the EIL trigger value of 500 mg/kg at five locations ranging between 640 mg/kg (SS01_ 0.5-0.6) and 900 mg/kg (SS01_1.0-1.1). These exceedances were identified throughout the SIC study area where concentrations were generally detected slightly below or above the EIL trigger values
- Low manganese concentrations were reported in soils identified as PASS at SS07_1.5-1.6, which reported concentrations of 26 mg/kg.

Discussion

No results were reported in exceedance of the adopted HIL-F guideline criteria and hence no risk to human health, with relation to metals, is anticipated.

Elevated chromium, manganese and nickel concentrations were detected above the adopted environmental investigation level (EIL) trigger values throughout the SIC study area. However because there have been no historic industrial land use practices within the SIC study area these concentrations are considered representative of background concentrations.

7.3 Potential Acid Sulfate Soils Assessment

The investigation of PASS was undertaken through the completion of field tests and laboratory analysis. The field tests completed were used in conjunction with other field observations to develop a preliminary understanding of the environment. Additional tests were conducted on selected samples using laboratory analyses to provide more detailed information on existing conditions.

Laboratory analytical tests quantitatively assess the amount of existing plus potential acidity present in the soil and hence provide a general measure of the risks of acidic conditions forming if these soils are disturbed. The assessment criteria adopted for the PASS acts as a guide to determine whether soils will generally require treatment and/or management based in the net acidity produced by the soil.

7.3.1 pH_f Field Test Results

The pH_f test measures the existing acidity and is therefore a useful indicator as to whether actual ASS is present. As illustrated in **Table 7-3**, sands and sand dominant soils are generally alkaline to near neutral and are dominant in the landform units associated with the longitudinal dunes and interdunal swales, fringing and coastal dunes and the alluvial/colluvial plains. Mean pH_f values range between 8.93 (calcareous SANDSTONE of the fringing and coastal dunes) and 7.33 pH (red brown gravelly sandy CLAY of the alluvial/colluvial plains)

Sandy soils of the samphire flats and the tidal creek, mangrove swamp and intertidal flats, recorded alkaline to near neutral pH_f values. The high pH_f values are considered most likely a result of high carbonate content reported in the form of shell. Mean pH_f values of these sandy soils range between pH 8.28 and pH 7.76. pH_f values.

Clayey soils of the samphire flats recorded near neutral to slightly acidic with mean pH_f values ranging between pH 7.35 to pH 6.96 (with the minimum pH values reported ranging between pH 4.80 and pH 5.02).

Sandy and clayey soils of the supratidal flats were slightly acidic with mean pH_f values ranging between pH 6.57 to pH 6.31. Claypan soils encountered were typically alkaline to near neutral with mean pH_f values ranging between pH 8.82 to pH 7.05.

In summary, pH_f results indicate soils are generally alkaline and there is no existing acidity in the shallow profile across Ashburton North and surrounds, with the exception of slightly acidic soils which were identified where organic matter and/or marine deposits were identified.

7.3.2 pH_{fox} Field Test Results

The pH_{fox} test (or rapid oxidation) is used to indicate the presence of iron sulfides or PASS. The test involves adding 30% hydrogen peroxide to a sample of soil, thereby replicating what would naturally occur if the soils were exposed to air. Where sulfides are present, a reaction will occur. The reaction can be influenced by the amount of sulfides in the sample and the presence of organic matter where the more vigorous the reaction, the greater potential for acidity (generally). The end pH_{fox}, provides an indication of the potential for a soil to become acidic, whereby the lower the pH the greater the potential acidity.

Based on this assumption, pH_{fox} values remained above neutral, and reactions with the peroxide reactant were generally absent, in red earth soil profiles of the landform units

7 BSQ and PASS Investigation Results

associated with the longitudinal dunes and interdunal swales, and of the fringing and coastal dunes, and alluvial/colluvial plains.

Reactions with claypan soils were generally reported as low to medium with end mean pH_{fox} values ranging from pH 9.08 to pH 6.89 (an increase in pH in some cases).

The most reactive soil profiles were reported in grey to brown clayey soils (with variable mottling) typically encountered within the landform units associated with the intertidal flats, tidal creek and mangrove swamp, samphire flats and supratidal salt flats of the Terrestrial Assessment area. Reactive soils were also detected within marine/organic deposits identified at shallow depths within the alluvial/colluvial plains and fringing and coastal dunes along the north eastern boundary of Ashburton North and surrounds.

These soils have mean pH_{fox} values ranging between pH 5.93 (light brown silty sandy clay of the alluvial/colluvial plains) and pH 0.87 (grey clay of the fringing and coastal dunes) and are considered PASS. In general, soil metals mobilise as soil pH drops below pH 5.5 and therefore, for the purpose of this investigation, this is considered the trigger value for PASS soils with regard to field pH tests.

Table 7-3 pH_f and pH_{fox} Field Test Results for Typical Soil Profiles Encountered within the Terrestrial Assessment Area

Landform Unit	Soil Type	pH(f)	pH(fox)	pH(f)		pH(fox)	
		mean[7]	mean	min	max	min	max
Longitudinal Dunes and Interdunal Swales	light brown to red brown SAND	8.28	7.25	6.34	9.57	5.86	9.28
	SANDSTONE/calcareous SANDSTONE	8.93	8.88	8.72	9.49	7.03	9.31
	silty sandy GRAVEL	7.77	7.33	7.34	8.15	6.57	7.87
	silty SAND	8.34	7.08	6.02	9.70	6.20	8.56
Fringing and Coastal Dunes	calcareous SANDSTONE	8.60	7.52	8.11	9.20	6.59	8.64
	grey CLAY	7.09	0.87	5.50	7.83	0.70	1.05
	silty SAND, SAND some shell	7.84	7.12	7.34	8.33	6.37	7.68
Alluvial/Colluvial Plains	CLAY, brown to grey with yellow mottles	6.72	4.93	5.99	7.36	3.60	6.01
	clayey SAND, red brown	8.25	8.10	6.63	9.00	5.40	8.79
	gravelly SAND, red brown	7.56	7.87	7.00	8.25	7.30	8.20
	gravelly sandy CLAY, red brown	7.33	6.39	7.16	7.75	5.61	7.22
	SAND, brown	7.95	6.40	7.25	8.90	4.33	9.06
	SAND, very fine grained, red brown	7.80	6.38	6.38	1.42	6.38	6.38
	silty CLAY, red/brown, high plasticity	7.91	7.83	7.79	8.22	7.47	8.04
	silty SAND red/brown	7.58	7.17	6.21	9.33	5.06	9.00
	silty sandy CLAY, light brown	7.55	5.93	6.29	8.80	5.02	6.83
	silty sandy CLAY, red brown	7.39	6.84	6.35	8.24	5.10	7.88
Samphire Flats	CLAY, variable plasticity grey, variable mottling	6.64	4.40	4.80	7.36	0.75	7.64
	Clayey SAND, fine grained, red brown	7.35	8.02	7.04	7.61	7.26	8.27
	sandy CLAY to CLAY, variable plasticity, red/brown	6.96	6.31	5.02	7.65	0.92	6.31
	silty SAND, red brown	8.12	7.62	8.12	8.12	7.62	7.62
Intertidal Flats, Tidal Creek and	silty SAND, brown	8.28	5.59	8.15	8.47	2.80	7.20
	CLAY, brown, medium plasticity	6.91	5.06	6.15	7.56	2.09	7.17

[7] Mean value calculations for pHf and pHfox are presented in detail in Appendix D.

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Landform Unit	Soil Type	pH(f)	pH(fox)	pH(f)		pH(fox)	
		mean[7]	mean	min	max	min	max
Mangrove Swamp	SAND, fine grained, dark grey	7.92	5.32	7.92	7.92	5.32	5.32
	SAND, fine to medium grained, red brown	7.76	6.74	7.37	7.96	6.40	6.97
	sandy CLAY, moderate plasticity, red brown with grey mottling	7.23	7.54	7.12	7.33	7.31	7.76
Supratidal Salt Flats	clayey SAND, fine grained, some black mottles, red/brown	6.57	6.50	6.57	6.57	6.50	6.50
	clayey SAND, low plasticity, light brown	6.37	4.51	5.74	7.21	2.20	7.74
	sandy CLAY, medium plasticity, red brown	6.55	5.33	5.32	6.99	1.94	7.84
	Sandy CLAY, moderate plasticity, grey some yellow mottles	6.31	5.07	5.06	7.62	2.17	5.07
Claypans	CLAY, red brown, high plasticity	7.05	6.89	6.94	7.15	6.63	7.10
	sandy CLAY, red/brown, some large shell fragments	7.58	7.90	7.26	8.01	7.15	8.20
	silty SAND, limestone fragments, red brown	8.82	9.08	8.71	8.97	9.01	9.11
	Silty SAND, very fine to fine grained, light brown	7.68	7.79	7.42	8.15	7.29	8.55
	silty sandy CLAY, low plasticity, red brown	8.15	8.49	7.50	8.80	7.89	9.09

7.3.3 Carbonate 'Fizz' Test Results

Using the presence/absence approach, reactions indicative of calcareous material (fizzing), was identified in soil profiles comprising variable amounts of shell fragments and/or sandstone, including red brown sands with silt and clay components. No reaction with HCl was observed in profiles comprising high plasticity, brown to grey clay material.

While there is evidence of carbonate material present in soil profiles across Ashburton North and surrounds, it was generally absent in material suspected of being PASS (clays and silts of marine/mangrove deposits) with the exception of where shell fragments were detected, such as in the shallow soils of profiles located at E018 and E019. The carbonate 'fizz' field test results are presented in **Appendix D** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

7.3.4 Ashburton North and Surrounds-Analytical Results

The Chromium suite analytical results are presented in **Appendix D** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]). **Figure 9** presents the samples that exceed the selected action criteria of 0.03 %S for net acidity. Laboratory certificates are attached as **Appendix E** of Appendix HI Draft EIS/ ERMP [Chevron, 2010]).

Analytical results for the Chromium suite can be summarised as follows:

- pH_{KCl} values ranged between 5.2 pH (E018_3.0) and 9.9 pH (E003_2.0-2.15 and E019_0.0) across Ashburton North and surrounds indicating soils range between acidic and alkaline.
- Reported pH_{KCl} below 7 pH were generally detected at depth along the north east boundary of Ashburton North and surrounds.
- Reported TAA concentrations (existing acidity), greater than the adopted action criteria, were detected at E018 (MB18A [0.06 %S]) at a depth of 3.0m which is located in the north east extent of Ashburton North and surrounds.

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- Calculated net acidity concentrations in exceedance of the action criteria, ranged between 0.11 %S (E010_2.0) and 1.34 %S (E019_1.5), and were generally detected along the north eastern extent of Ashburton North and surrounds.
- ANC ranged between 34.7% kg $CaCO_3$/t (E003_2.0-2.15) and 0.11% kg $CaCO_3$/t (E006_1.5) indicating that some soils are present that contain the potential to buffer potential acidity. The most significant being within sands and clays comprising sandstone and limestone of the Dune and Onslow land systems.
- ANC was typically absent in PASS profiles reported within the supratidal salt flats, the samphire flats and the marine deposits underlying the fringing and coastal dunes and the alluvial/colluvial plains. ANC was in excess for PASS profiles reported at two locations only, underlying the intertidal flats, mangrove swamp and tidal creek and the alluvial/colluvial plains. ANC is discussed further in **Section 8.2.**

7.3.5 SIC Study Area-Analytical Results

- pH_{KCl} values ranged between 5.4 pH (QC01 for E007_0.5-0.6)[8] and 9.2 pH (SS05_1.0-1.5) along the SIC study area indicating soils range between acidic and alkaline.
- No TAA concentrations (existing acidity), was detected in exceedance of the adopted trigger value of 0.03 %S.
- Calculated net acidity concentrations in exceedance of the action criteria, was detected at one location only (QC01 for E007_0.5-0.6) within the boundary of the northern extent of the SIC study area of the supratidal salt flats with a concentration of 0.21 %S.
- Corresponding soil profile was sandy CLAY, moderate plasticity, fine to med grained, dark organic matter present, grey with some yellow mottling which was detected to the depth of hand auger (1.5 mbgl).
- ANC ranged between 2.63 % kg $CaCO_3$/t (SS03_0.5-0.6) and 0.51% kg $CaCO_3$/t (SS04_1.0-1.1) indicating that soils encountered within the SIC study area have significantly less potential buffering capacity than Ashburton North and surrounds.
- ANC was typically absent in profiles comprising of PASS material.
- Corresponding soil profiles exhibiting greater capacity for ANC comprise of fine grained red brown clayey SAND. ANC is discussed further in **Section 8.2.**

7.3.6 Additional Data Review

The following section summarises the findings of the additional data review of investigations completed by Coffey (2010) and Golders (2010a, 2010b and 2010c) for the Wheatstone Project as discussed in **Section 6.1.3**

Appendix A presents the results of the review, including the criteria used to derive a classification (low, moderate, high potential to generate acidity) (see **Section 8** for discussion) used in the assessment of PASS within the Terrestrial Assessment area.

Coffey (2010) Factual Interpretative Report-Onshore Geotechnical Investigation

A summary of the PASS review is as follows:

- PASS was identified at a total of 31 bore locations and was generally located towards the north eastern boundary of the Terrestrial Assessment area (**Figure 11**).

[8] Due to elevated RPD values, the field duplicate QC01, which has the higher pH value, was used for interpretation.

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- PASS was identified at shallow depths ranging between 0.5 mbgl and 4.4 mbgl (mean 2.25 m bgl) (elevations were not provided on the draft logs).
- PASS was intercepted at depths of less than 1 mbgl generally along the intertidal flats, tidal creek and mangrove swamps. The majority of PASS was intercepted between 1.0 and 3.0 m bgl within the samphire flats, the alluvial colluvial plains and along the fringing and coastal dune network.
- The thickness of the PASS lens ranged between 0.2 and 3.5 m (mean 1.34 m).
- PASS was therefore identified within landforms associated with samphire flats, alluvial/colluvial plains, fringing and coastal dunes and intertidal and supratidal salt flats. Although PASS is typically not associated with fringing and coastal dunes, it is anticipated underlying marine/organic deposits are associated with the adjacent Ashburton River delta and the Hooley Creek catchment.
- PASS was typically characterised as CLAY to clayey SAND/SAND, low to high plasticity, brown to dark grey; fine to medium grained, mottling may range from yellow and orange, firm to very soft.
- PASS was further identified at depth within the samphire flats located between the longitudinal dune network and the coastal dunes along the western boundary. This area was limited in analytical information only due to accessibility of drill rigs and core loss at shallow depths during hand augering, across the relatively water logged area associated with this landform unit. Based on the geotechnical log review, however, this landform unit will typically comprise of PASS at shallow depths.
- PASS material was not identified along the coastal dunes located between the Ashburton River Delta and the samphire flats/claypans. The geotechnical bores located along this area generally intercepted red earths typically comprising SAND/SAND/sandy GRAVEL, orange to red brown, minor silt, minor clay, fine to medium grained sand, sub rounded, moderately sorted, quartz major with ironstone, sandstone grains.

Golder (2010a) Potential Acid Sulfate Soil Investigation Final Factual Report

A summary of the review is as follows:

- Field tests undertaken for pH_f and pH_{fox} identified 45 locations that were actual ASS. i.e. where partial or complete oxidation had/ was occurring. These soils were typically located at depth, and slightly above the watertable, where water table fluctuations (seasonal rather than tidal) are considered the main factor driving the natural oxidation of this material.
- Analytical results reported PASS, above the specified trigger value of 0.03 %S, at a total of 114 locations. A maximum of 16.34 %S was reported at ES122 at a depth of 3.25 mbgl. The mean value for %S was 3.92 %S.
- PASS was generally located toward the north and north eastern boundary of the Terrestrial Assessment area, including the southern part of the Borrow Area 2 and of the low lying area to the west of the longitudinal dune network.
- PASS was identified at depths ranging between 0.25 mbgl and 5.25 mbgl (mean 2.15 mbgl). Corresponding elevations indicate PASS was typically encountered below 3 mAHD ranging between 1.52 and -3.0 mAHD (mean 0.60 mAHD) and was typically intercepted at or below the watertable (assuming some change in elevation due to tidal fluctuations).

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- PASS was intercepted at depths of less than 1 mbgl generally along the intertidal flats, tidal creek and mangrove swamps and the northern part of the supratidal flats. The majority of PASS was intercepted between 1.0 and 3.0 m bgl within the samphire flats, the alluvial colluvial plains, and the southern part of the supratidal flats including the fringing and coastal dune network.
- The thickness of the PASS lens ranged between 0.1 and 3.25 m (mean 1.23 m).
- PASS of less than 1.0 m in thickness was generally detected below the intertidal flats, tidal creek and mangrove swamps and of the supratidal flats. PASS lenses of between 1 and 3 m were reported along the samphire flats, fringing and coastal dunes and alluvial plains.
- PASS was also identified a depths typically below 2 mbgl, on the southern part of the Borrow Area 2 located to the east of the longitudinal dunes, which is bound by the supratidal salt flats.
- PASS was therefore identified within landforms associated with saline and samphire flats, alluvial/colluvial plains, fringing and coastal dunes and intertidal and supratidal flats.
- Corresponding soil profiles were typically characterised as dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND,with trace organics. Mottling was identified in both clayey and sandy profiles, ranging in colour from yellow and orange, indicating evidence of oxidation considered to be typical of a fluctuating water table.

Golder (2010b) Potential Acid Sulfate Soil Investigation -Borrow Areas

The additional PASS investigation undertaken for Borrow Area 4 can be summarised as follows:

- Field tests undertaken for pH_f and pH_{fox} identified no samples with actual ASS.
- Field tests screening criteria categorised all samples as 'low' risk.
- Analytical results reported no samples with TAA (actual acidity) above or equal to the DEC action criteria of 0.03%S.
- Analytical results (SPOCAS and Scr) reported PASS, above the specified trigger value of 0.03 %S, in four samples at a total of three locations (BP4_1, BP4_2 and BP4_3). A maximum concentration of 0.21 %S was reported at BP4_2 at a depth of 3.25 mbgl comprising red brown, fine grained SAND.
- PASS material located at BP4_1 was identified at a depth of 4.75 mbgl with a reported net acidity concentration of 0.15 %S. This material was not typically indicative of PASS given the soils profile comprised of red brown silty sand and the initial field screening tests assigned this material as 'low' risk.
- PASS material located at BP4_2 was identified at a depth of 1.0 mgl (0.03%S) and 2.25 mbgl (0.19%S) in soils comprising red brown silty clayey SAND and red brown sandy clayey GRAVEL, respectively.
- It should be noted that the low net acidity concentrations reported of these soil profiles, typically known as the Ashburton Red Beds (Coffey, 2009), are not characteristic of PASS.
- Thickness of a profile, typically indicative of PASS, could not be determined from the test pit logs or from field screening results.

7 BSQ and PASS Investigation Results

Golder (2010c) Domgas Preliminary Geotechnical Information

A summary of the Technical memorandum for the Domgas study area, with regards to PASS is as follows:

- Field tests undertaken for pH_f and pH_{fox} identified no samples with actual ASS.
- Field tests screening criteria categorised all samples as 'low' risk.
- Based on these field test results, no analytical tests were submitted for analysis using the SPOCAS or Scr methods.

7.3.7 Acid Sulfate Soils Discussion

The results of the field and analytical investigations, the geotechnical bore review and the Golder (2010a, 2010b and 2010c) PASS investigation review, indicate that PASS is present at shallow depths ranging between 0.25 m bgl and 5.25 mbgl with a thickness ranging between 0.2 and 3.5 m, predominantly along the north and north eastern extent of the Terrestrial Assessment area and of the samphire flats to the west of the longitudinal dune network, although PASS has been identified as far south along the supratidal salt flats to where the SIC study area boundary is located.

PASS was also identified at depths typically below 2.5 mbgl (and below 1.5 mAHD), on the southern part of the Borrow Area 2 located to the east of the longitudinal dunes, which is bound by the supratidal salt flats, and to a lesser extent PASS was identified intermittently on the adjacent Borrow Area 3 where PASS was typically identified in low lying claypan areas.

Figure 12 and **Figure 13** illustrate the inferred depth at which PASS was identified and the approximate thickness of these lenses.

Corresponding soil profiles were typically characterised as dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND, with trace organics. Mottling was identified in both clayey and sandy profiles, ranging in colour from yellow to orange, indicating evidence of oxidation considered to be typical of a fluctuating water table. These soils are visually identifiable in comparison to the red earths and sandstone pavement typically encountered throughout the Terrestrial Assessment area.

Uncharacteristically however, soils of the Ashburton Red Beds (Coffey, 2009), in this case comprising red brown SAND to silty clayey GRAVEL, exhibited low net acidity concentrations in exceedance of the DEC trigger value of 0.03%S, for approximately 10% of the samples submitted for analysis in Borrow Area 4.

PASS was also identified in landforms associated with samphire flats, alluvial/colluvial plains and fringing and coastal dunes. Although PASS is typically not encountered within landform units associated with the fringing and coastal dunes, it is believed that shallow marine/organic deposits may be associated with the bordering Ashburton River delta and the Hooley Creek catchment and underlies this network as a chenier formation.

Actual ASS was detected at depth, and slightly above the watertable, at a total of 46 locations within the Terrestrial Assessment area where red and yellow mottling, reported in the soil logs, suggests historical oxidation around the depth of the water table. It was noted also that manganese concentrations were significantly lower in profiles where either actual

7 BSQ and PASS Investigation Results

acidity was present, or acidic pH values were reported. This suggests that manganese has been mobilised through natural processes associated with PASS oxidation.

The ANC of the Terrestrial Assessment area is generally high, however is typically absent in soil profiles identified as PASS. Soils with the highest ANC throughout Ashburton North and surrounds generally comprised of sands and sand clays with shell, limestone and/or sandstone interbedded throughout. ANC of the SIC study area was significantly lower with highest buffering capacity detected in the red clayey sands. Where net acidity concentrations in exceedance of the action criteria were reported, corresponding ANC concentrations were non existent or negligible.

The effectiveness of the ANC in maintaining soil pH at acceptable levels (i.e. pH 6.5 to 9.0 pH or as background levels) depends on the type, amount and particle size of the carbonate present. Shells and carbonate materials often have an insoluble coating which limits ANC availability.

For this reason, and as PASS typically has negligible ANC, any reported ANC needs to be considered in conjunction with the type of ground disturbance proposed and mitigation strategies applied with this in mind. For example, regardless of the ANC of the surrounding environment, PASS that is oxidised in an *in-situ* environment can only utilise the ANC of the immediate profile, and then it must be considered, whether there is sufficient availability of the carbonate material to buffer the potential acidity.

This is discussed further in **Section 8.2.**

Locations of PASS within the Terrestrial Assessment Area

8.1 PASS Assessment Approach

A PASS map was produced identifying areas reported below the DEC trigger value of 0.03%S and as low, moderate and high potential to generate acidity for the Terrestrial Assessment area and is primarily based on % S concentrations reported of analytical data provided by Golder (2010a and 2010b) and on baseline analytical data completed by URS as part of this investigation.

The sulphur criteria trigger values presented in **Table 8.1** were statistically derived based on the frequency distribution for %S (sum of TPA and TAA). As per DEC guidelines, the highest %S per bore location across the Terrestrial Assessment area was used for this analysis. The calculations and subsequent histograms derived from the analytical data are presented in **Appendix A.**

The basis for selecting the criteria values was derived by the frequency of which it occurred within the selected interval (intervals of 1%S were calculated). Based on this, the presence of occurrence was calculated across the following collective intervals:

- Below the DEC trigger value of 0.03%S.
- 0.03 to <1.0%S.
- 1.0 to <5.0%S.
- ≥5.0%S.

Where analytical data was absent across the Terrestrial Assessment area, soils were further classified based on strategies provided by Atkinson *et al* (1996) and Ahern *et al* (1998), which utilised the following site specific inputs.

- Interpretation of aerial photography (e.g. elevation and landforms of less than 5mAHD)
- Landforms identified in the field (e.g. identification of landforms typically associated with PASS).
- Soil profiles intercepted (clays, organic clays and sands brown to dark grey). These soils are typically visually identifiable in comparison with the red earths and sandstone pavement typically encountered within the Terrestrial Assessment area.

The criteria are summarised in **Table 8.1.**

8.2 PASS Identification

Based on the above criteria a PASS map was generated for the Terrestrial Assessment area (**Figure 14-1 to 14-5).**

PASS of high acid generating potential is typically located in the north and north eastern extent of the Terrestrial Assessment area within the intertidal mud flats. Although PASS is typically not associated with landform units associated with the fringing and coastal dunes and the adjacent alluvial/colluvial plains, it is believed that shallow marine/organic deposits may be associated with the Ashburton River delta and the Hooley Creek catchment which underlies this network, and as a result, PASS of high acid generating potential was reported along the north eastern boundary below these landforms.

Along the western boundary of the Ashburton North study area, the samphire flats and clayey plains generally have high potential to generate acidity, as is the case with the

8 Locations of PASS within the Terrestrial Assessment Area

southern part of Borrow Area 2, where PASS of high acid generating capacity was typically observed at depths greater than 3 mbgl.

Given the variable nature of the acid generating potential of material encountered, it is typical to encounter PASS of moderate acid generating potential interspersed in pockets in areas identified as high potential. This is noted along the north western boundary of the Terrestrial Assessment area and the southern part of the Borrow Area 2.

The area to the north north west of the Terrestrial Assessment area, closest to the Indian Ocean, has been classified as low potential for encountering PASS based on soil types encountered at depth, and inferred landforms, which are considered indicative of PASS. Although Golder (2010) field screening tests did not detect PASS, it is considered prudent that a low potential ranking is put in place until further confirmatory analytical testing is undertaken at this location.

In the absence of any information regarding the small islands located east of Borrow Area 2, they have been classified as moderate potential to generate acidity. However it is considered likely that PASS would be intercepted at depths close to the water table, such as that encountered at Borrow Area 2.

The supratidal salt flats are considered to be of low acid generating potential. PASS material is typically encountered at shallow depths (<1 mbgl) and have a thickness of less than 1.0mbgl. Clayey pockets dotting the SIC study area have low acid generating potential, given that low %S have been detected as far south as the Accommodation Village.

The northern limits of Borrow Area 4 is considered to be of low acid generating potential based on analytical tests which identified net acidity in exceedance of the adopted DEC guideline criteria in 10% of soil samples characterised as Ashburton Reds.

Landforms associated with the longitudinal dune network, where soils are typically of terrestrial origin and contain significant authigenic carbonates (formed *in-situ*) and of the coastal dunes located to the east of the Ashburton River delta are not considered to have the potential to generate acidity.

Borrow Area 1, the majority of Borrow Area 3 and 4, the Domgas Study area, and the majority of the SIC study area has been reported to be below the DEC trigger value of 0.03%S, given the nature of the landforms, field screening and analytical test results (Golder 2010a, 2010b and 2010c) and based on soil types encountered.

8 Locations of PASS within the Terrestrial Assessment Area

Table 8-1 PASS Mapping

Classification Criteria	Criteria for acid generating capacity of PASS			
	Below DEC Trigger value of 0.03%S	Low Potential for generating acidity	Moderate Potential for generating acidity	High Potential for generating acidity
Sulfide Content	Non-detect	0.03 to > 1.0 %S	1.0 to <5.0 %S	≥ 5%S
Typical Landform	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation) and alluvial colluvial	Typically the Supratidal Flats, although also of fringing landforms	Typically samphire flats and chenier formations, alluvial/colluvial plains of low lying areas	Typically samphire flats and clayey plains, intertidal areas, of mangrove swamps alluvial/colluvial plains of low lying
Soil Type	Red earths sands/clays and sandstone/limestone pavement	Dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND	Dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND	Dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND

8.3 Acid Neutralising Capacity

ANC is a measure of a soil's inherent ability to buffer acidity and resist the lowering of the soil pH. Acid buffering in the soil may be provided by dissolution of calcium and/or magnesium carbonates (for example shell or limestone), cation exchange reactions, and by reaction with the organic and clay fractions. The effectiveness of these buffering components in maintaining soil pH at acceptable levels (e.g. pH 6.5–9.0) will depend on the types and quantities of clay minerals in the soil, and on the type, amount and particle size of the carbonates or other minerals present.

With regard to the most likely sources of silicate-induced acid neutralisation are clay minerals and chlorite. The other silicate minerals do not contain neutralising cations (quartz, kaolinite) or their dissolution rate is so low, with minor cation exchange capacity, that ANC is negligible (muscovite, albite, orthoclase).

Although there is evidence of significant ANC of the surrounding environment of the Terrestrial Assessment area e.g. as reported for soil profiles with significant shell, limestone and/or sandstone, it ranged greatly depending on the composition of the soil profile (e.g. whether it was clay, sand or of marine/mangrove origin).

The current NATA accredited analytical methodology used by ALS, described in **Section 6.3.2,** to determine the ANC of a soil is in accordance with the guidelines, however the DEC (2009a) acknowledge that in addition to this test method, other aspects need to be considered. This is mainly because the net acidity leached to the environment upon disturbance of PASS, depends not only on the amount and rate of acid generation, but also on the amount and reactivity of the neutralising components in the soil. The actual amount of neutralising capacity available under real field conditions is influenced by particle size or fineness of acid neutralising material, armouring and reaction kinetics. For this reason, and as PASS typically has negligible ANC, any reported ANC needs to be considered in conjunction with the type of ground disturbance proposed and mitigation strategies applied.

Conclusions

A BSQ and landforms assessment was completed for the Terrestrial Assessment area. This assessment comprised of a desktop review of available data and site specific assessments.

The objectives of the investigation were to complete a general regional and site specific assessment of the soils and landforms identified within Ashburton North and surrounds and the SIC study area, identify baseline metal concentrations of the surface and subsurface profile and identify the general presence or absence of PASS and subsequently derive a PASS map for material encountered within the Terrestrial Assessment area.

A summary of the findings of the works performed are as follows:

- A series of seven land systems were identified within the Terrestrial Assessment area, and include the Littoral, Onslow, Dune, Minderoo, Giralia, Stuart and Uaroo land systems.
- The landforms associated with these land systems include:
  - Littoral land system: intertidal creeks, mangrove, supratidal salt flats and samphire flats
  - Onslow land system: alluvial/colluvial plains, minor claypans and fringing and coastal dunes
  - Dune land system: longitudinal dunes, interdunal swales, alluvial/colluvial plains and claypans.
  - Minderoo land system: alluvial plains and sandy plains.
  - Giralia land system: linear (parallel), sandy and calcrete plains.
  - Stuart land system: undulating plains, minor hills and broad lower plains.
  - Uaroo land system: low hills, low stony rises and pebbly, sandy and calcrete plains.
- Based on the results of the field dispersion tests, clay and/or clayey soils identified within Ashburton North and surrounds and the SIC study area generally slake (slightly) but are non dispersive (Class 4, 5 or 6). PASS was classified as potentially dispersive (Class 3).
- The results of the erodibility assessment indicated landform units of the longitudinal dune network, fringing and coastal dunes and mainland dunes have very high to extreme erosion potential for wind and high erosion potential for water.
- No analytical results for metals were reported in exceedance of the adopted HIL-F guideline criteria and therefore it is considered there is no risk to human health.
- Elevated arsenic, chromium, manganese and nickel concentrations were detected above the adopted EIL trigger values within the north western and north eastern extent of Ashburton North and surrounds and chromium and manganese within the SIC study area
- Because there have been no historic industrial land use practices within the Terrestrial Assessment area and it is not anticipated that adjacent land use practices (Onslow Salt) have negatively impacted these areas.
- Further, a comparison of the these results against an assessment of heavy metals completed by Oceanica (2005) and URS (2008) along the Pilbara coastline of similar deltaic systems, also reported elevated concentrations of arsenic, chromium and nickel. The elevated metals encountered are comparable suggesting that the high background levels are likely a result of the weathering of terrestrial origin.
- The results of the desktop assessment, field and analytical investigations, the geotechnical bore review and the Golder (2010a, 2010b and 2010c) PASS investigation review, indicate that PASS is present at shallow depths ranging between 0.25 m bgl and 5.25 mbgl with a thickness ranging between 0.2 and 3.5 m, predominantly along the north and north eastern extent of the Terrestrial Assessment area, and of the samphire flats to

9 Conclusions

the west of the longitudinal dune network, although PASS has been identified as far south along the supratidal salt flats to where the SIC study area boundary is located.

- PASS was also identified at depths typically below 2.5 mbgl (and below 1.5 mAHD), on the southern part of the Borrow Area 2 located to the east of the longitudinal dunes, which is bound by the supratidal salt flats, and to a lesser extent, PASS was identified intermittently on the adjacent Borrow Area 3, located to the east of the Borrow Area 2, where PASS was typically identified in low lying claypan areas.
- Corresponding soil profiles were typically characterised as dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND, with trace organics. Mottling was identified in both clayey and sandy profiles, ranging in colour from yellow and orange, evidence of oxidation considered to be typical of a fluctuating water table (seasonal rather than tidal).
- These soils are considered to be of marine/organic origin and are generally located within landform units associated with the intertidal flats, tidal creek and mangrove swamp of the Littoral land system and within the supratidal flats, clayey plains and samphire flats where groundwater was intercepted.
- PASS was also identified comprising of marine /organic deposits in landforms associated with the alluvial/colluvial plains and fringing and coastal dunes.
- Uncharacteristically, soils of the Ashburton Red Beds (Coffey, 2009), in this case comprising red brown SAND to silty clayey GRAVEL, exhibited low net acidity concentrations in exceedance of the DEC trigger value of 0.03%S, for approximately 10% of the samples submitted for analysis in Borrow Area 4.
- A PASS map was produced identifying areas reported below the DEC trigger value of 0.03%S and as low, moderate and high potential to generate acidity for the Terrestrial Assessment area.
- Based on the results of the PASS assessment, PASS of high acid generating potential is typically located in the north and north eastern extent of the Terrestrial Assessment area of the intertidal flats, the samphire flats along the north western boundary, along the southern boundary of Borrow Area 2 (below 3 mbgl), and below alluvial colluvial plains where shallow marine/organic deposits were identified.
- The area to the north north west of the Terrestrial Assessment area, closest to the Indian Ocean, has been classified as low potential for encountering PASS based on soil types encountered at depth, and inferred landforms, which are considered indicative of PASS.
- Given the variable nature of the acid generating potential of material encountered, it is typical to encounter PASS of moderate acid generating potential interspersed in pockets in areas identified as high potential. This is noted along the north western boundary of the Terrestrial Assessment area and the southern part of the Borrow Area 2.
- The supratidal salt flats are considered to be of low acid generating potential where PASS material was typically encountered at shallow depths (<1 mbgl) with a thickness of less than 1.0mbgl. Clayey pockets dotting the SIC study area have been classified as low acid generating potential, given that low %S have been detected as far south as the Accommodation Village.
- Landforms associated with the longitudinal dune network, where soils are typically of terrestrial origin and contain significant authigenic carbonates (formed *in-situ*) and of the coastal dunes located to the east of the Ashburton River delta are not considered to have the potential to generate acidity.

9 Conclusions

- The northern limits of Borrow Area 4 is considered to be of low acid generating potential based on analytical tests which identified net acidity in exceedance of the adopted DEC guideline criteria in 10% of soil samples characterised as Ashburton Reds.
- Borrow Area 1, the majority of Borrow Area 3 and 4, the Domgas Study area, and the majority of the SIC study area has been reported to be below the DEC trigger value of 0.03%S, given the nature of the landforms, field screening and analytical results (Golder 2010a, 2010b and 2010c) and based on soil types encountered.
- Although there is evidence of significant potential ANC of the soils profiles of the Terrestrial Assessment area (e.g. as reported for soil profiles with significant shell, limestone and/or sandstone), it ranged greatly depending on the composition of the soil profile (e.g. whether it was clay, sand or of marine/mangrove origin).

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Limitations

URS Australia Pty Ltd (URS) has prepared this report in accordance with the usual care and thoroughness of the consulting profession for the use of Chevron and only those third parties who have been authorised in writing by URS to rely on the report. It is based on generally accepted practices and standards at the time it was prepared. No other warranty, expressed or implied, is made as to the professional advice included in this report. It is prepared in accordance with the scope of work and for the purpose outlined in the Signed CTR T3.1, T3.1A, 62 and 84.

The methodology adopted and sources of information used by URS are outlined in this report. URS has made no independent verification of this information beyond the agreed scope of works and URS assumes no responsibility for any inaccuracies or omissions. No indications were found during our investigations that information contained in this report as provided to URS was false.

This report was prepared between 27 March 2009 and 8 November 2010 and is based on the conditions encountered and information reviewed at the time of preparation. URS disclaims responsibility for any changes that may have occurred after this time.

This report should be read in full. No responsibility is accepted for use of any part of this report in any other context or for any other purpose or by third parties. This report does not purport to give legal advice. Legal advice can only be given by qualified legal practitioners.

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Figures

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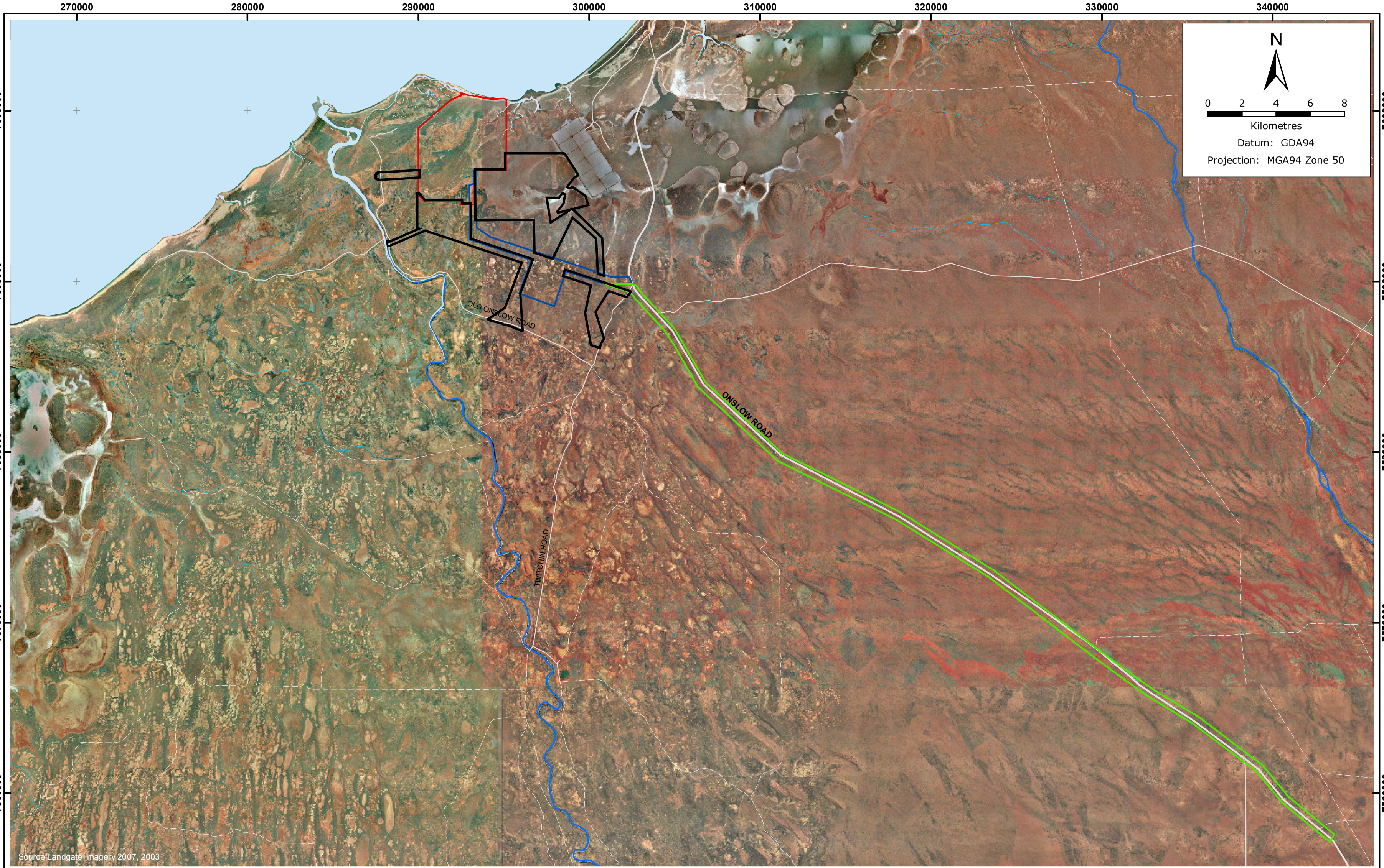

Legend

Construction Study Area	Ashburton North and Surrounds	**Road (GA, 2006)**	**Watercourse (GA, 2008)**
	SIC and Camp Study Area	Major Road	Major Watercourses
	Domgas Study Area	Minor Road	Minor Watercourses
		Track	

Client	Project		Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment		Terrestrial Assessment Area
URS	Drawn: MR/RNM	Approved: MN	Date: 14/05/2010
	Job No.: 42907466	File No.: 42907466-RL-003_RB.mxd	Figure: 1
			Rev. B
			A3

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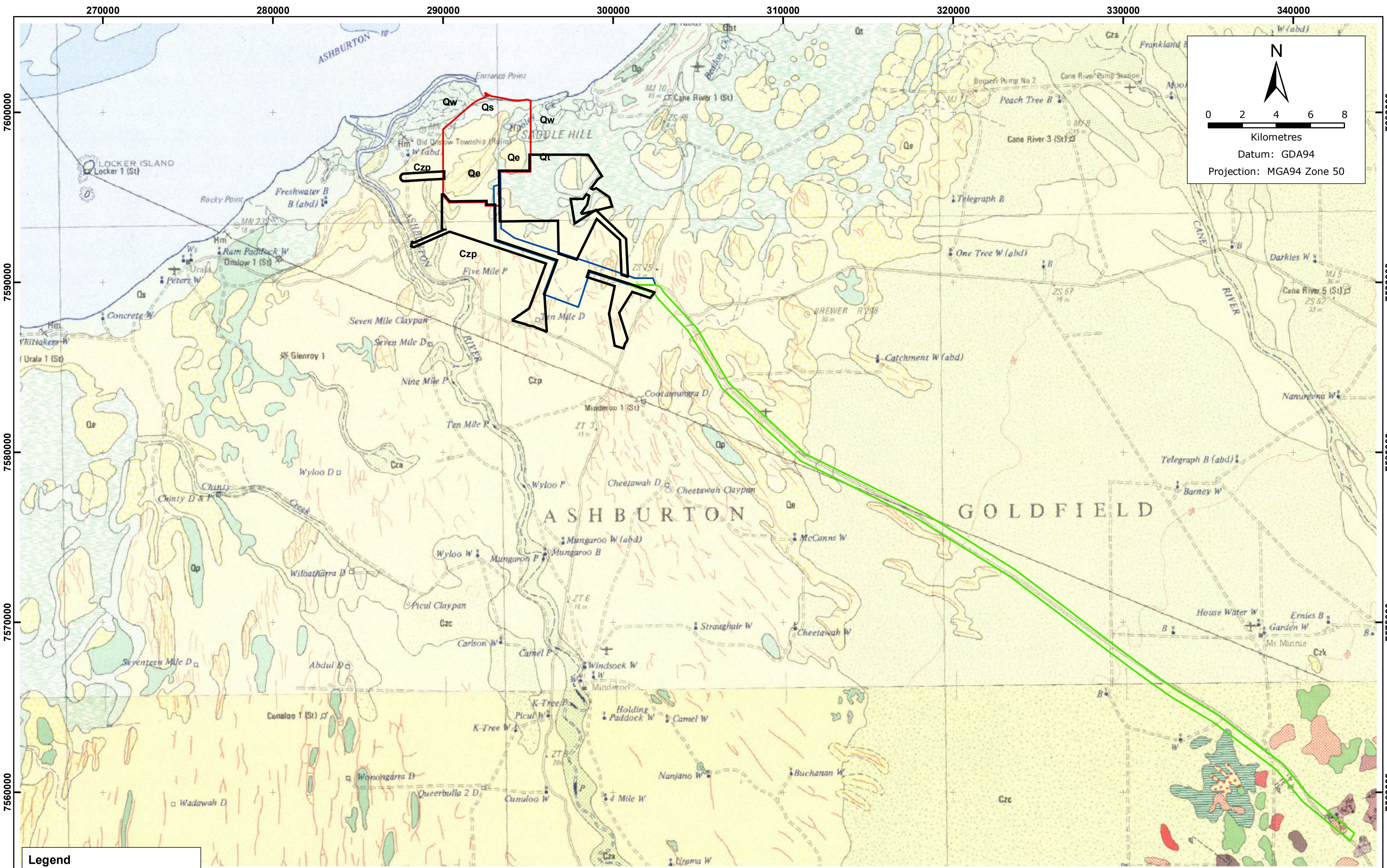

Legend

- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area

Qr Ningaloo Reef - living coralgal reef
Qs Beaches and coastal dunes - light grey, unconsolidated and poorly consolidated quartzose calcarenite
Qw Intertidal flats and mangrove swamps - calcareous clay, silt and sand
Qt Supratidal flats - calcareous clay, silt and sand with authigenic gypsum and superficial algal mats and salt crusts
Qp Claypans - poorly sorted clay, silt, sand and minor pebbles
Qe Longitudinal and network dunes and residual sand plains - reddish-brown to yellowish quartz sand
Czk Calcrete - lumpy to nodular or massive, authigenic limestone, locally silicified
Cza Alluvium - clay, silt, sand and gravel, partly calcreted
Czc Colluvium - poorly sorted clay, silt, sand and gravel; formed on plains and slopes by sheet floodand deflatation; includes minor laterite exposed
Czp Claypan-dominant terrain - claypans with longitudinal and net dunes, and/or flat deflation-lag surfaves; clay, silt, sand and gravel

Source: Landgate Imagery 2007, 2003, Geological Survey of Western Australia

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Regional Surficial Geology
URS	Drawn: MR/RNM; Approved: MN; Date: 14/05/2010	Figure: 2 — Rev. B
	Job No.: 42907466; File No.: 42907466-RL-004_RB.mxd	A3

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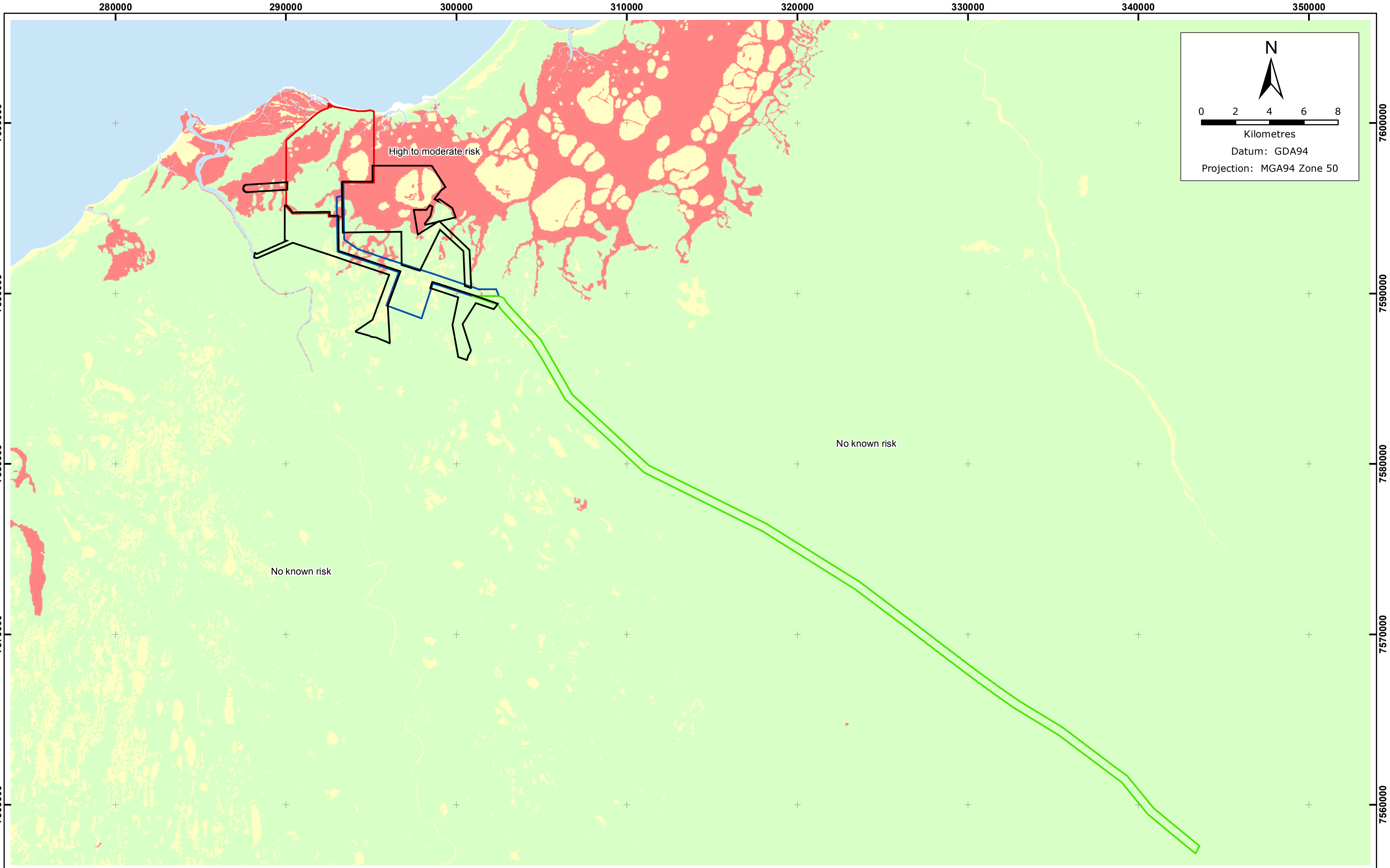

Legend

- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area

ASS Risk Category (DEC 2006)

- High to moderate risk
- Moderate to low risk
- No known risk

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	ASS Risk Map
URS	Drawn: MR/RNM; Approved: MN; Date: 14/05/2010	Figure: 3; Rev. B
	Job No.: 42907466; File No.: 42907466-RL-006_RB.mxd	A3

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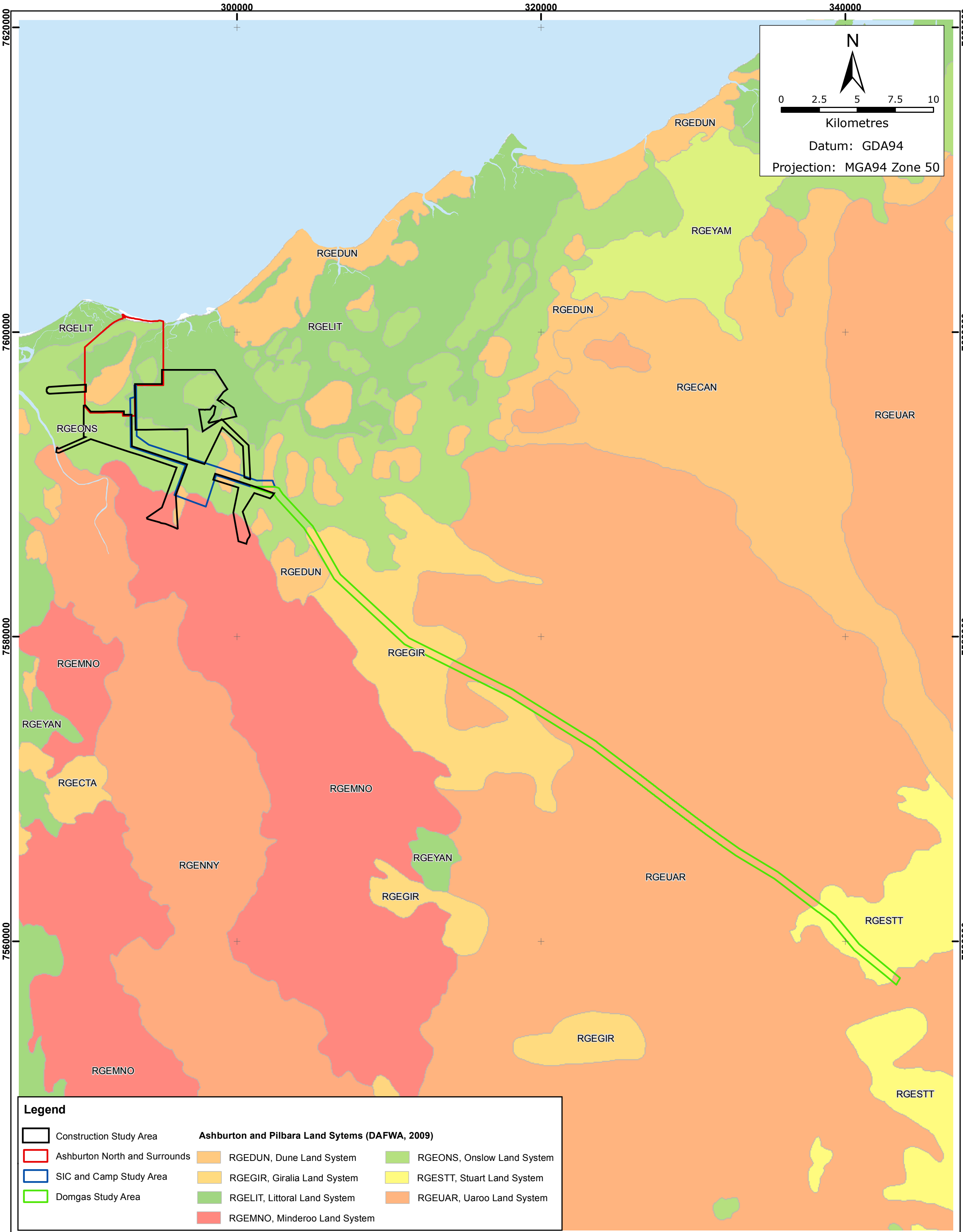

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Land Systems of the Terrestrial Assessment Area
URS	Drawn: MR/RNM; Approved: MN; Date: 14/05/2010	Figure: 4; Rev. B
	Job No.: 42907466; File No.: 42907466-RL-005_RB.mxd	A3

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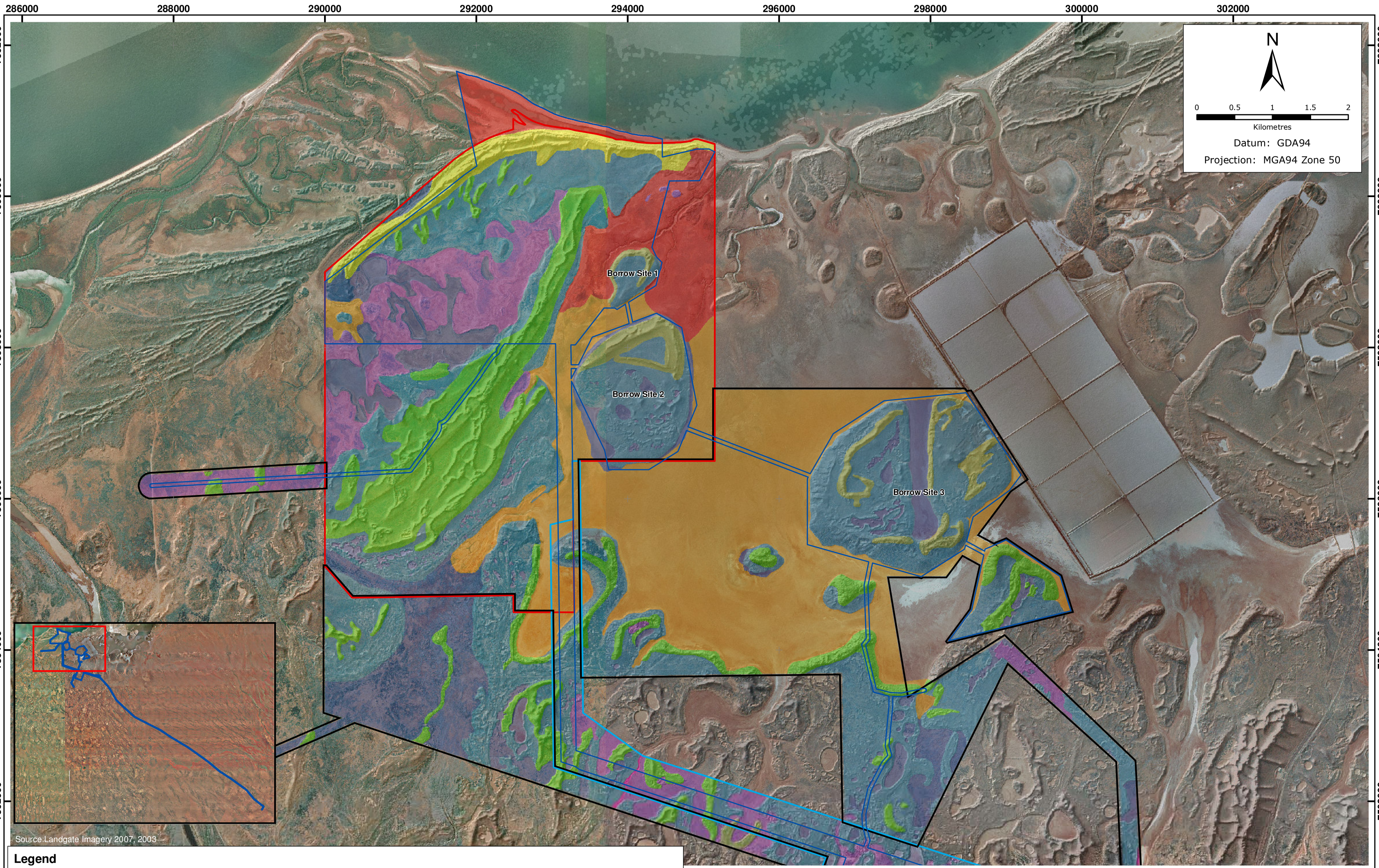

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area

Landform Units

- ALC, Alluvial / Colluvial
- CPB, Claypans and Clay Plains
- DA, Drainage Area
- FCD, Fringing and Coastal Dunes
- LDS, Longitudinal Dunes and Interdunal Swales
- MRD, Mainland Remnant Dunes
- SF, Saline Flats
- SFC, Samphire Flat
- SH, Stony Hills
- SSF, Supratidal Salt Flats
- TCM, Tidal Creek, Mangrove Swamp, Intertidal Flats

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Landform Units of the Terrestrial Assessment
URS	Drawn: MR/RNM/CJT; Approved: MN; Date: 05/11/2010; Job No.: 42907466; File No.: 42907466-RL-002B.mxd	Figure: 5-1; Rev. B; A3

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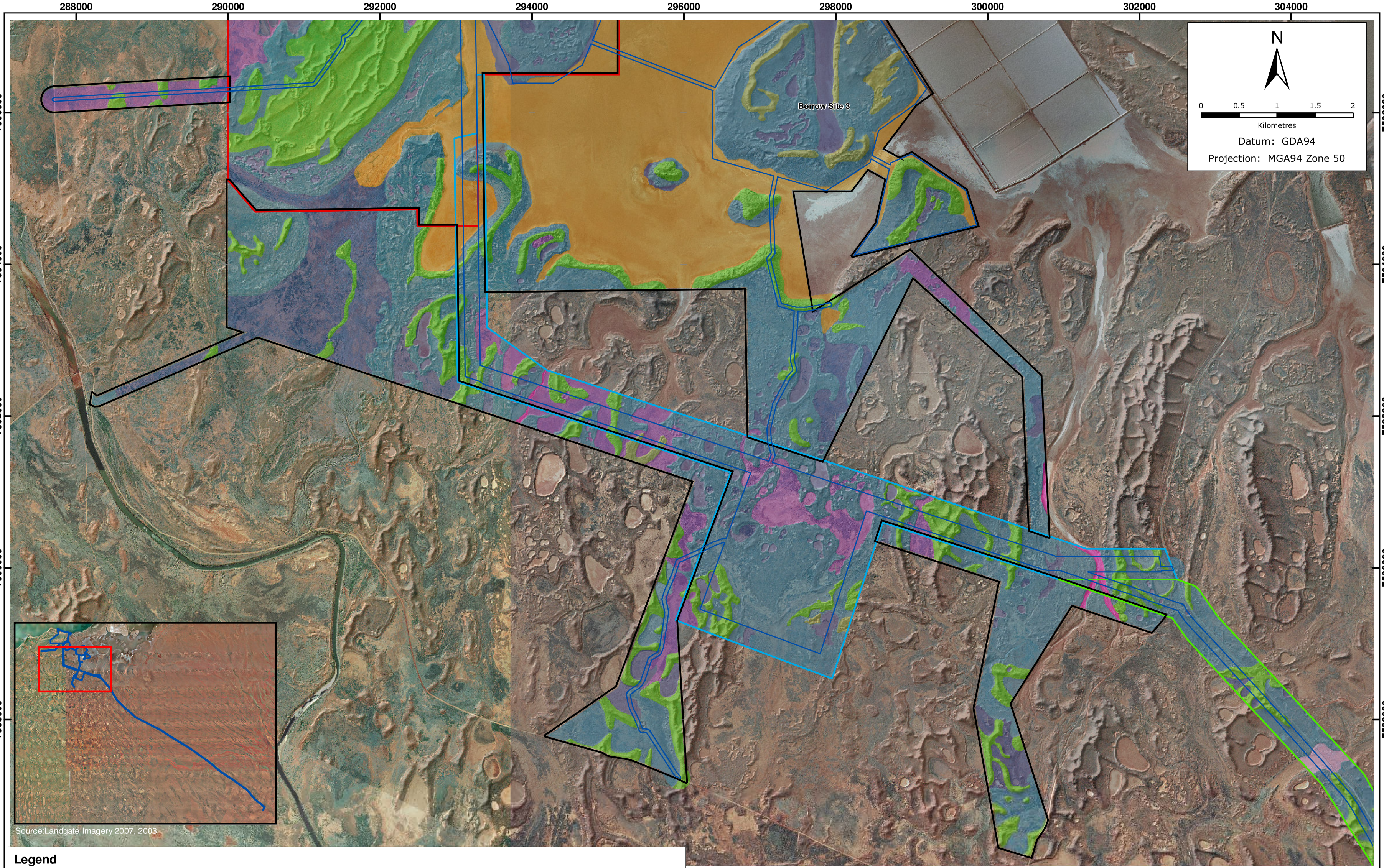

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area

Landform Units

- ALC, Alluvial / Colluvial
- CPB, Claypans and Clay Plains
- DA, Drainage Area
- FCD, Fringing and Coastal Dunes
- LDS, Longitudinal Dunes and Interdunal Swales
- MRD, Mainland Remnant Dunes
- SF, Saline Flats
- SFC, Samphire Flat
- SH, Stony Hills
- SSF, Supratidal Salt Flats
- TCM, Tidal Creek, Mangrove Swamp, Intertidal Flats

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Landform Units of the Terrestrial Assessment
URS	Drawn: MR/RNM/CJT; Approved: MN; Date: 08/11/2010	Figure: 5-2; Rev. C
	Job No.: 42907466; File No.: 42907466-RL-002_RC.mxd	A3

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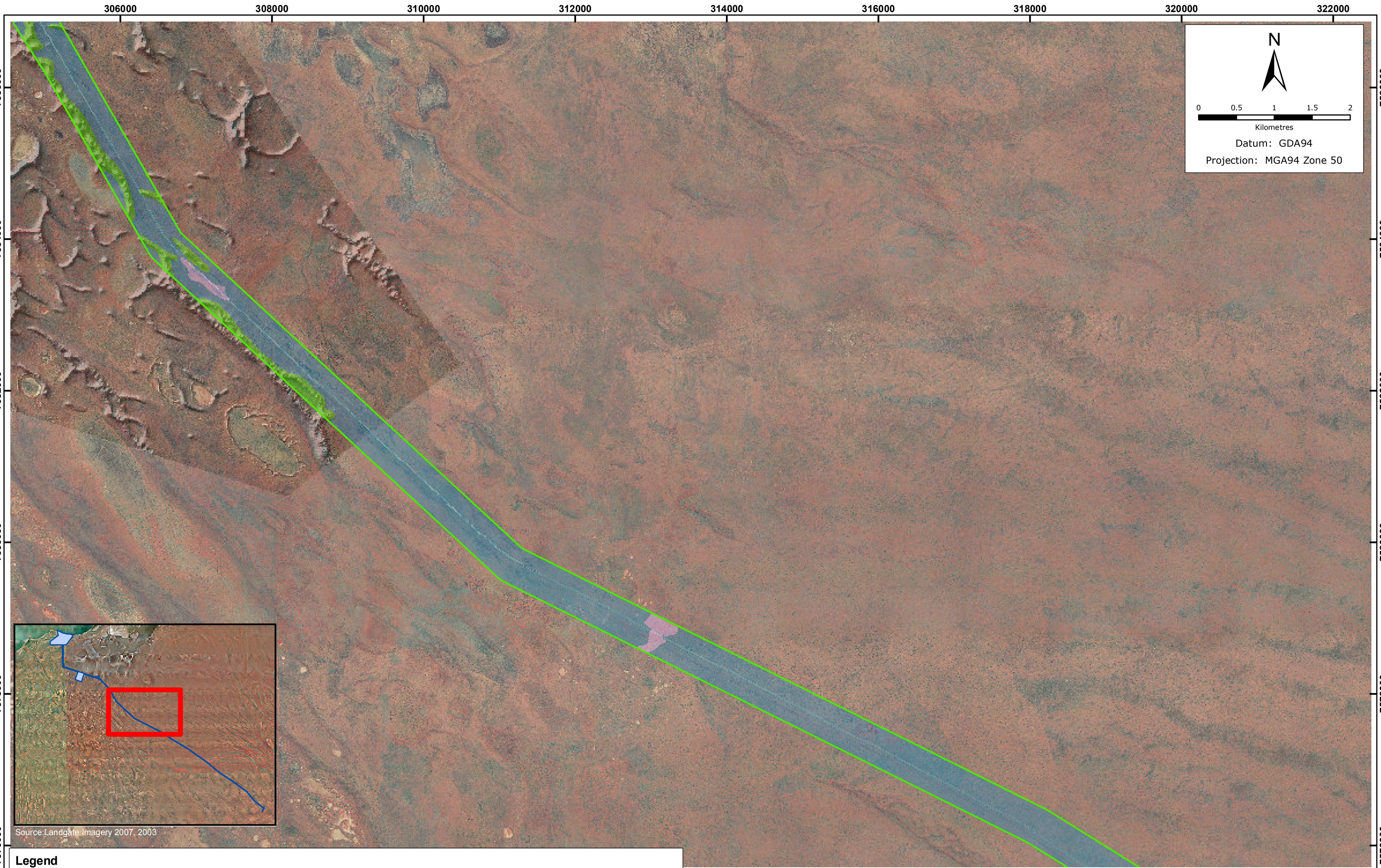

Legend

- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area

Landform Units

- ALC, Alluvial / Colluvial
- CPB, Claypans and Clay Plains
- DA, Drainage Area
- FCD, Fringing and Coastal Dunes
- LDS, Longitudinal Dunes and Interdunal Swales
- MRD, Mainland Remnant Dunes
- SF, Saline Flats
- SFC, Samphire Flat
- SH, Stony Hills
- SSF, Supratidal Salt Flats
- TCM, Tidal Creek, Mangrove Swamp, Intertidal Flats

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Landform Units of the Terrestrial Assessment
URS	Drawn: MR/RNM; Approved: MN; Date: 14/05/2010	Figure: 5-3; Rev. A
	Job No.: 42907466; File No.: 42907466-RL-002C.mxd	A3

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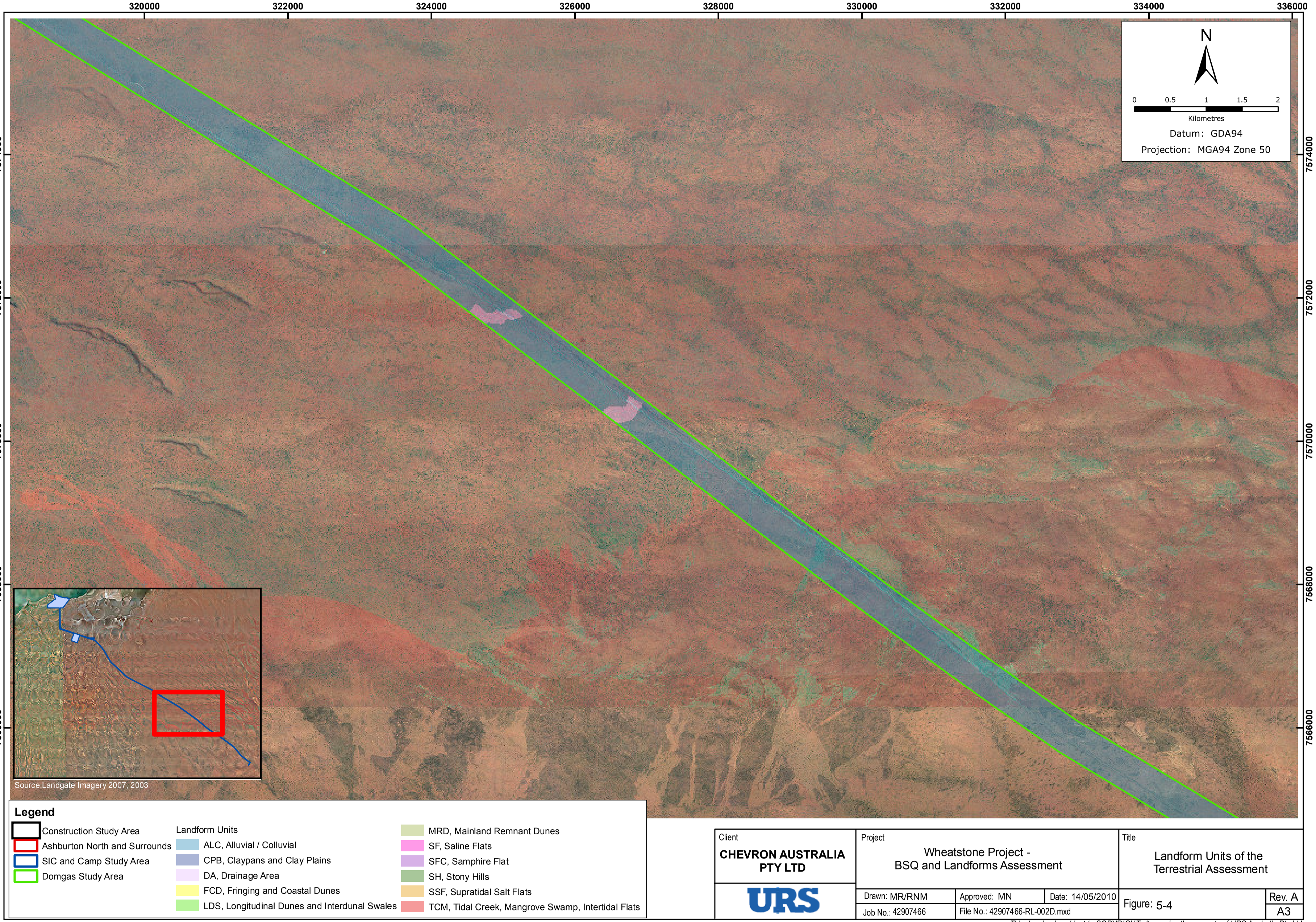

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Landform Units of the Terrestrial Assessment
URS	Drawn: MR/RNM; Approved: MN; Date: 14/05/2010	Figure: 5-4; Rev. A
	Job No.: 42907466; File No.: 42907466-RL-002D.mxd	A3

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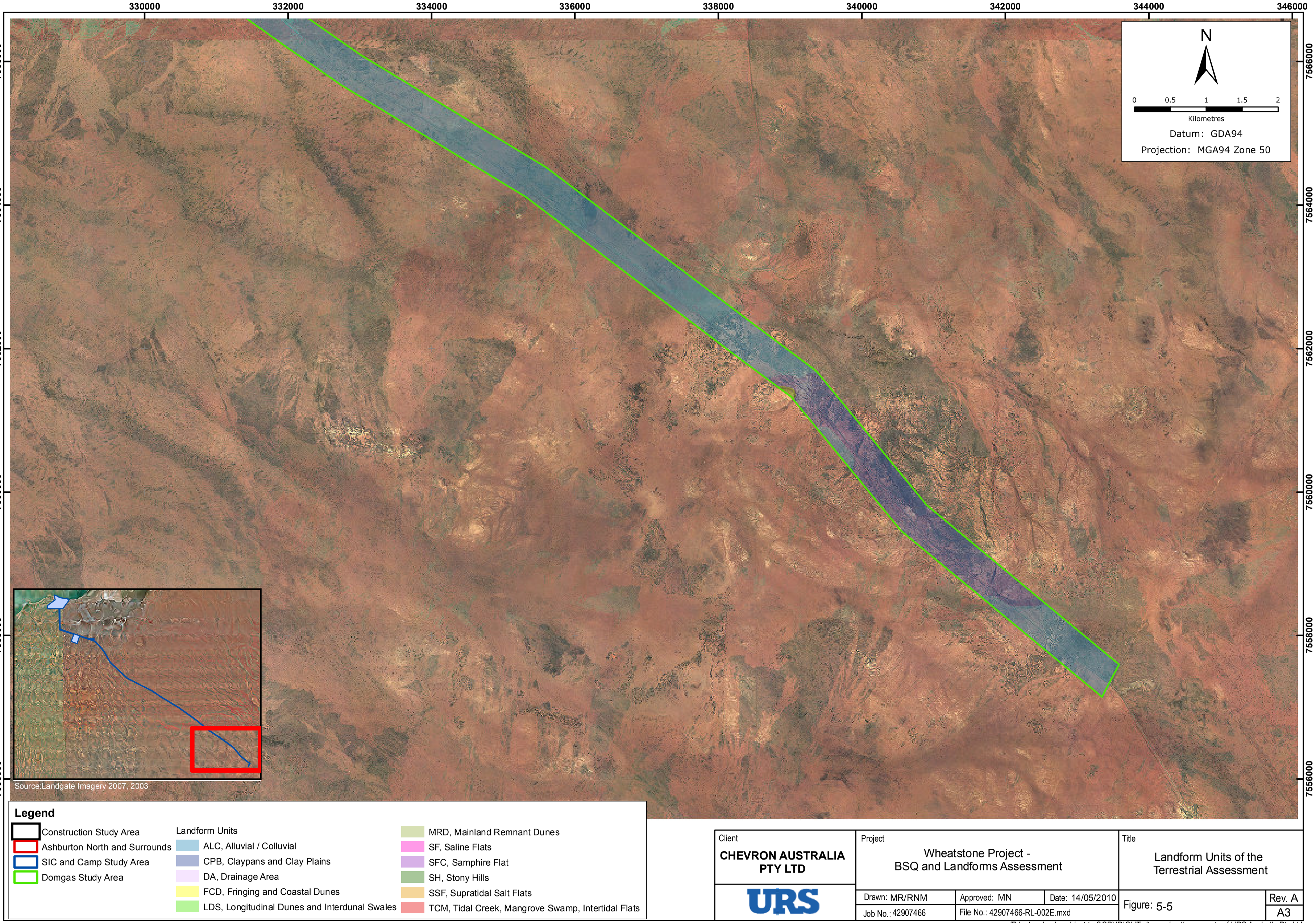

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Landform Units of the Terrestrial Assessment
URS	Drawn: MR/RNM; Approved: MN; Date: 14/05/2010	Figure: 5-5; Rev. A
	Job No.: 42907466; File No.: 42907466-RL-002E.mxd	A3

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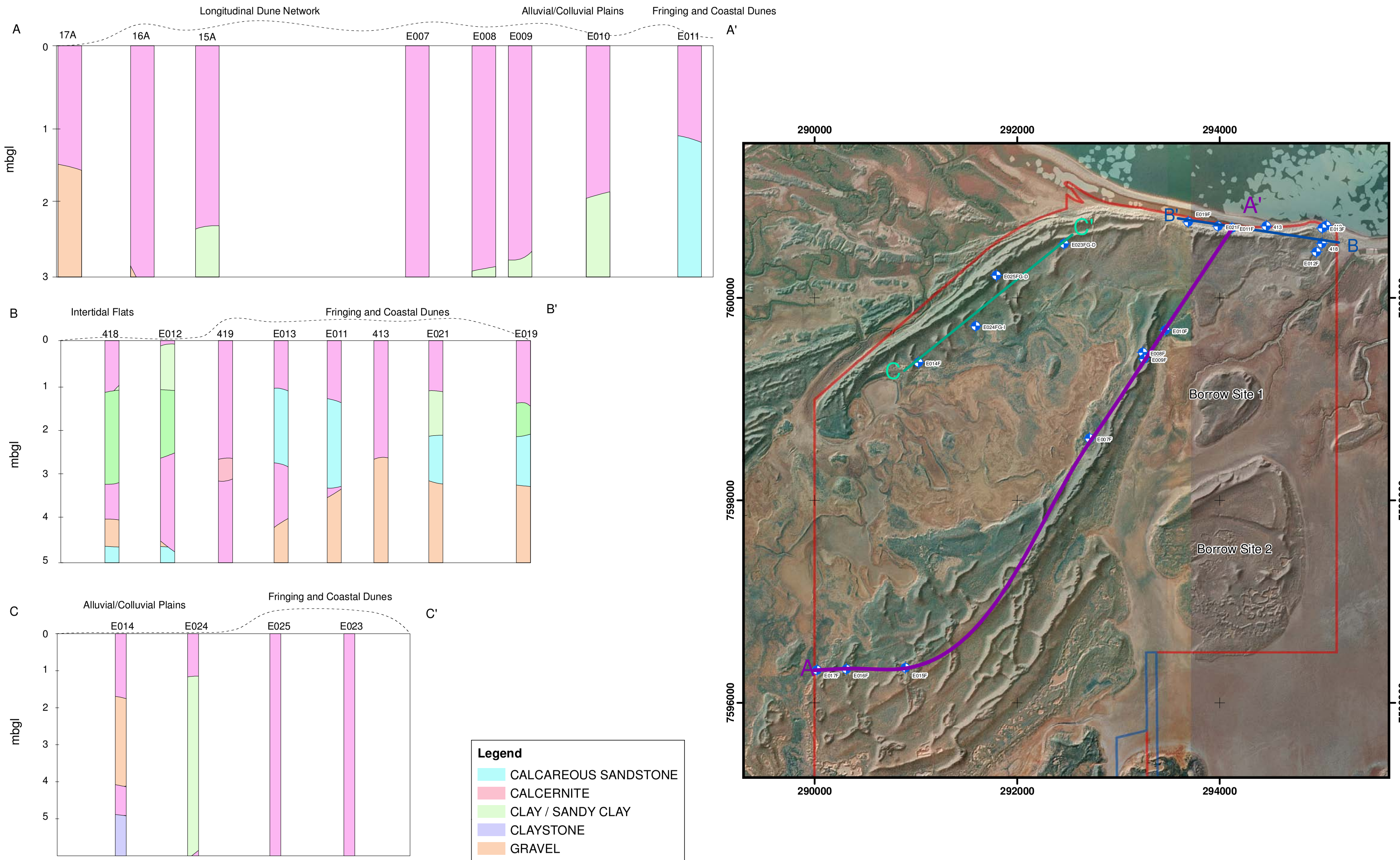

Legend

- CALCAREOUS SANDSTONE
- CALCERNITE
- CLAY / SANDY CLAY
- CLAYSTONE
- GRAVEL
- PASS
- RED SANDS

Source:
Landgate Imagery 2007, 2003

Client: **CHEVRON AUSTRALIA PTY LTD**

URS

Project: Wheatstone Project - BSQ and Landforms Assessment

Title: Soil Profiles Cross-Sections

Drawn: RNM/CJT	Approved: MJN	Date: 05/11/2010	Figure: 6	Rev. B
Job No.: 42907466	File No.: 42907466-RL-009_RB.mxd			A3

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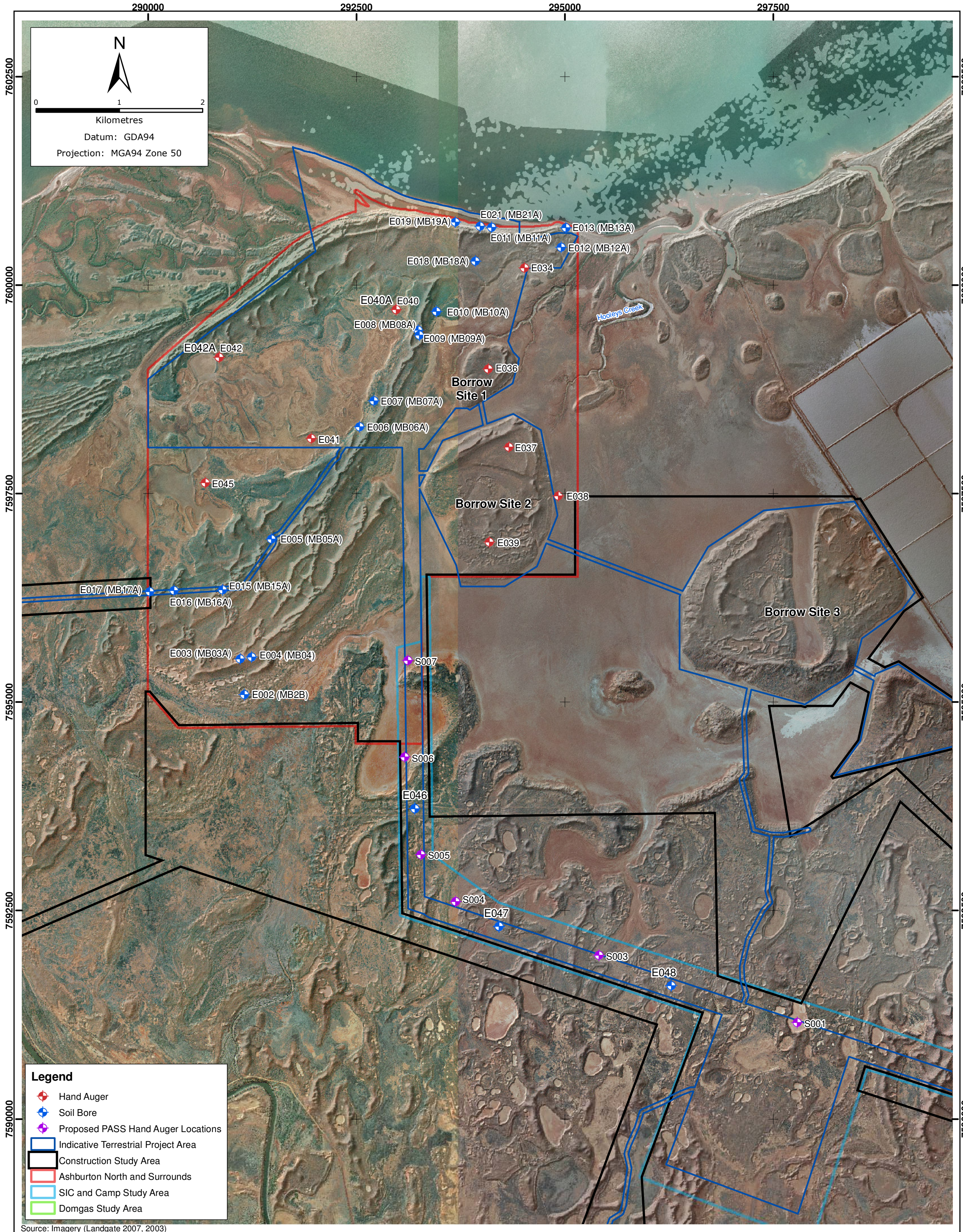

Source: Imagery (Landgate 2007, 2003)
Hand Auger, Soil Bore and Pass Hand Auger Locations - Data Sources: (URS and Coffey 2009) and (URS,2009)

Client **CHEVRON AUSTRALIA PTY LTD**	Project Wheatstone Project - BSQ and Landforms Assessment			Title Environmental Soil Bore and Hand Auger Locations	
URS	Drawn: RNM/CJT	Approved: MJN	Date: 05/11/2010	Figure: 7	Rev. C
	Job No.: 42907466	File No.: 42907466-RL-010_RC.mxd			A3

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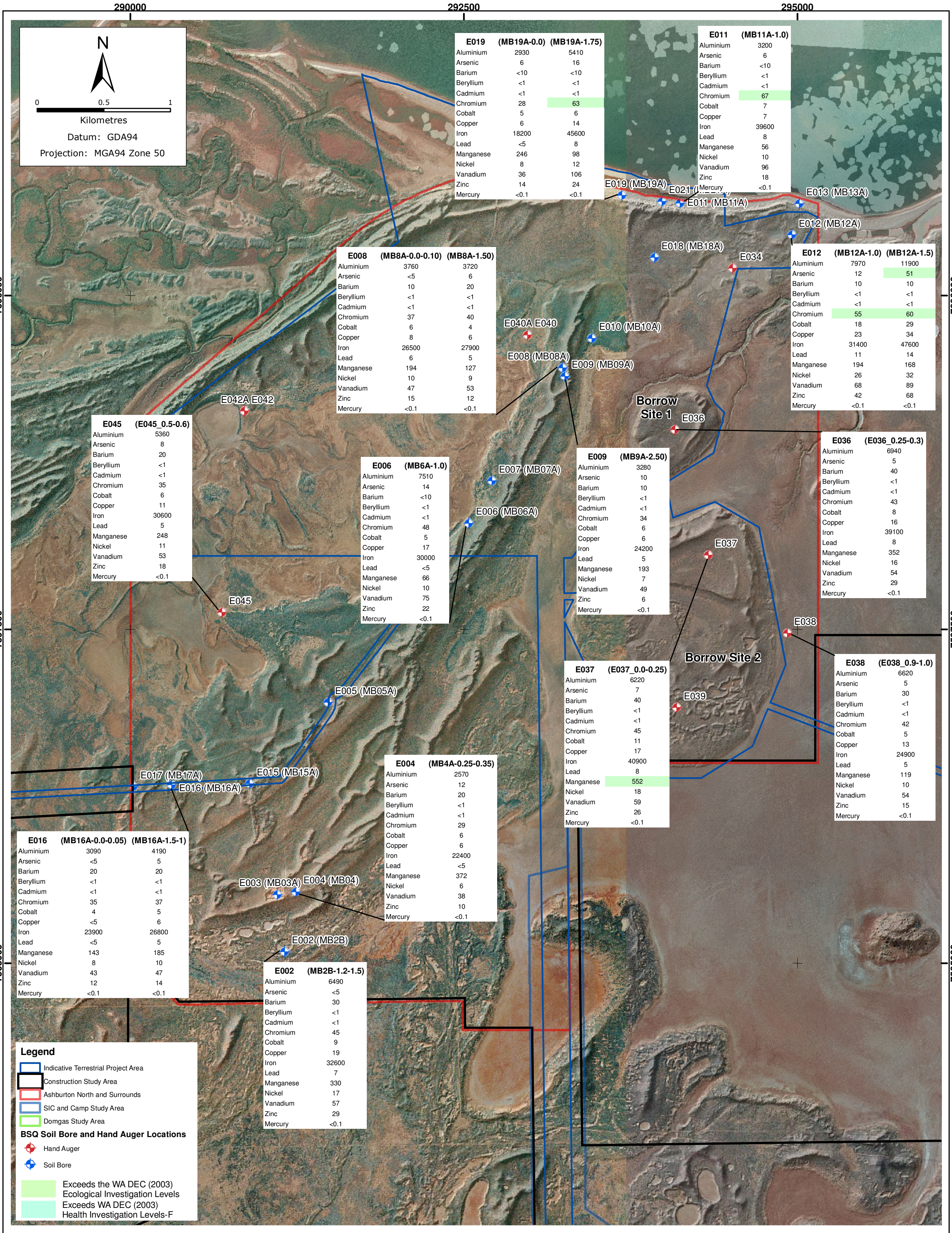

Source: Landgate Imagery 2007, 2003

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Analytical Results Metals
URS	Drawn: RNM/CJT; Approved: MN; Date: 05/11/2010	Figure: 8-1; Rev. B
	Job No.: 42907466; File No.: 42907466-RL-011_RB.mxd	A3

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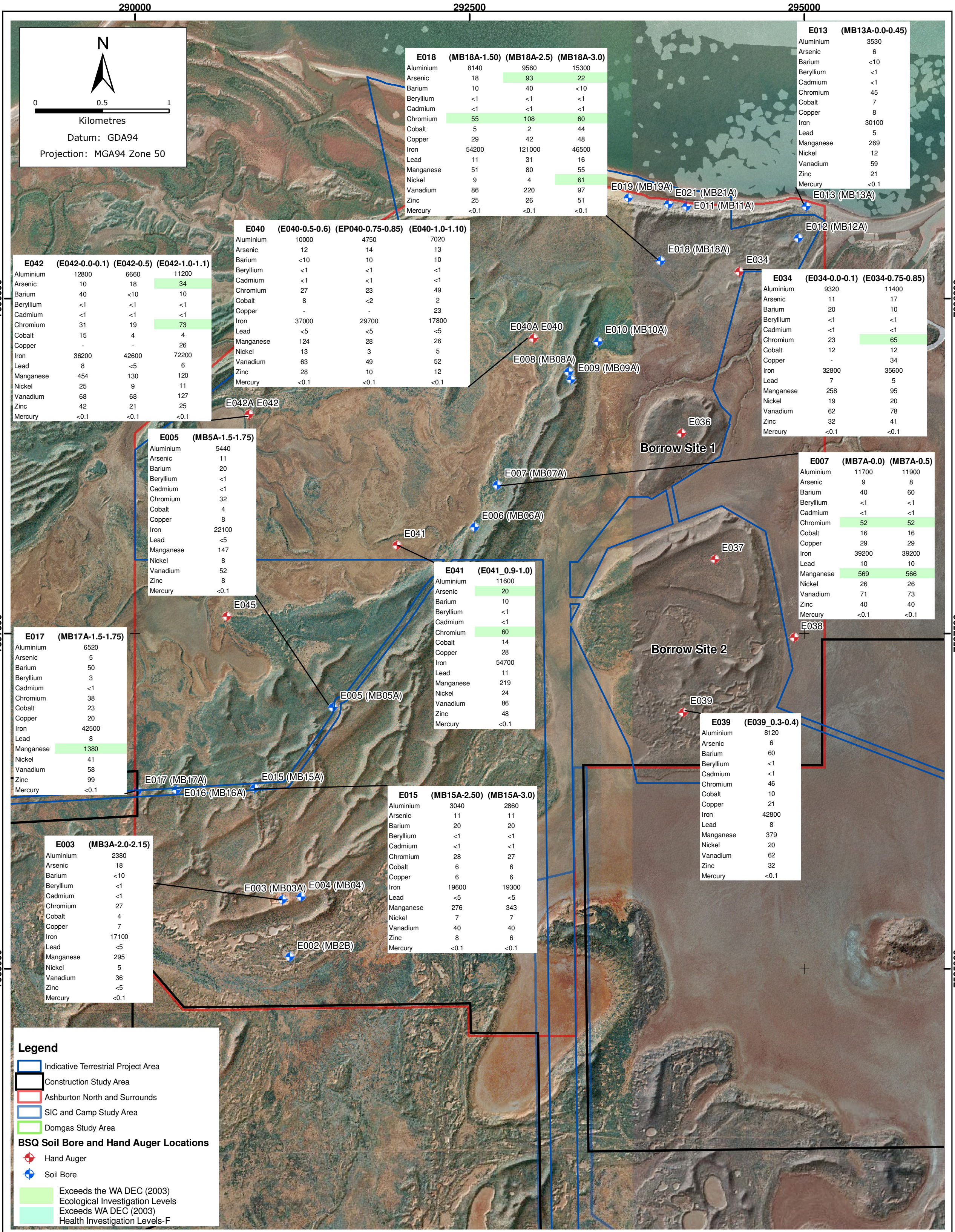

E013	(MB13A-0.0-0.45)
Aluminium	3530
Arsenic	6
Barium	<10
Beryllium	<1
Cadmium	<1
Chromium	45
Cobalt	7
Copper	8
Iron	30100
Lead	5
Manganese	269
Nickel	12
Vanadium	59
Zinc	21
Mercury	<0.1

E018	(MB18A-1.50)	(MB18A-2.5)	(MB18A-3.0)
Aluminium	8140	9560	15300
Arsenic	18	93	22
Barium	10	40	<10
Beryllium	<1	<1	<1
Cadmium	<1	<1	<1
Chromium	55	108	60
Cobalt	5	2	44
Copper	29	42	48
Iron	54200	121000	46500
Lead	11	31	16
Manganese	51	80	55
Nickel	9	4	61
Vanadium	86	220	97
Zinc	25	26	51
Mercury	<0.1	<0.1	<0.1

E040	(E040-0.5-0.6)	(EP040-0.75-0.85)	(E040-1.0-1.10)
Aluminium	10000	4750	7020
Arsenic	12	14	13
Barium	<10	10	10
Beryllium	<1	<1	<1
Cadmium	<1	<1	<1
Chromium	27	23	49
Cobalt	8	<2	2
Copper	-	-	23
Iron	37000	29700	17800
Lead	<5	<5	<5
Manganese	124	28	26
Nickel	13	3	5
Vanadium	63	49	52
Zinc	28	10	12
Mercury	<0.1	<0.1	<0.1

E042	(E042-0.0-0.1)	(E042-0.5)	(E042-1.0-1.1)
Aluminium	12800	6660	11200
Arsenic	10	18	34
Barium	40	<10	10
Beryllium	<1	<1	<1
Cadmium	<1	<1	<1
Chromium	31	19	73
Cobalt	15	4	4
Copper	-	-	26
Iron	36200	42600	72200
Lead	8	<5	6
Manganese	454	130	120
Nickel	25	9	11
Vanadium	68	68	127
Zinc	42	21	25
Mercury	<0.1	<0.1	<0.1

E034	(E034-0.0-0.1)	(E034-0.75-0.85)
Aluminium	9320	11400
Arsenic	11	17
Barium	20	10
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	23	65
Cobalt	12	12
Copper	-	34
Iron	32800	35600
Lead	7	5
Manganese	258	95
Nickel	19	20
Vanadium	62	78
Zinc	32	41
Mercury	<0.1	<0.1

E005	(MB5A-1.5-1.75)
Aluminium	5440
Arsenic	11
Barium	20
Beryllium	<1
Cadmium	<1
Chromium	32
Cobalt	4
Copper	8
Iron	22100
Lead	<5
Manganese	147
Nickel	8
Vanadium	52
Zinc	8
Mercury	<0.1

E007	(MB7A-0.0)	(MB7A-0.5)
Aluminium	11700	11900
Arsenic	9	8
Barium	40	60
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	52	52
Cobalt	16	16
Copper	29	29
Iron	39200	39200
Lead	10	10
Manganese	569	566
Nickel	26	26
Vanadium	71	73
Zinc	40	40
Mercury	<0.1	<0.1

E041	(E041_0.9-1.0)
Aluminium	11600
Arsenic	20
Barium	10
Beryllium	<1
Cadmium	<1
Chromium	60
Cobalt	14
Copper	28
Iron	54700
Lead	11
Manganese	219
Nickel	24
Vanadium	86
Zinc	48
Mercury	<0.1

E017	(MB17A-1.5-1.75)
Aluminium	6520
Arsenic	5
Barium	50
Beryllium	3
Cadmium	<1
Chromium	38
Cobalt	23
Copper	20
Iron	42500
Lead	8
Manganese	1380
Nickel	41
Vanadium	58
Zinc	99
Mercury	<0.1

E039	(E039_0.3-0.4)
Aluminium	8120
Arsenic	6
Barium	60
Beryllium	<1
Cadmium	<1
Chromium	46
Cobalt	10
Copper	21
Iron	42800
Lead	8
Manganese	379
Nickel	20
Vanadium	62
Zinc	32
Mercury	<0.1

E015	(MB15A-2.50)	(MB15A-3.0)
Aluminium	3040	2860
Arsenic	11	11
Barium	20	20
Beryllium	<1	<1
Cadmium	<1	<1
Chromium	28	27
Cobalt	6	6
Copper	6	6
Iron	19600	19300
Lead	<5	<5
Manganese	276	343
Nickel	7	7
Vanadium	40	40
Zinc	8	6
Mercury	<0.1	<0.1

E003	(MB3A-2.0-2.15)
Aluminium	2380
Arsenic	18
Barium	<10
Beryllium	<1
Cadmium	<1
Chromium	27
Cobalt	4
Copper	7
Iron	17100
Lead	<5
Manganese	295
Nickel	5
Vanadium	36
Zinc	<5
Mercury	<0.1

Source: Landgate Imagery 2007, 2003

Client **CHEVRON AUSTRALIA PTY LTD**	Project Wheatstone Project - BSQ and Landforms Assessment	Title Analytical Results Metals
URS	Drawn: RNM Approved: MN Date: 14/05/2010	Figure: 8-2 Rev. A
	Job No.: 42907466 File No.: 42907466-RL-011B.mxd	A3

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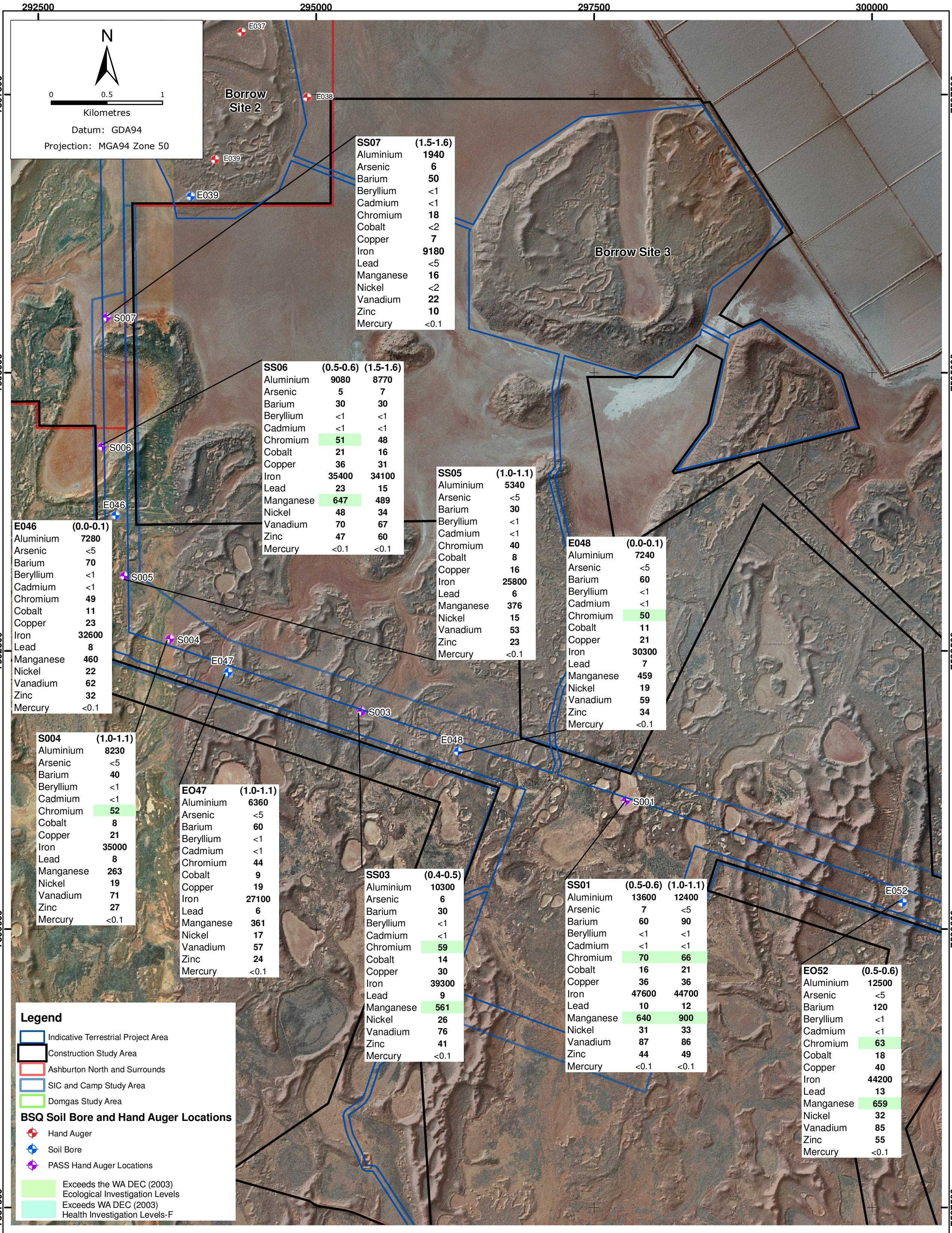

Source: Landgate Imagery 2007, 2003

Client CHEVRON AUSTRALIA PTY LTD	Project Wheatstone Project - BSQ and Landforms Assessment	Title Analytical Results Metals
URS	Drawn: RNM/CJT Approved: MJN Date: 05/11/2010 Job No.: 42907466 File No.: 42907466-RL-011C_RB.mxd	Figure: 8-3 Rev. B A3

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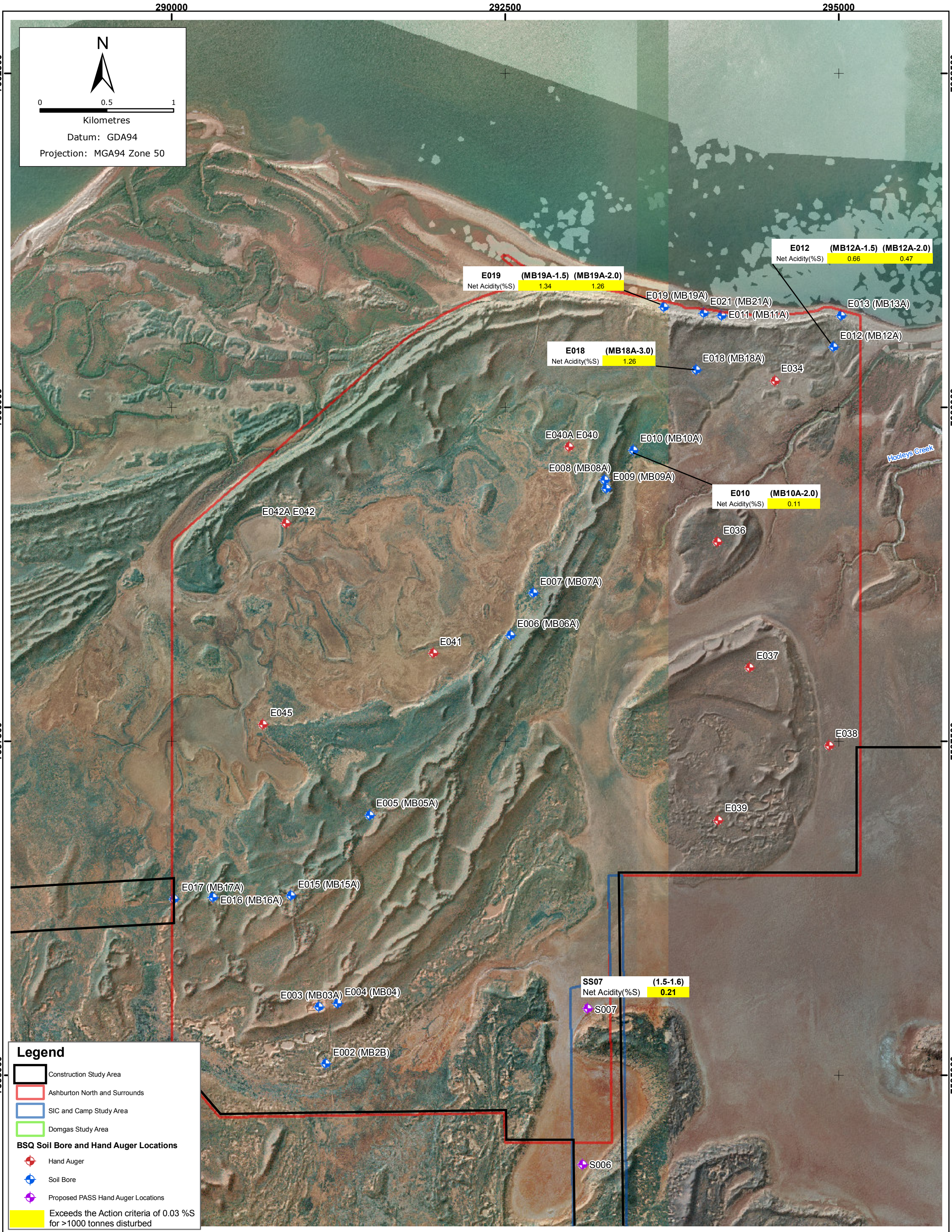

Source: Landgate Imagery 2007, 2003

Client: **CHEVRON AUSTRALIA PTY LTD**	Project: Wheatstone Project - BSQ and Landforms Assessment	Title: Soil Analytical Results Net Acidity Action Criteria Exceedances
URS	Drawn: RNM; Approved: MJN; Date: 14/05/2010	Figure: 9; Rev. A
	Job No.: 42907466; File No.: 42907466-RL-012.mxd	A3

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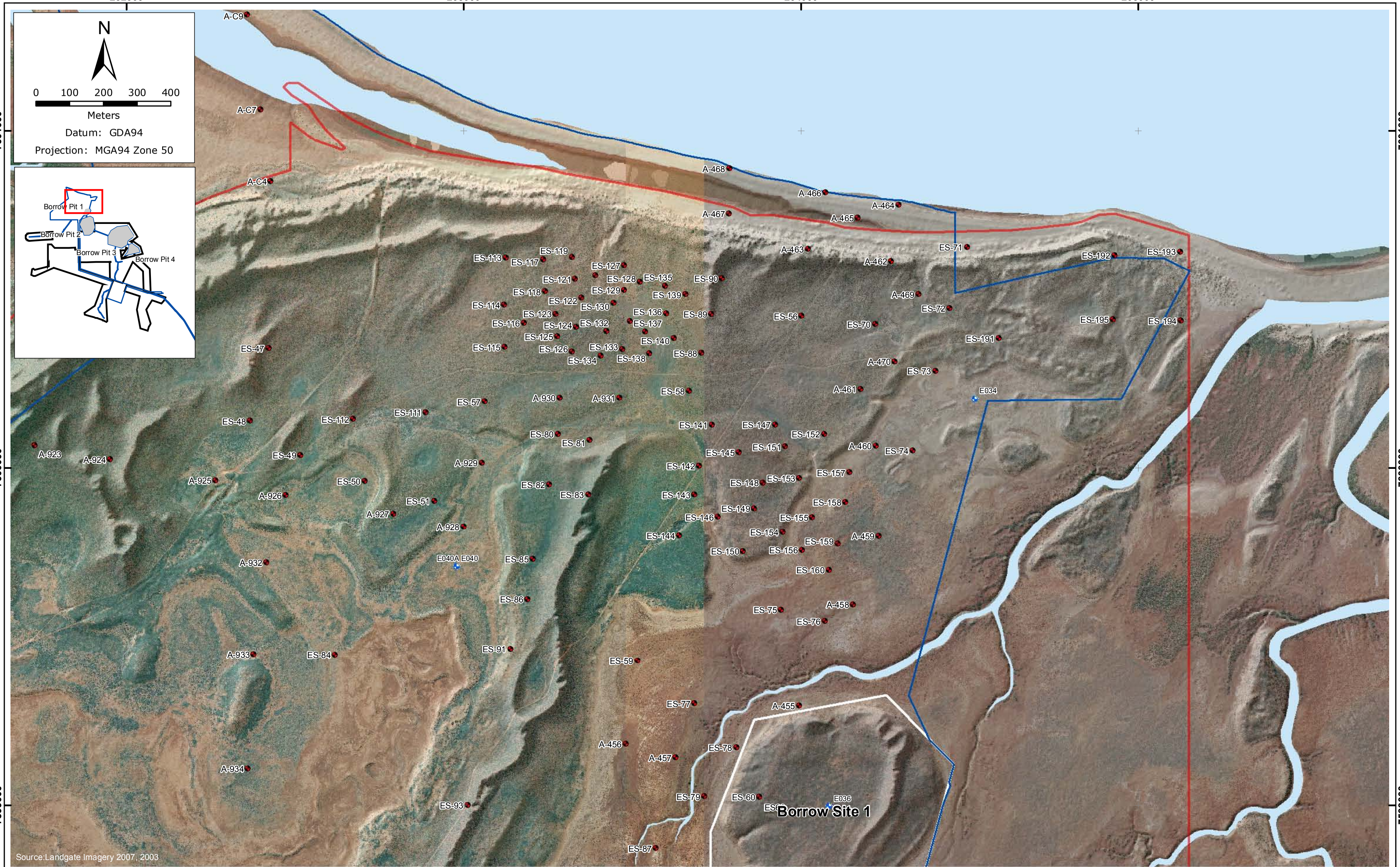

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- Environmental Boreholes Phase 3 (Golder Associates, Oct 2010)
- BSQ Hand Auger

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project BSQ and Landforms Assessment		Title: Data Review
URS	Drawn: MR	Approved: MN	Date: 17/12/2010
	Job No.: 42907466	File No.: 42907466-RL-018A_RB.mxd	Figure: 10-1
			Rev. B
			A3

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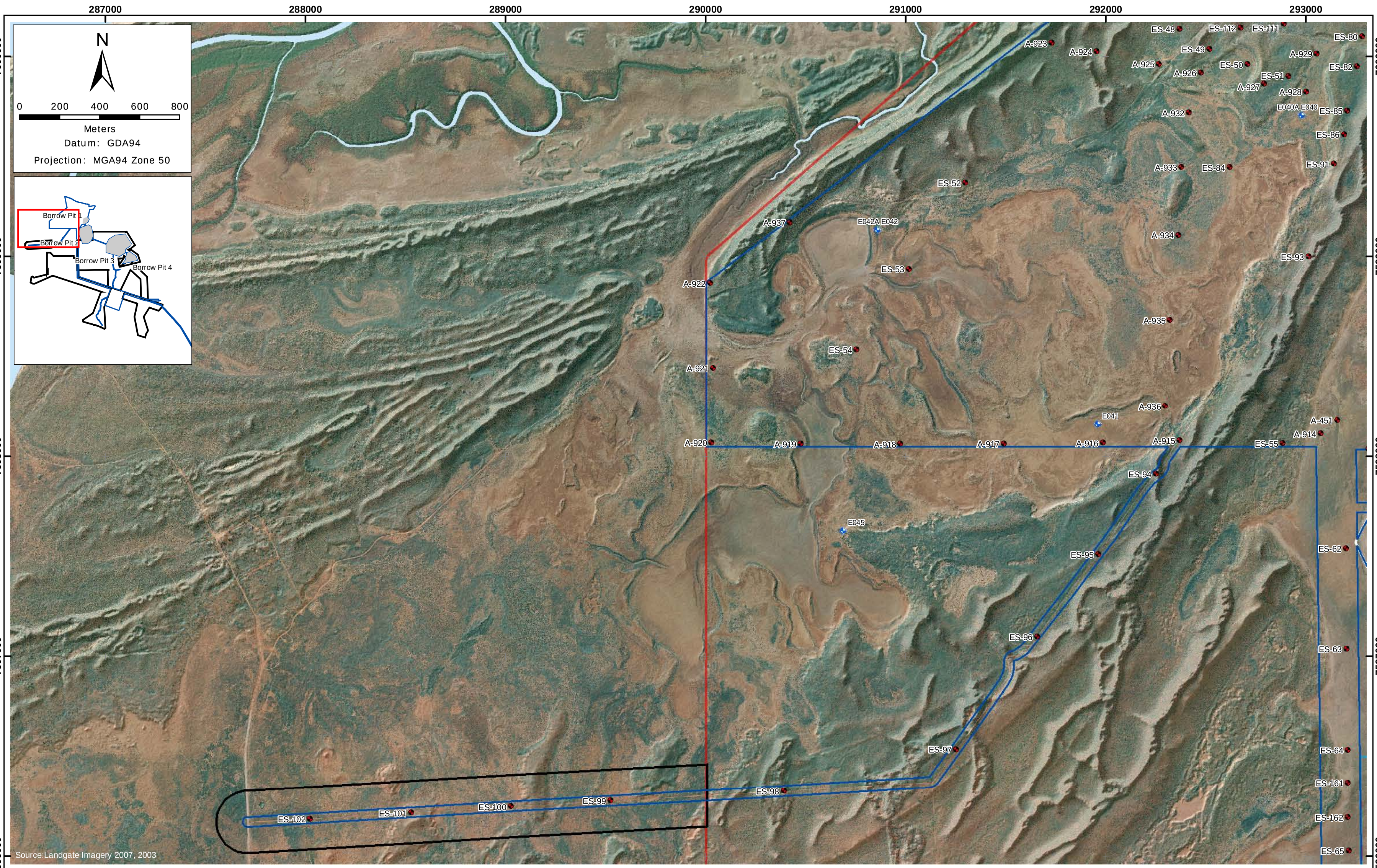

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- Environmental Boreholes Phase 3 (Golder Associates, Oct 2010)
- BSQ Hand Auger

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project BSQ and Landforms Assessment	Data Review
URS	Drawn: MR / Approved: MN / Date: 17/12/2010	Figure: 10-2 / Rev. B
	Job No.: 42907466 / File No.: 42907466-RL-018B_RB.mxd	A3

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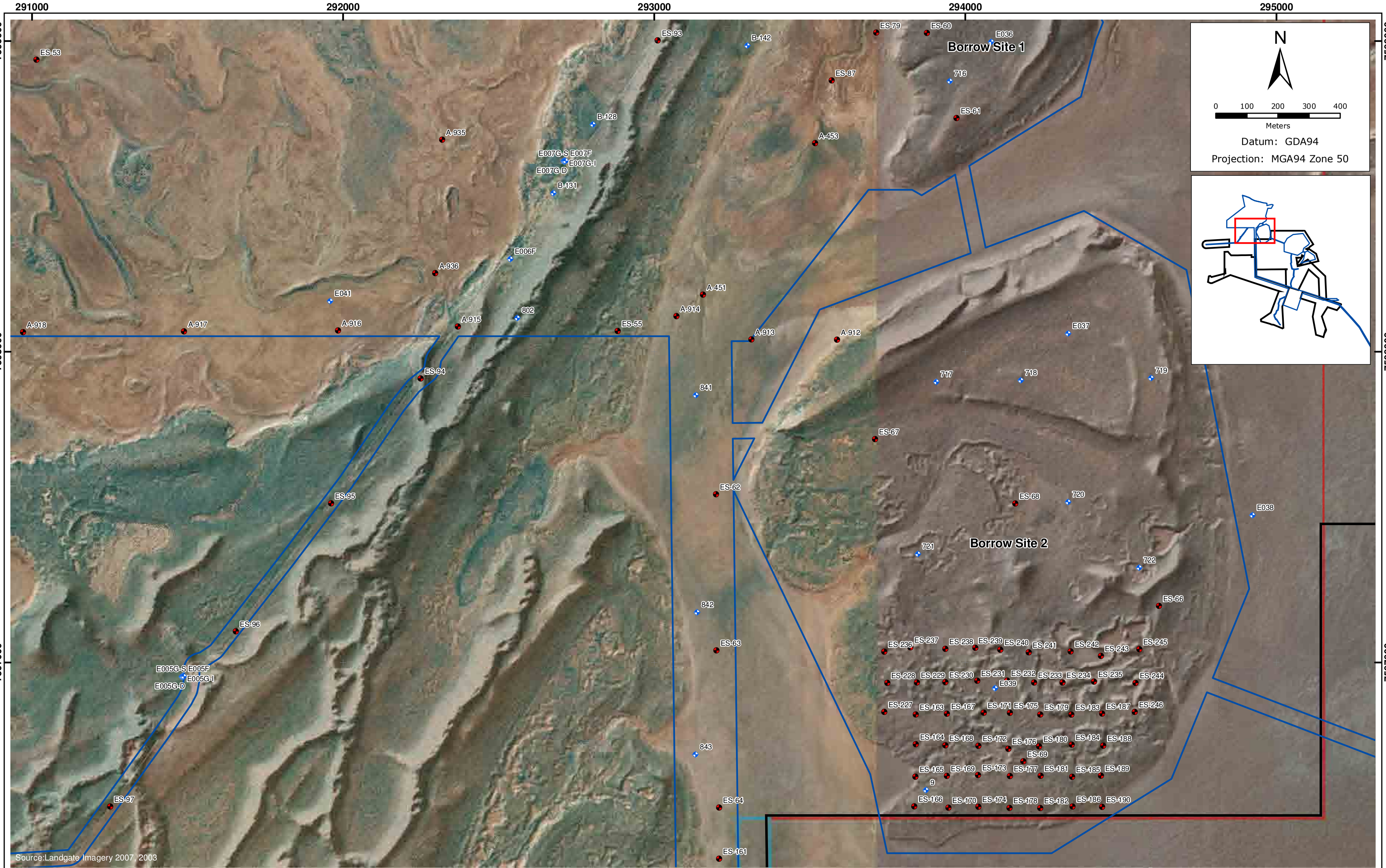

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- Environmental Boreholes Phase 3 (Golder Associates, Aug 2010)
- Geotechnical Bore & BSQ Hand Auger Locations

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	Data Review
URS	Drawn: CJT; Approved: MN; Date: 04/11/2010	Figure: 10-3; Rev. A
	Job No.: 42907466; File No.: 42907466-RL-018C.mxd	A3

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Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- Environmental Boreholes Phase 3 (Golder Associates, Oct 2010)
- BSQ Hand Auger

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project BSQ and Landforms Assessment	Data Review
URS	Drawn: MR · Approved: MN · Date: 17/12/2010	Figure: 10-4 · Rev. B
	Job No.: 42907466 · File No.: 42907466-RL-018D_RB.mxd	A3

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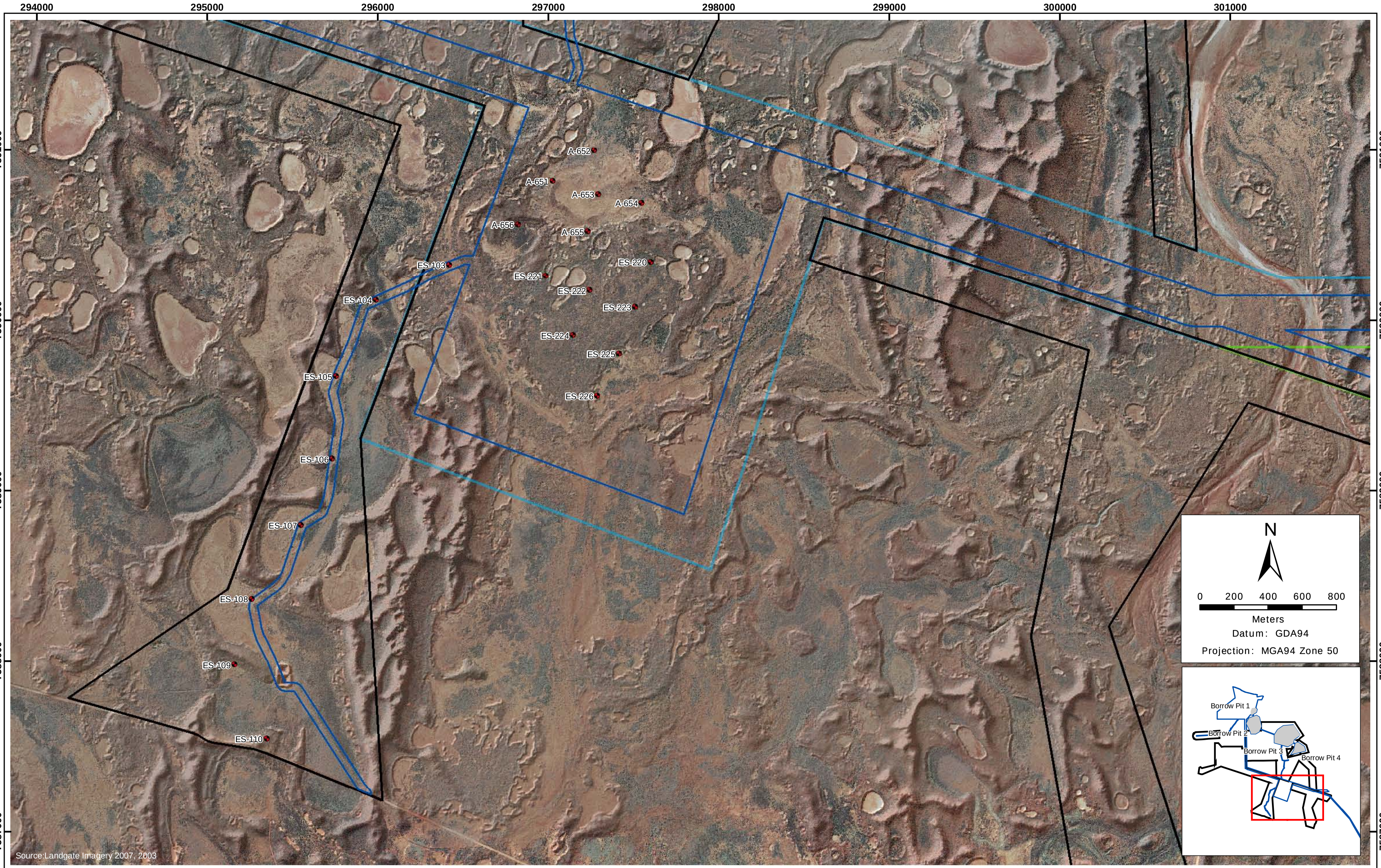

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- Environmental Boreholes Phase 3 (Golder Associates, Oct 2010)
- BSQ Hand Auger

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project BSQ and Landforms Assessment	Data Review
URS	Drawn: MR / Approved: MN / Date: 17/12/2010	Figure: 10-5 / Rev. B
	Job No.: 42907466 / File No.: 42907466-RL-018E_RB.mxd	A3

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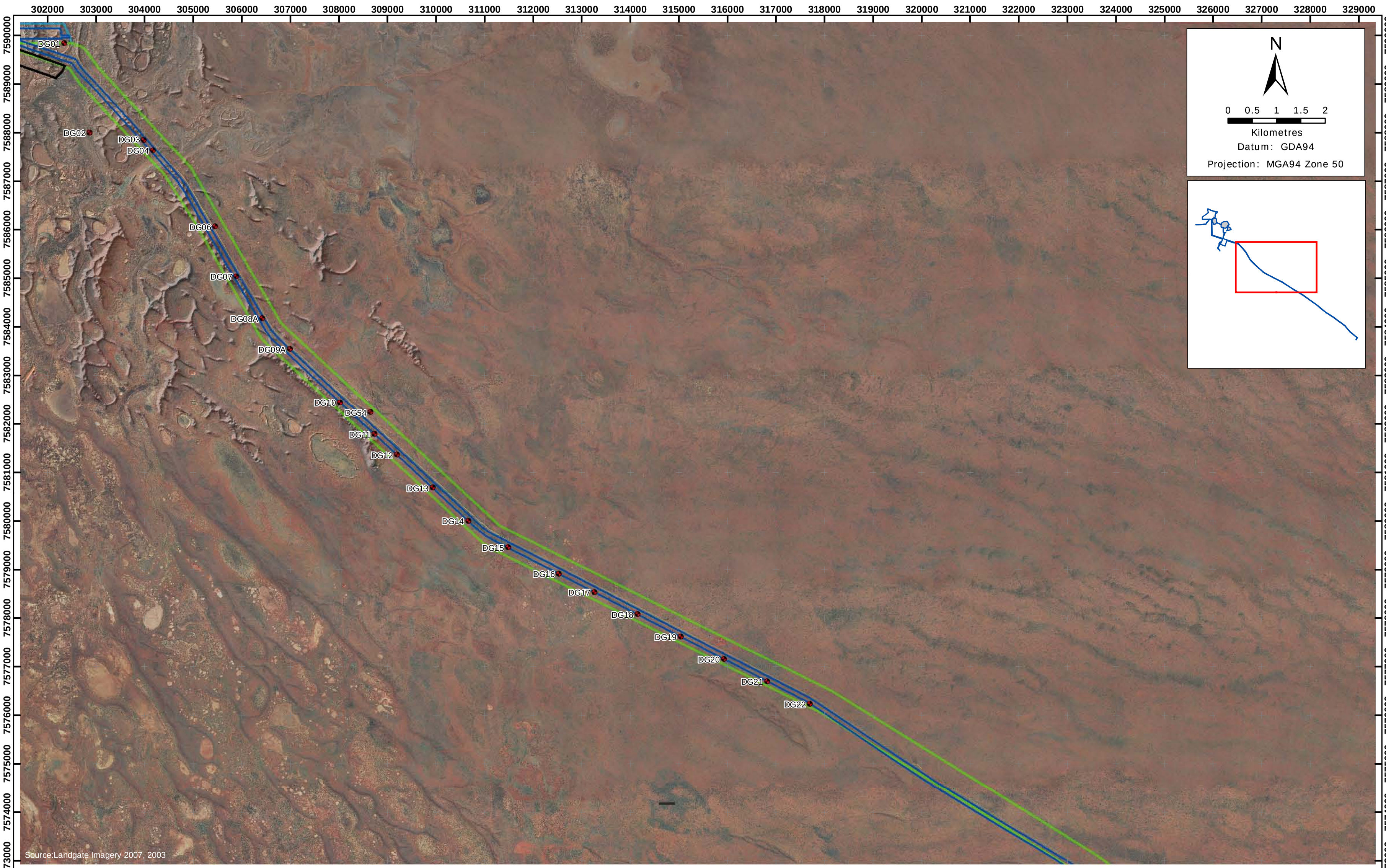

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- SIC and Camp Study Area
- Domgas Study Area
- Environmental Boreholes Phase 3 (Golder Associates, Oct 2010)

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project BSQ and Landforms Assessment	Data Review
URS	Drawn: MR / Approved: MN / Date: 17/12/2010 Job No.: 42907466 / File No.: 42907466-RL-018F.mxd	Figure: 10-6 / Rev. A / A3

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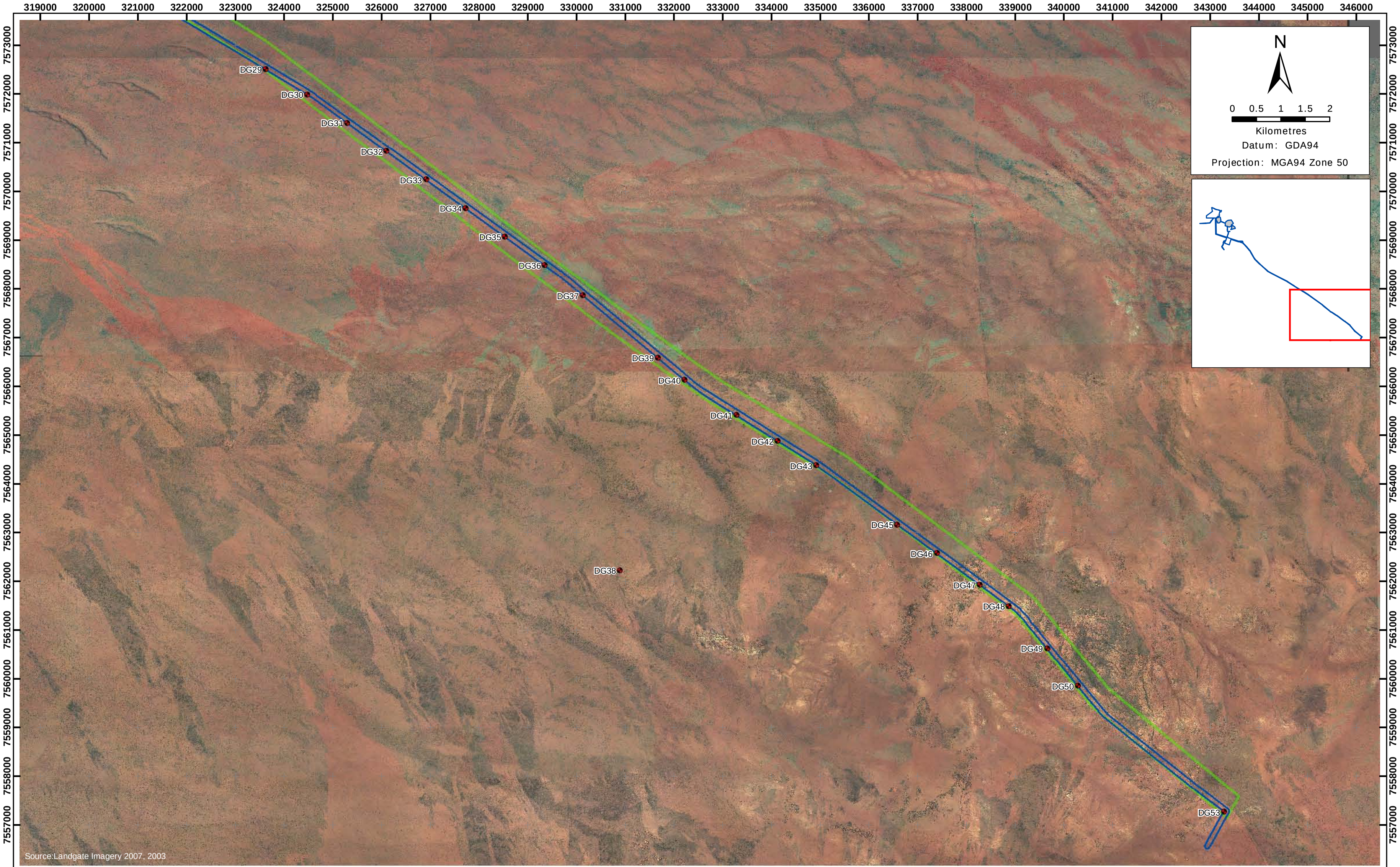

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- Environmental Boreholes Phase 3 (Golder Associates, Oct 2010)
- BSQ Hand Auger

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project BSQ and Landforms Assessment	Data Review
URS	Drawn: MR / Approved: MN / Date: 17/12/2010	Figure: 10-7 / Rev. A
	Job No.: 42907466 / File No.: 42907466-RL-018G.mxd	A3

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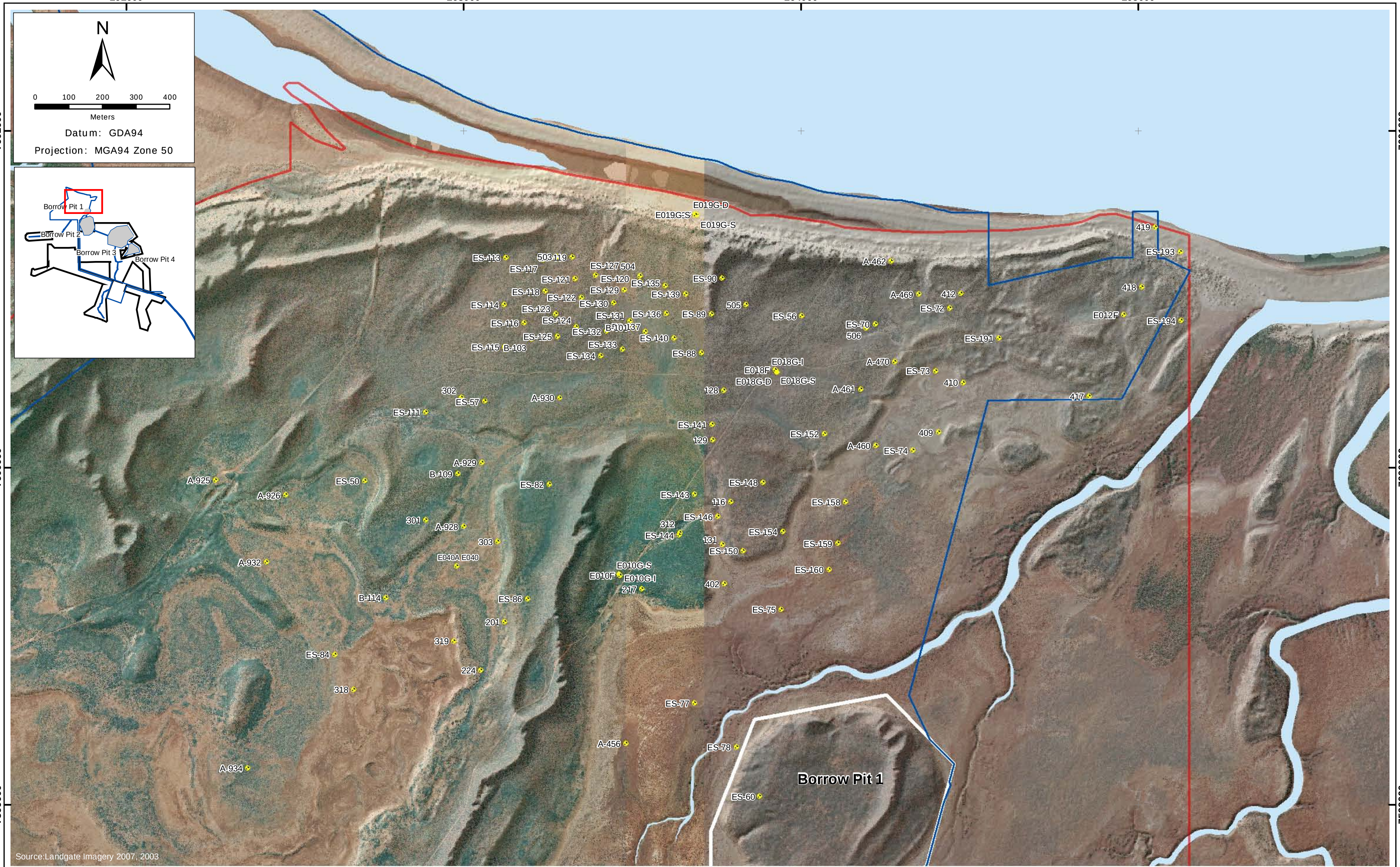

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- PASS Identified

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Identification
URS	Drawn: CJT/MR; Approved: MN; Date: 15/12/2010	Figure: 11-1; Rev. B
	Job No.: 42907466; File No.: 42907466-RL-019A_RB.mxd	A3

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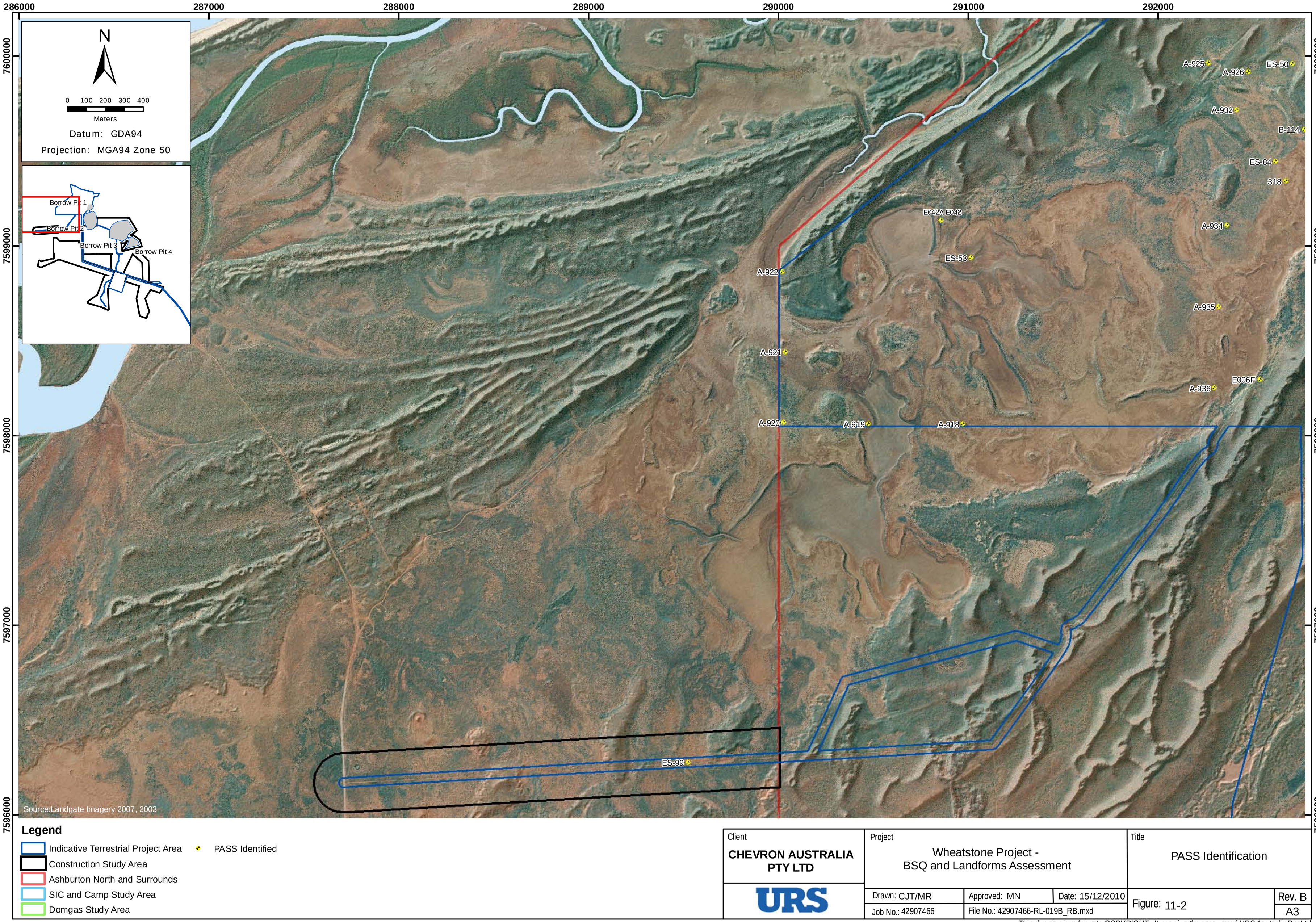

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Identification
URS	Drawn: CJT/MR; Approved: MN; Date: 15/12/2010	Figure: 11-2; Rev. B
	Job No.: 42907466; File No.: 42907466-RL-019B_RB.mxd	A3

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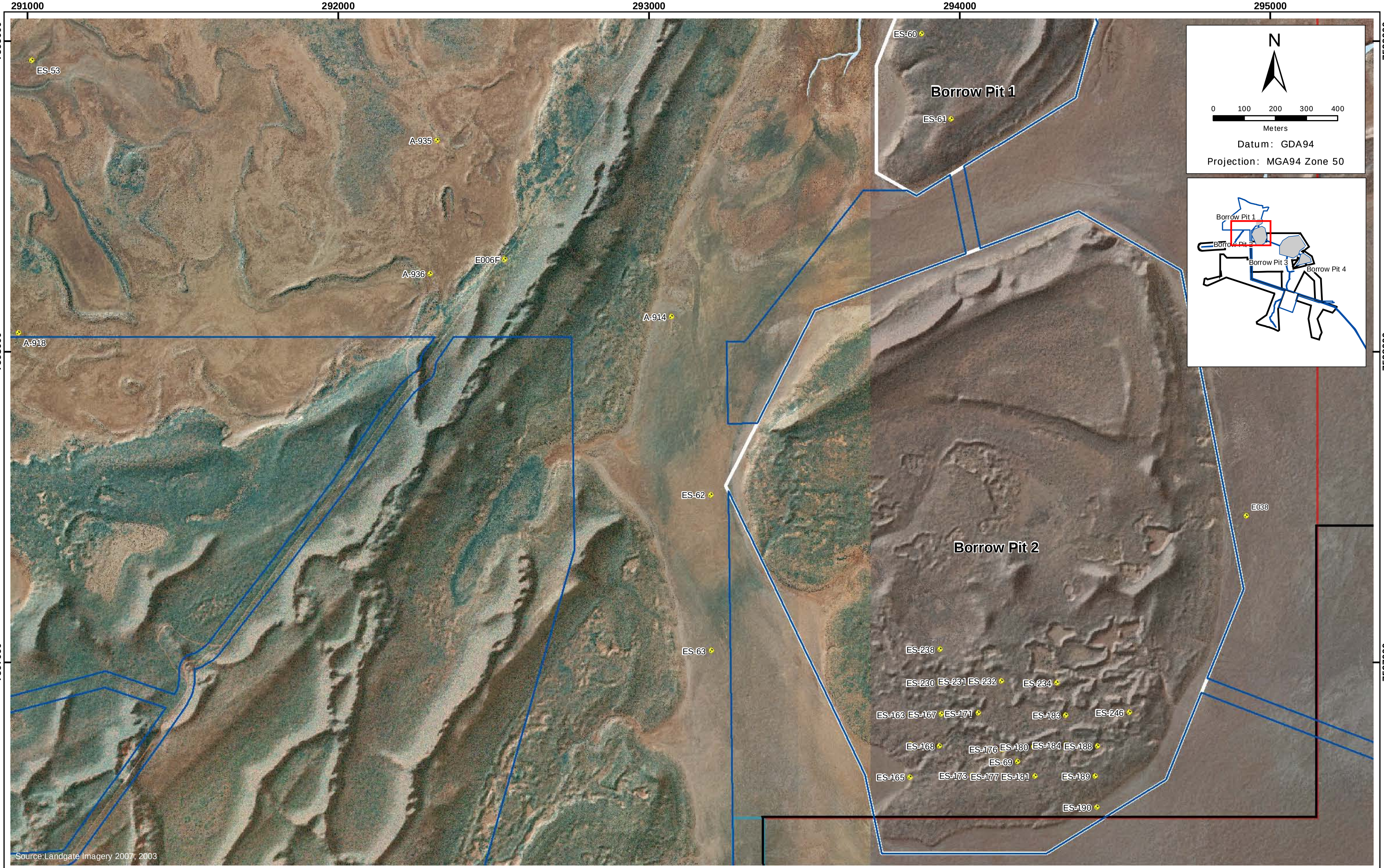

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- PASS Identified

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Identification
URS	Drawn: CJT/MR · Approved: MN · Date: 15/12/2010	Figure: 11-3 · Rev. B
	Job No.: 42907466 · File No.: 42907466-RL-019C_RB.mxd	A3

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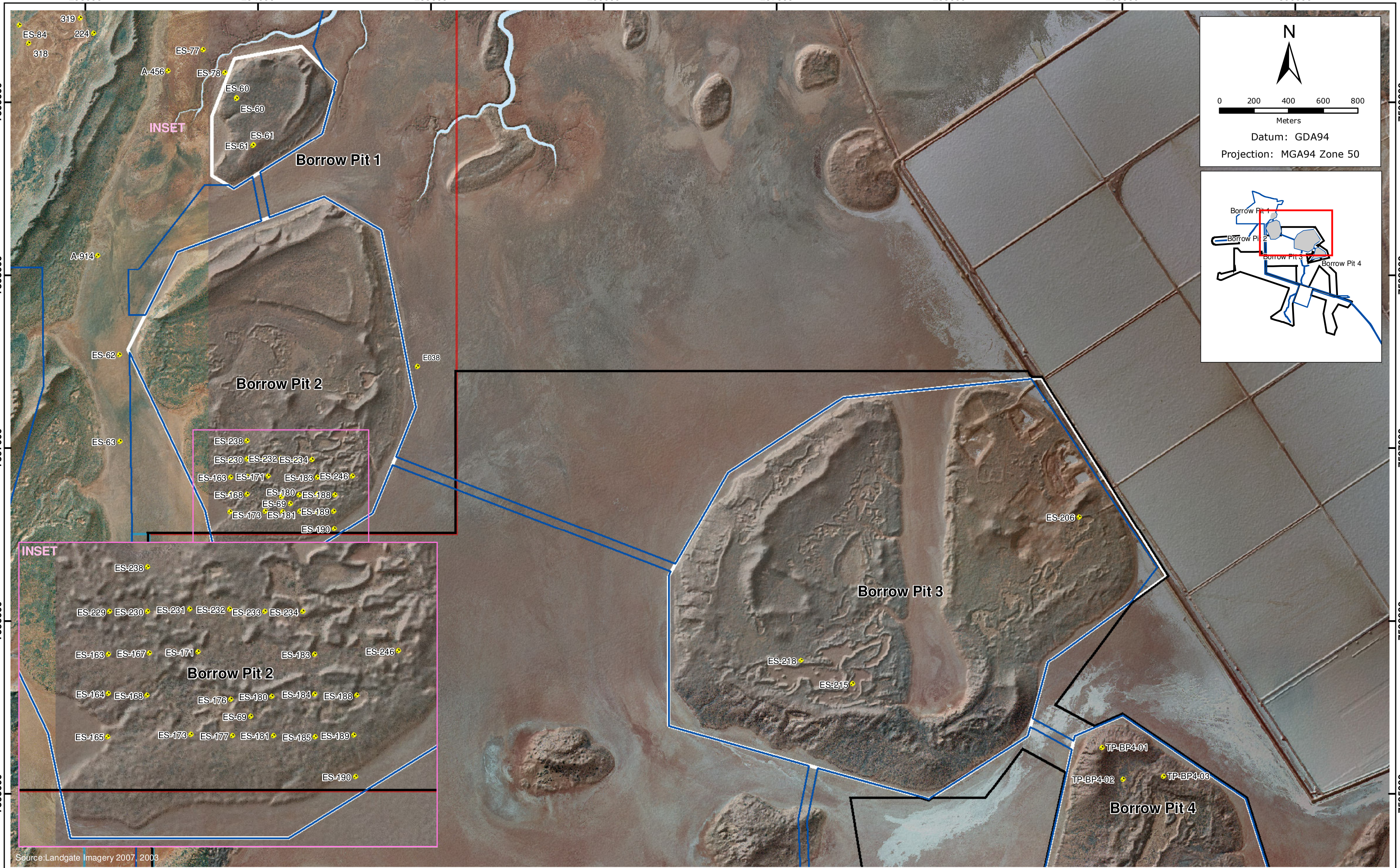

Legend

- Indicative Terrestrial Project Area
- Construction Study Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- PASS Identified

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Identification
URS	Drawn: CJT/MR; Approved: MN; Date: 22/12/2010; Job No.: 42907466; File No.: 42907466-RL-019D_RC.mxd	Figure: 11-4; Rev. C; A3

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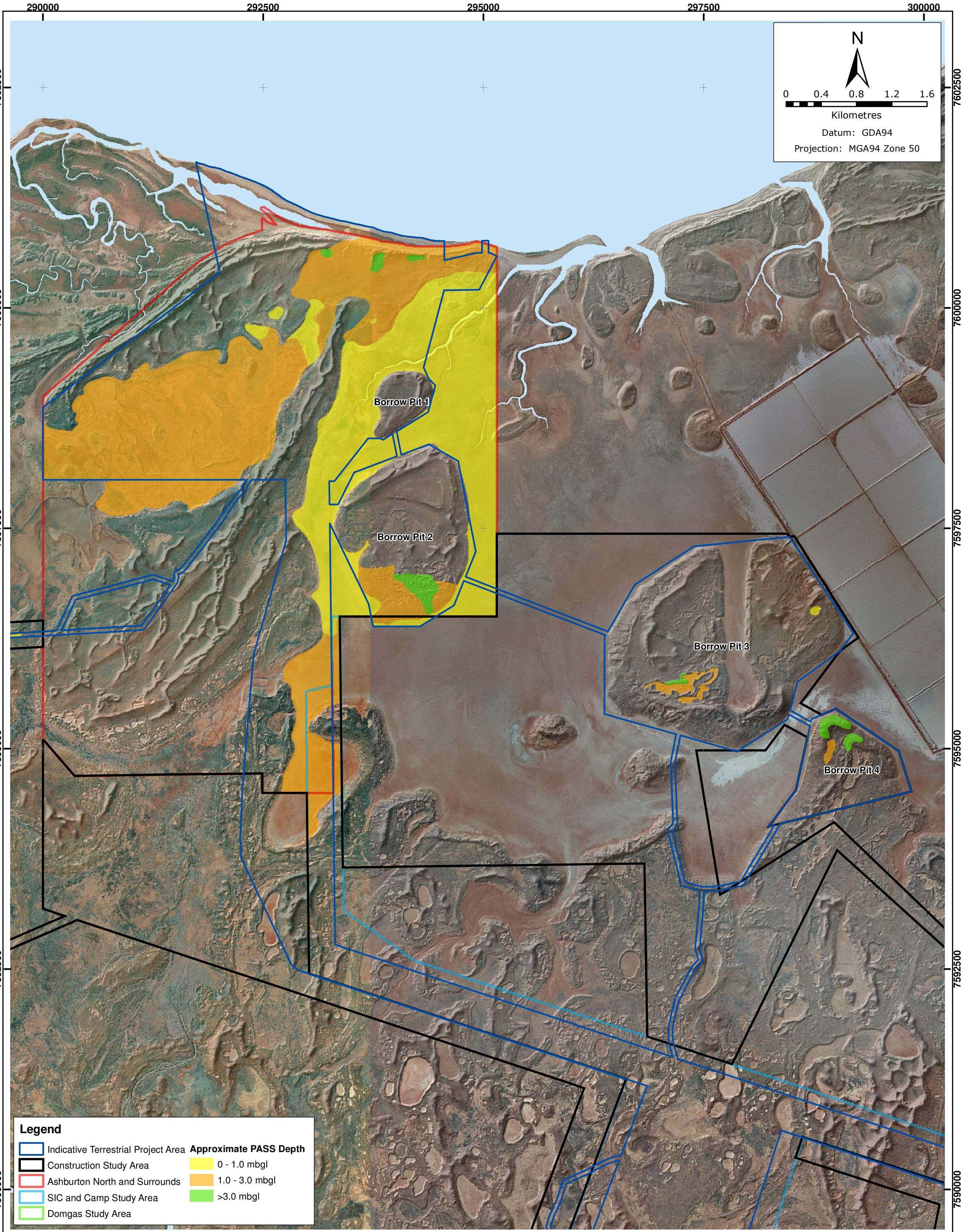

Source: Landgate Imagery 2007, 2003

Client: CHEVRON AUSTRALIA PTY LTD	Project: Wheatstone Project BSQ and Landforms Assessment		Title: Inferred PASS Depth
URS	Drawn: MR/CJT	Approved: MJN	Date: 22/12/2010
	Job No.: 42907466	File No.: 42907466-RL-015_RG.mxd	Figure: 12 / Rev. G / A3

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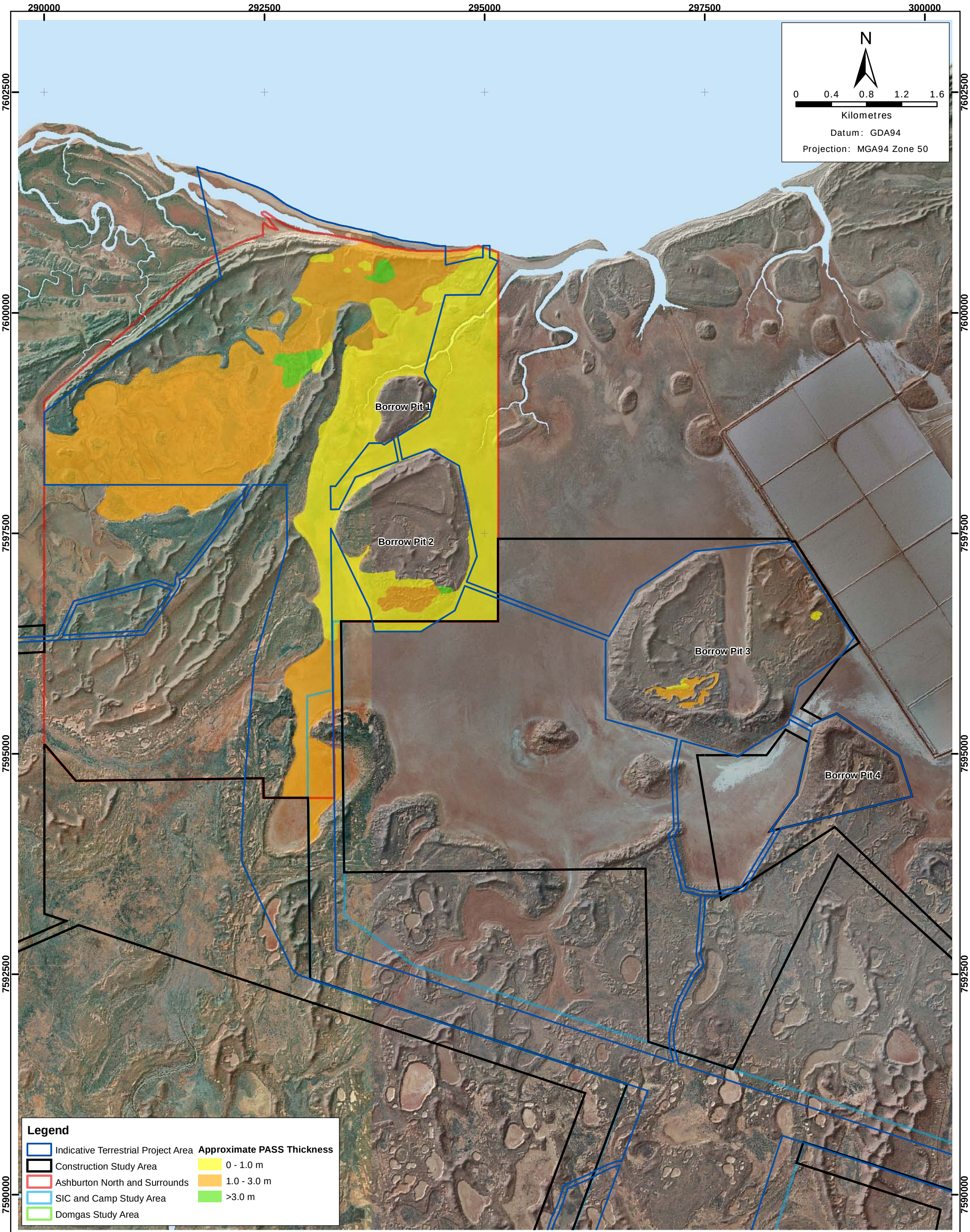

Source: Landgate Imagery 2007, 2003

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project BSQ and Landforms Assessment	Inferred PASS Thickness
URS	Drawn: MR / Approved: MJN / Date: 17/12/2010 Job No.: 42907466 / File No.: 42907466-RL-016_RF.mxd	Figure: 13 / Rev. F / A3

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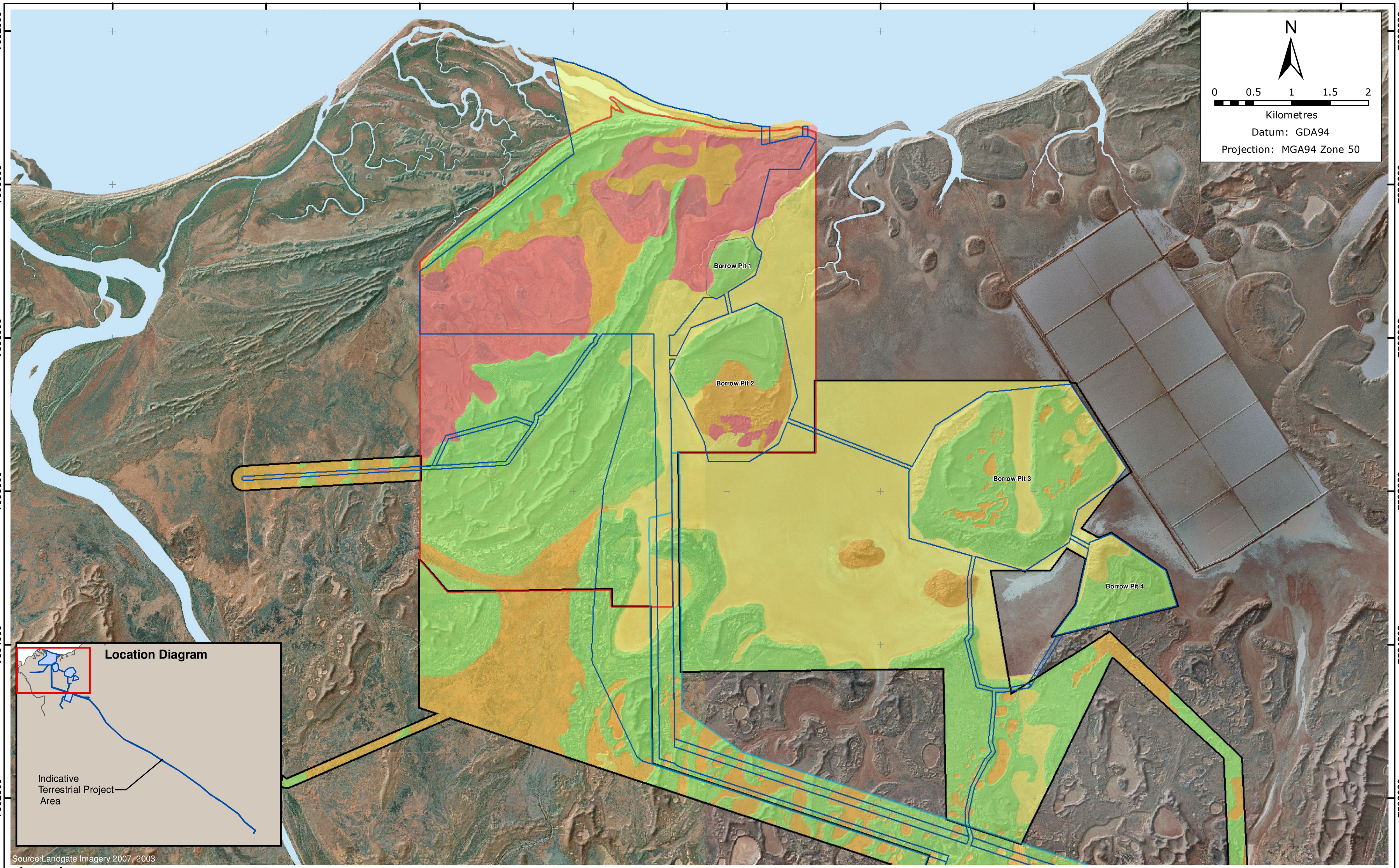

Legend

- Indicative Terrestrial Project Area
- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area
- Construction Study Area

PASS Assessment (URS, 2010)

- Below DEC Trigger Value of 0.03%S
- Low Potential to Generate Acidity
- Moderate Potential to Generate Acidity
- High Potential to Generate Acidity

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Map
URS	Drawn: MR/CJT; Approved: MN; Date: 22/12/2010; Job No.: 42907466; File No.: 42907466-RL-008_RF.mxd	Figure: 14-1; Rev. E; A3

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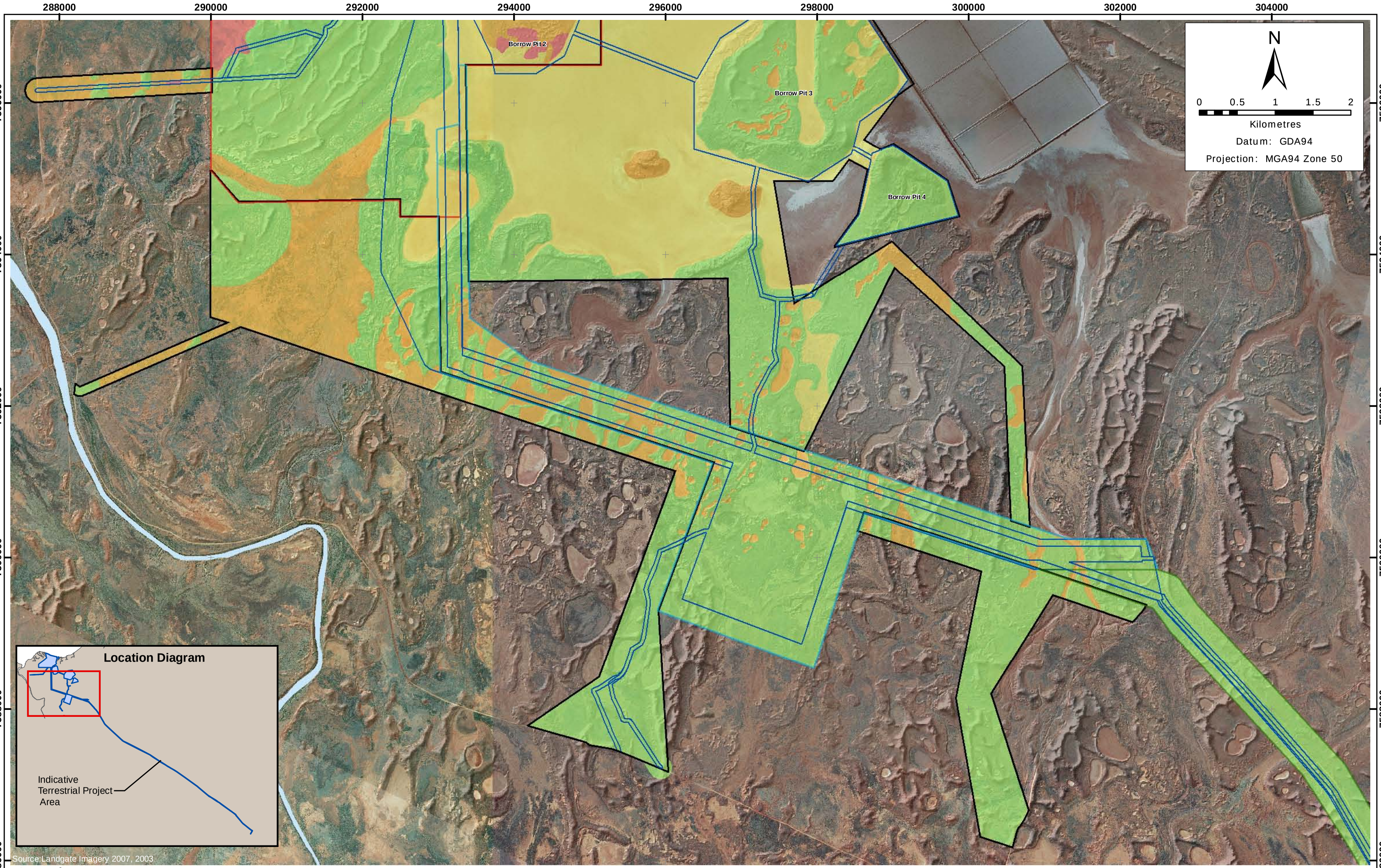

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Map
URS	Drawn: MR; Approved: MN; Date: 16/12/2010; Job No.: 42907466; File No.: 42907466-RL-008B_RC.mxd	Figure: 14-2; Rev. C; A3

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Legend

- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area

PASS Assessment (URS, 2010)

- Below DEC Trigger Value of 0.03%S
- Low Potential to Generate Acidity
- Moderate Potential to Generate Acidity
- High Potential to Generate Acidity

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Map
URS	Drawn: MR/CJT; Approved: MN; Date: 05/11/2010	Figure: 14-3; Rev. D
	Job No.: 42907466; File No.: 42907466-RL-008C_RD.mxd	A3

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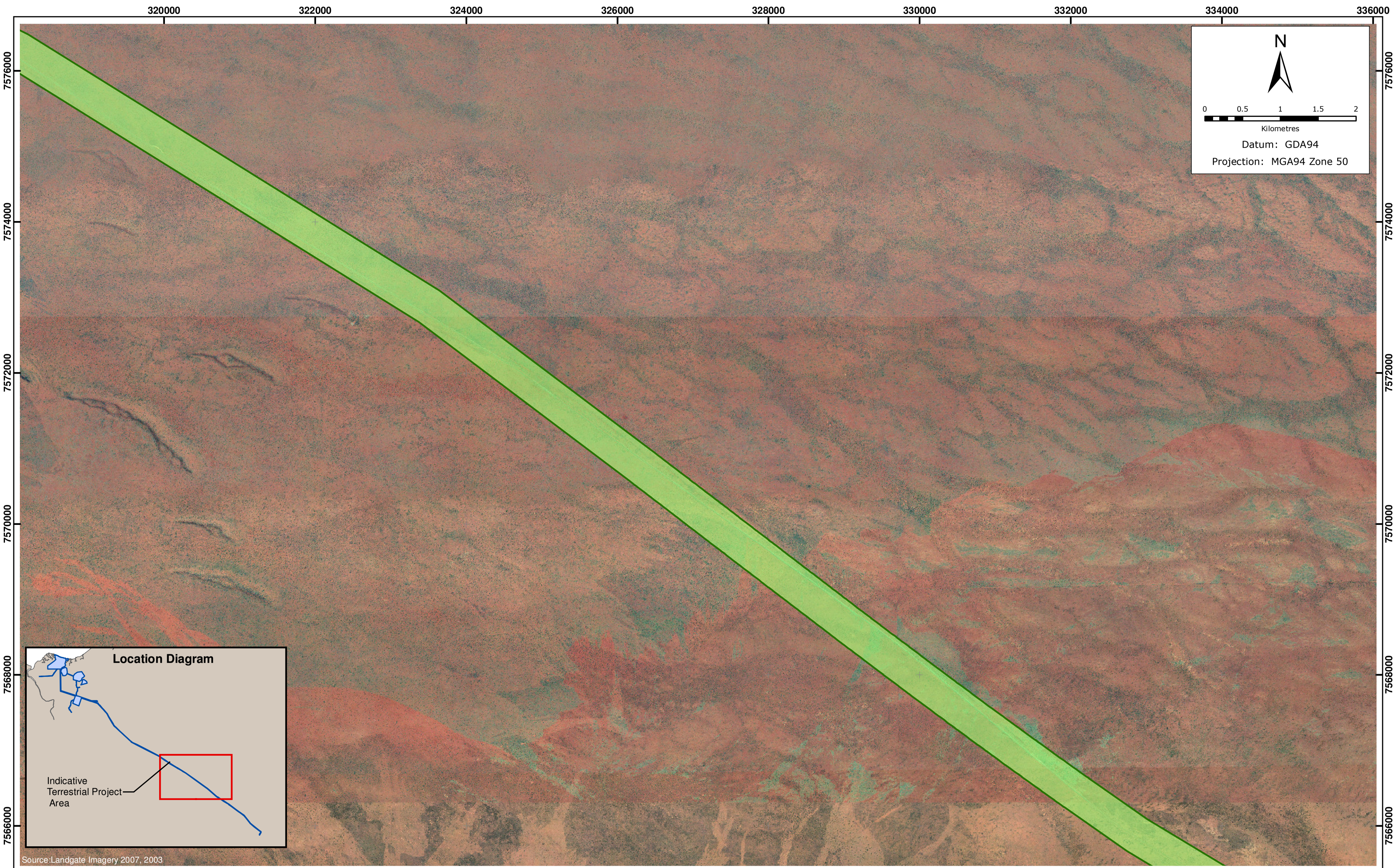

Legend

- Ashburton North and Surrounds
- SIC and Camp Study Area
- Domgas Study Area

PASS Assessment (URS, 2010)

- Below DEC Trigger Value of 0.03%S
- Low Potential to Generate Acidity
- Moderate Potential to Generate Acidity
- High Potential to Generate Acidity

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Map
URS	Drawn: MR/CJT; Approved: MN; Date: 05/11/2010	Figure: 14-4; Rev. D
	Job No.: 42907466; File No.: 42907466-RL-008D_RD.mxd	A3

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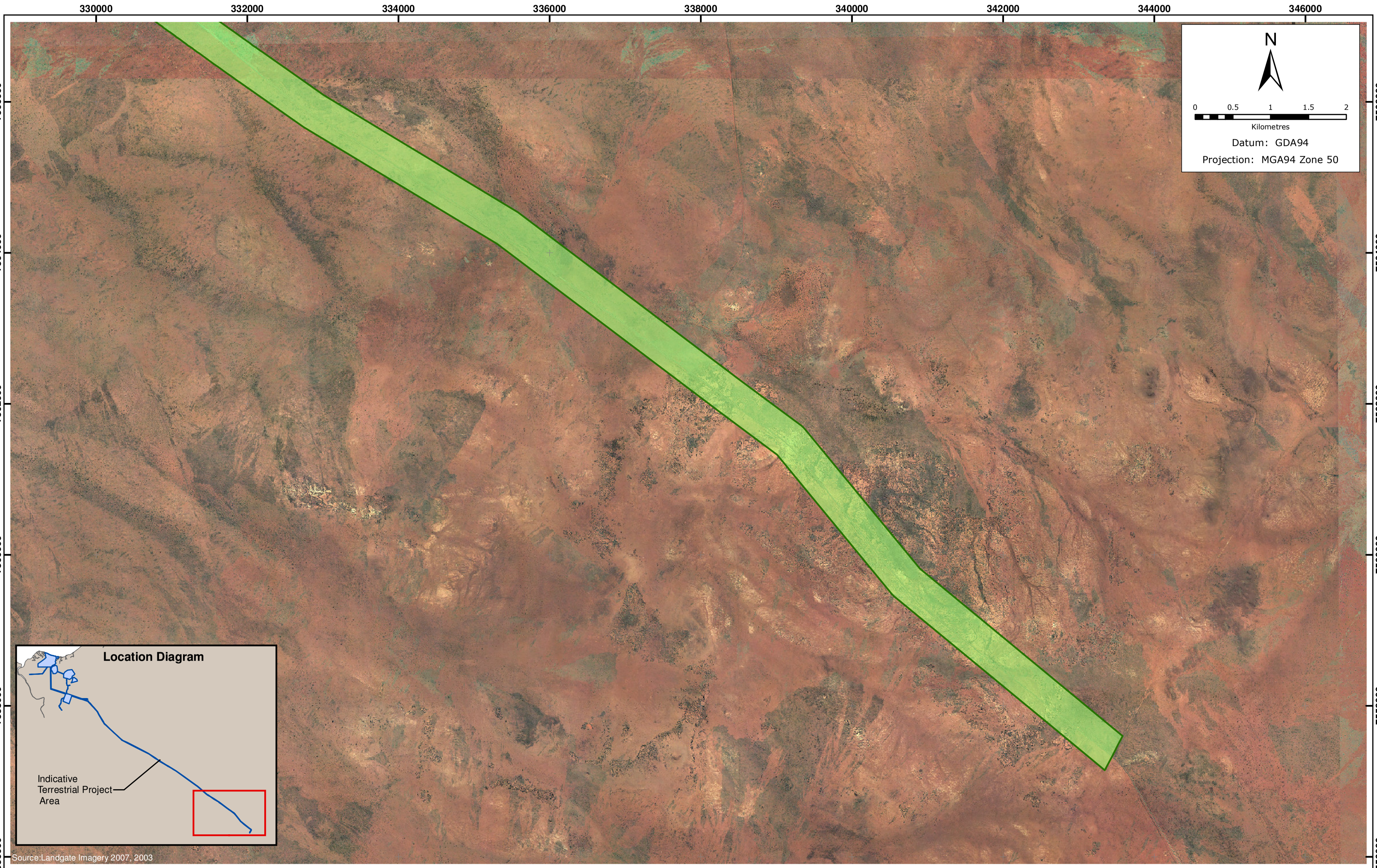

Client	Project	Title
CHEVRON AUSTRALIA PTY LTD	Wheatstone Project - BSQ and Landforms Assessment	PASS Map
URS	Drawn: MR/CJT; Approved: MN; Date: 05/11/2010; Job No.: 42907466; File No.: 42907466-RL-008E_RD.mxd	Figure: 14-5; Rev. D; A3

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A

Appendix A PASS Assessment Calculations

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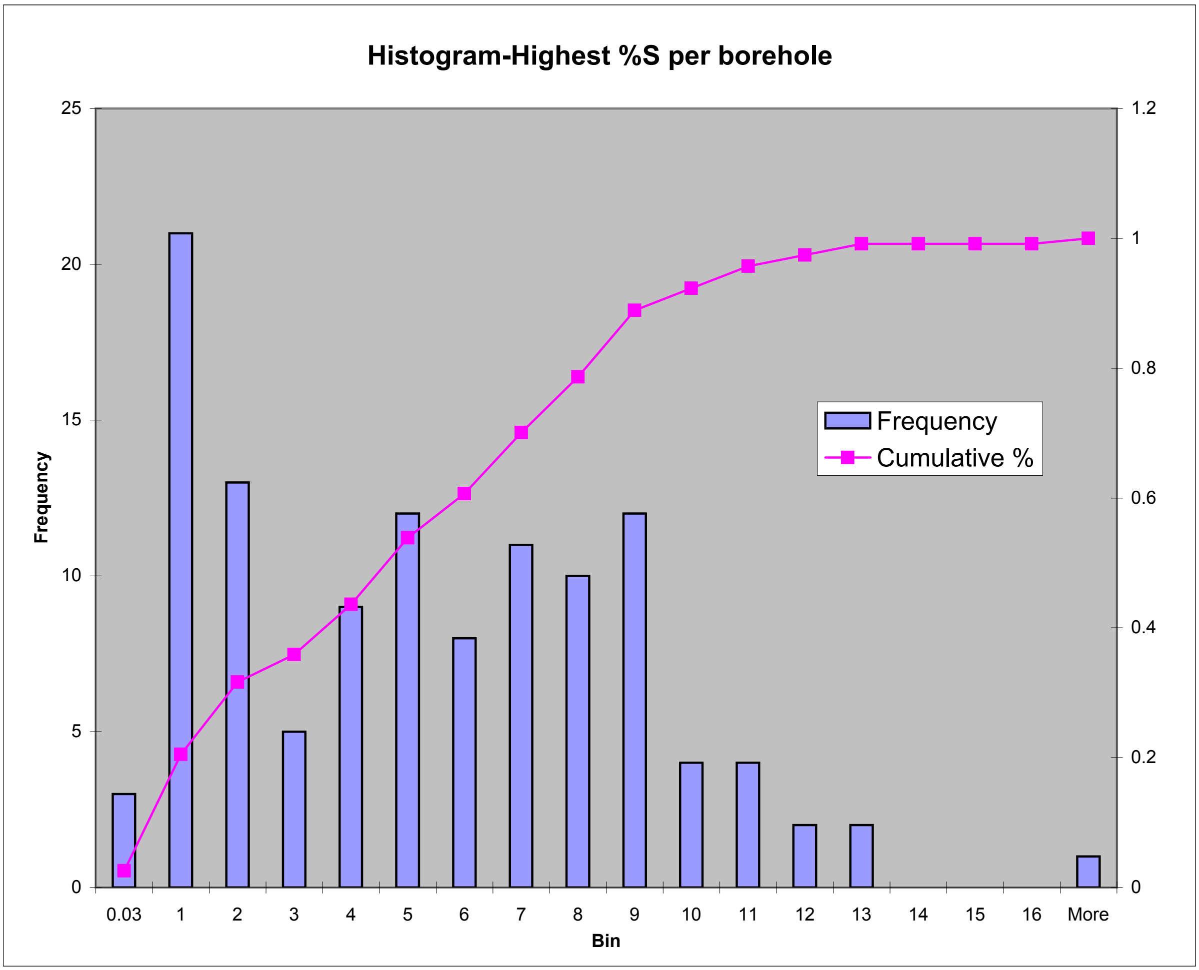
Frequency Distribution Results for Highest %S per Borehole

Bin	Frequency	Cumulative %
0.03	3	2.56%
1	21	20.51%
2	13	31.62%
3	5	35.90%
4	9	43.59%
5	12	53.85%
6	8	60.68%
7	11	70.09%
8	10	78.63%
9	12	88.89%
10	4	92.31%
11	4	95.73%
12	2	97.44%
13	2	99.15%
14	0	99.15%
15	0	99.15%
16	0	99.15%
More	1	100.00%



Golder Bore location	PASS DEPTH based on soil profiles (mbgl)	Golder Sample Identification	Pass depth based on samples (mbgl)	Net Acidity (exc. ANC) (%S)	Net Acidity AVERAGE (%S)	Net Acidity Highest Value (%S)
A456	1	A456-008	1.75	0.58	0.58	0.58
		A457-006	1.75	0.00	0.00	0.00
		A458-007	1.5	0.00	0.00	0.00
A460	1	A460-003	1.25	7.78	6.50	7.78
		A460-005	1.75	5.22		
A461	1.7	A461-008	1.85	0.12	4.90	10.01
		A461-010	2.25	10.01		
		A461-012	2.75	5.90		
		A461-014	3.25	3.57		
A462	5	A462-020	5	5.32	5.32	5.32
A469	2	A469-010	2	0.40	3.74	7.12
		A469-012	2.5	6.29		
		A469-014	3	7.12		
		A469-016	3.75	3.38		
		A469-018	4.25	1.50		
A470	2.2	A470-012	2.5	10.58	4.52	10.58
		A470-014	3	4.33		
		A470-016	3.5	2.13		
		A470-018	4	1.03		
A914	1	A914-005	1	1.06	1.00	1.48
		A914-007	1.5	0.47		
		A914-009	2	1.48		
A916	1.8	A916R-009	2	1.35	3.16	4.96
		A916R-011	2.5	4.96		
A917	3.75	A917R-016	3.75	1.29	1.29	1.29
A918	3	A918-014	3.25	1.00	0.92	1.00
		A918-016	3.75	0.83		
A919	1.5	A919-007	1.5	2.04	3.36	6.81
		A919-009	2	6.81		
		A919-011	2.5	4.48		
		A919-013	3	0.10		
A920	1	A920-009	2	6.31	4.26	6.31
		A920-011	2.5	4.38		
		A920-013	3	2.09		
A921	0.5	A921-003	0.5	0.18	3.44	6.44
		A921-005	1	6.44		
		A921-007	1.5	6.03		
		A921-009	2	4.53		
		A921-011	2.5	0.04		
A922	2.25	A922-009	2	0.86	0.77	1.37
		A922-011	2.5	1.37		
		A922-013	3	0.08		
A925	0.5	A925-004	0.75	11.15	4.77	11.15
		A925-006	1.25	5.36		
		A925-008	1.75	2.44		
		A925-010	2.25	0.13		
A926	1	A926-006	1.25	0.21	1.39	2.57
		A926-008	1.75	2.57		
A928	1	A928-006	1.25	6.32	5.56	8.30
		A928-008	1.75	8.30		
		A928-010	2.25	5.54		
		A928-012	2.75	2.07		
A929	0.8	A929-004	0.8	0.18	4.17	7.30
		A929-006	1.25	7.30		
		A929R-001	1.6	6.19		
		A929R-003	2	4.53		
		A929R-005	2.5	2.63		
A930	1.5	A930-007	1.5	0.28	2.60	4.78
		A930-009	2.25	4.78		
		A930-011	2.5	4.07		
		A930-013	3	1.27		
A932	1.1	A932-005	1.1	7.56	7.81	9.58
		A932-007	1.5	8.88		
		A932-009	2	9.58		

Golder Bore location	PASS DEPTH based on soil profiles (mbgl)	Golder Sample Identification	Pass depth based on samples (mbgl)	Net Acidity (exc. ANC) (%S)	Net Acidity AVERAGE (%S)	Net Acidity Highest Value (%S)
		A932-011	2.5	5.21		
		A932-013	3	2.19		
A934	1.2	A934-005	1.1	3.81	3.29	3.81
		A934-007	1.5	3.69		
		A934-009	2	2.38		
A935	1.5	A935-005	1	0.09	1.45	3.57
		A935-007	1.5	3.57		
		A935-010	2.25	0.70		
A936	2.25	A936-010	2.25	0.44	0.50	0.54
		A936-012	2.75	0.54		
		A936-014	3.25	0.51		
ES50	1	ES50-006	1.25	4.11	2.20	4.11
		ES50-008	1.75	0.15		
		ES50-010	2.25	2.34		
ES53	1.25	ES53-006	1.25	6.99	6.99	6.99
ES56	2.75	ES56-012	2.75	2.30	1.88	2.30
		ES56-014	3.25	1.59		
		ES56-016	3.75	1.74		
ES57	2.25	ES57-010	2.25	2.36	2.81	4.25
		ES57-012	2.75	1.81		
		ES57-014	3.25	4.25		
ES62	0.5	ES62-004	0.75	1.00	1.00	1.00
ES63	0.25	ES63-002	0.25	0.32	0.32	0.32
ES69	2.75	ES69-014	3.25	7.92	4.93	7.92
		ES69-016	3.75	6.00		
		ES69-018	4.25	0.87		
ES70	1.25	ES70-007	1.25	5.59	3.10	5.59
		ES70-009	1.75	1.84		
		ES70-011	2.25	1.88		
ES72	2.25	ES72-012	2.75	5.50	5.20	7.10
		ES72-014	3.25	7.10		
		ES72-016	3.75	3.01		
ES73	1	ES73-005	1	1.87	1.83	1.87
		ES73-007	1.5	1.78		
ES74	0.5	ES74-005	1	6.84	5.02	6.84
		ES74-007	1.5	4.92		
		ES74-009	2	3.31		
ES75	0.75	ES75-005	1	2.59	2.59	2.59
ES77	1	ES77-006	1.25	1.70	1.70	1.70
ES78	1	ES78-006	1.25	5.08	5.08	5.08
ES82	2.35	ES82-013	2.75	4.29	4.29	4.29
ES84	1.25	ES84-006	1.25	5.10	5.10	5.10
ES86	3	ES86-013	3	0.59	0.59	0.59
ES88	2.25	ES88-011	2.25	0.81	2.85	4.80
		ES88-013	2.6	4.80	3.53	3.53
		ES88-015	2.9	3.19		
		ES88-017	3.35	2.59		
		ES89-019	4.35	0.05	1.27	1.91
ES89	4.1	ES89-021	4.85	1.69		
		ES89-023	5.35	1.91		
		ES89-025	5.85	1.26		
		ES89-027	6.35	1.43		
ES90	4.25	ES90-019	4.25	8.31	5.85	8.31
		ES90-021	4.75	5.02		
		ES90-023	5.25	4.21		
ES99	1	ES99-006	1.25	0.91	3.95	5.48
		ES99-008	1.75	5.45		
		ES99-010	2.25	5.48		
ES111	2	ES111-009	2	1.85	1.90	1.94
		ES111-011	2.5	1.94		
ES113	2.6	ES113-013	2.6	0.73	0.73	0.73
ES114	2.5	ES114-014	3	4.94	4.24	4.94
		ES114-016	3.5	3.53		
ES115	1.9	ES115-014	2.7	6.29	7.28	8.26

Golder Bore location	PASS DEPTH based on soil profiles (mbgl)	Golder Sample Identification	Pass depth based on samples (mbgl)	Net Acidity (exc. ANC) (%S)	Net Acidity AVERAGE (%S)	Net Acidity Highest Value (%S)
		ES115-016	3.1	8.26		
ES116	2.55	ES116-017	3.75	3.15	3.15	3.15
ES117	3.1	ES117-016	3.3	3.96	3.96	3.96
ES118	2.7	ES118-016	3	11.28	8.98	12.90
		ES118-018	3.5	12.90		
		ES118-020	3.9	2.76		
ES119	2.25	ES119-015	3.5	3.06	3.06	3.06
		ES120-010	2.25	10.72	8.97	10.72
ES120	2.25	ES120-012	2.75	7.22		
ES121	2.8	ES121-016	3.25	8.20	4.83	8.20
		ES121-018	3.75	4.44		
		ES121-020	4.25	1.86		
ES122	2.7	ES122-014	3.25	16.34	9.56	16.34
		ES122-016	3.75	8.28		
		ES122-018	4.25	4.06		
ES123	2.7	ES123-016	3.75	7.48	7.48	7.48
ES124	2.5	ES124-013	3	6.50	6.68	6.85
		ES124-015	3.5	6.85		
ES125	2.15	ES125-013	2.8	6.90	7.88	8.86
		ES125-015	3.25	8.86		
ES127	2	ES127-012	2.3	7.99	8.53	9.77
		ES127-014	2.75	9.77		
		ES127-017	3.25	7.82		
ES128	2	ES128-015	3	6.66	5.05	6.66
		ES128-017	3.5	3.44		
ES129	1.5	ES129-011	2.25	7.75	5.67	7.75
		ES129-013	2.75	3.58		
ES130	2.9	ES130-014	3.25	4.04	4.04	4.04
ES131	2	ES131-011	2.2	1.42	1.45	1.63
		ES131-013	2.5	1.30		
		ES131-015	3	1.63		
ES132	2.5	ES132-015	3.5	3.46	3.46	3.46
ES133	2	ES133-012	2.45	12.22	9.77	12.22
		ES133-014	3	7.31		
ES134	2.25	ES134-012	2.75	6.44	6.39	6.44
		ES134-014	3.25	6.33		
ES135	2.25	ES135-013	2.45	9.99	9.99	9.99
ES136	2	ES136-009	2	2.06	4.16	7.00
		ES136-011	2.5	7.00		
		ES136-013	3	3.43		
ES137	2.1	ES137-011	2.1	10.83	8.49	10.83
		ES137-013	2.6	6.82		
		ES137-015	3.1	7.82		
ES139	2.25	ES139-014	3	4.15	4.15	4.15
ES140	2.25	ES140-010	2.25	1.18	4.64	8.10
		ES140-013	2.9	8.10		
ES141	1.9	ES141-011	2.1	5.59	3.78	5.59
		ES141-013	2.5	1.96		
ES143	1.2	ES143-007	2.25	0.27	0.27	0.27
ES144	1.2	ES144-007	1.5	7.51	5.21	7.51
		ES144-009	2	6.33		
		ES144-011	2.5	1.78		
ES146	0.7	ES146-004	0.7	4.44	1.66	4.44
		ES146-006	1.25	0.38		
		ES146-008	1.75	0.17		
ES148	2.25	ES148-010	2	3.25	2.51	3.25
		ES148-012	2.5	2.67		
		ES148-014	3	1.60		
ES150	2.2	ES150-012	2.5	8.39	8.39	8.39
ES152	2.2	ES152-011	2.5	8.28	7.75	8.28
		ES152-013	3	7.21		
ES154	1.75	ES154-008	1.75	11.69	7.15	11.69
		ES154-010	2.25	2.60		
ES158	0.5	ES158-005	0.5	1.96	1.96	1.96

Golder Bore location	PASS DEPTH based on soil profiles (mbgl)	Golder Sample Identification	Pass depth based on samples (mbgl)	Net Acidity (exc. ANC) (%S)	Net Acidity AVERAGE (%S)	Net Acidity Highest Value (%S)
ES159	0.75	ES159-004	0.75	0.99	0.99	0.99
ES160	0.75	ES160-005	0.75	1.70	1.70	1.70
ES162	0.75	ES162-004	0.75	0.64	0.64	0.64
ES163	3.25	ES163-014	3.25	5.20	5.89	6.57
		ES163-016	3.75	6.57		
ES164	2.75	ES164-004	0.75	0.00	4.97	7.38
		ES164-012	2.75	6.36		
		ES164-014	3.25	7.38		
		ES164-016	3.75	6.13		
ES165	1	ES165-005	1	0.50	0.50	0.50
ES167	3	ES167-015	3.5	1.34	1.91	2.42
		ES167-017	4	1.97		
		ES167-019	4.5	2.42		
ES168	2.75	ES168-012	2.75	0.85	0.63	0.85
		ES168-014	3.25	0.74		
		ES168-016	3.75	0.29		
ES171	2.75	ES171-013	3	4.14	5.84	8.11
		ES171-015	3.5	7.84		
		ES171-017	4	8.11		
		ES171-019	4.5	5.05		
		ES171-021	5	4.06		
ES173	3	ES173-014	3.25	0.68	0.68	0.68
ES176	3	ES176-013	3	0.17	0.20	0.36
		ES176-016	3.75	0.08		
		ES176-020	4.75	0.36		
ES177	2.5	ES177-014	3.25	4.77	4.77	4.77
ES180	3.5	ES180-017	4	2.47	2.62	4.03
		ES180-019	4.5	4.03		
		ES180-021	5	1.36		
ES181	2.75	ES181-012	2.75	1.51	5.46	9.40
		ES181-014	3.25	9.40		
ES183	3.25	ES183-014	3.25	0.72	0.72	0.80
		ES183-016	3.75	0.68		
		ES183-018	4.25	0.80		
		ES183-020	4.75	0.66		
ES184	3.25	ES184-014	3.25	5.99	6.17	8.33
		ES184-016	3.75	6.70		
		ES184-018	4.25	3.64		
		ES184-020	4.75	8.33		
		ES185-014	3.25	0.39	0.53	0.66
ES185	3.25	ES185-016	3.75	0.66		
ES188	2.35	ES188-010	2.25	1.71	1.05	1.71
		ES188-012	2.75	0.38		
ES189	2.3	ES189-010	2.3	0.06	0.48	1.76
		ES189-012	2.75	1.76		
		ES189-014	3.25	0.09		
		ES189-017	4	0.00		
ES190	1	ES190-006	1.25	2.20	2.20	2.20
ES191	2.75	ES191-013	3	0.78	0.78	0.78
ES193	1.5	ES193-007	1.5	0.86	0.86	0.86
ES194	2.5	ES194-011	2.5	0.26	0.26	0.26
ES206	0.8	ES206-004	0.8	0.05	0.05	0.05
ES215	2.5	ES215-011	2.5	5.26	5.26	5.26
ES220	4.4	ES220-019	4.4	0.03	0.03	0.03
ES229	3	ES229-015	3.5	3.69	3.69	3.69
ES230	3	ES230-014	3.25	5.51	3.22	5.51
		ES230-016	3.75	0.93		
ES231	3.25	ES231-015	3.5	6.38	3.82	6.38
		ES231-017	4	1.25		
ES232	3	ES232-014	3.25	8.05	6.41	8.05
		ES232-016	3.75	4.77		
ES233	4	ES233-017	4	8.96	6.11	8.96
		ES233-019	4.5	3.25		
ES234	5.25	ES234-023	5.5	0.51	0.51	0.51

PASS Analytical Data (Golder, 2010)

Golder Bore location	PASS DEPTH based on soil profiles (mbgl)	Golder Sample Identification	Pass depth based on samples (mbgl)	Net Acidity (exc. ANC) (%S)	Net Acidity AVERAGE (%S)	Net Acidity Highest Value (%S)
ES238	2	ES238-010	2.25	1.58	1.58	1.58
ES246	3	ES246-013	3	2.37	4.11	7.45
		ES246-015	3.5	3.06		
		ES246-017	4	4.44		
		ES246-019	4.5	7.45		
		ES246-021	5	4.71		
		ES246-023	5.5	4.58		
		ES246-025	6	2.18		

PASS Mapping Assessment Criteria

Criteria	High Potential for generating acidity	Typical Landform	Soil Type	Sulfide Content
site id	Location and type of assessment	Typically samphire flats, intertidal areas, of mangrove swamps alluvial/colluvial plains of low lying areas	Dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND	Above 5 %S
Environmental Programme (URS, 2010)				
E040	Littoral	spinifex and samphire moderately vegetated	CLAY, low to medium plasticity, grey	
	Samphire Flats	dry, no evidence of recent flooding or rain events		
	Aerial Photography (Landgate,2007)	No MBO detected, broad, low lying continuous flat area		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)			
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E040A	Littoral	spinifex and samphire moderately vegetated	CLAY, high plasticity, yellow/grey and red mottling	
	Samphire Flats	dry, no evidence of recent flooding or rain events		
	Aerial Photography (Landgate,2007)	No MBO detected, broad, low lying continuous flat area		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)			
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E042A	Littoral	Moderately to densely populated with samphire.	CLAY, high plasticity, yellow/grey and red mottling	
	Samphire Flats	some water inundation in adjacent samphire flats		
	Aerial Photography (Landgate,2007)	adjacent alluvial/colluvial plains		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	low lying, broad plains		
	Ashburton North Area	MBO detected slightly below surface (decomposed organic matter)		
	Groundtruthing (March-June, 2009)			
E042	Littoral	Moderately to densely populated with samphire.	CLAY, high plasticity, red/brown/grey some grey/yellow mottling	
	Samphire Flats	some water inundation in adjacent samphire flats		
	Aerial Photography (Landgate,2007)	adjacent alluvial/colluvial plains		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	low lying, broad plains, algal blooms and salt crusting on peripheral of flat		
	Ashburton North Area	MBO detected slightly below surface (decomposed organic matter)		
	Groundtruthing (March-June, 2009)			
GEOTECHNICAL BORE REVIEW				
201	Bore Log and/or core photo Assessment	samphire flats	ORGANIC SAND, fine to medium grained, black; with some fines	not tested
	Bore Log and/or core photo Assessment		(CL) CLAY, medium plasticity, grey; with some sand; very soft grading to Clayey SAND	not tested
319	Bore Log and/or core photo Assessment	samphire flats	Silty CLAY/Clayey SAND, dark grey to black, wet, high organics (CORE PHOTO ONLY)	not tested
224	Bore Log and/or core photo Assessment	samphire flats	CLAY/Clayey SAND, drak grey grading light grey (CORE PHOTOS ONLY)	not tested
B-109	Bore Log and/or core photo Assessment	samphire flats	CLAY, dark grey (CORE PHOTOS ONLY)	not tested
B-114	Bore Log and/or core photo Assessment	samphire flats	CLAY/Clayey SAND, dark brown (CORE PHOTOS ONLY)	not tested
301	Bore Log and/or core photo Assessment	samphire flats	CLAY/Clayey SAND, dark grey (CORE PHOTOS ONLY)	not tested
303	Bore Log and/or core photo Assessment	samphire flats	CLAY/Clayey SAND, brown, (CORE PHOTOS ONLY)	not tested
318	Bore Log and/or core photo Assessment	claypan are adjacent samphire flats	Silty CLAY/Clayey SAND, dark grey to black, wet, high organics (CORE PHOTO ONLY)	not tested
E032	Bore Log and/or core photo Assessment	Adjacent Intertidal Flats	Sand: Sand - Dark brown. Fine sand with minor silt (1 - 2 %), sub - rounded, well sorted, quartz major, Ironstone minor. Loose - very poorly consolidated. Minor organic content.	not tested
E033	Bore Log and/or core photo Assessment	Low lying area adjacent samphire flats and coastal dunes	CLAY: Dark grey, soft, sticky clay, high plasticity, very high organic content.	not tested
			clayey SAND, fine to medium grained sand, loose, brown, moist	not tested
116	Bore Log and/or core photo Assessment	south of coastal dunes and adjacent intertidal flats	CLAY/Clayey SAND, grey (CORE PHOTOS ONLY)	not tested
128	Bore Log and/or core photo Assessment	south of coastal dunes and adjacent intertidal flats	CLAY/Clayey SAND, grey (CORE PHOTOS ONLY)	not tested
129	Bore Log and/or core photo Assessment	south of coastal dunes and adjacent intertidal flats and samphire fla	CLAY/Clayey SAND, grey (CORE PHOTOS ONLY)	not tested
131	Bore Log and/or core photo Assessment	adjacent intertidal flats	CLAY/Clayey SAND, grey (CORE PHOTOS ONLY)	not tested
217	Bore Log and/or core photo Assessment	adjacent intertidal flats	(CH) SANDY CLAY, high plasticity, grey; with some organic matter, fibrous in pockets; sand is fine; very soft	not tested

PASS Mapping Assessment Criteria

Criteria	High Potential for generating acidity	Typical Landform	Soil Type	Sulfide Content
site id	Location and type of assessment	Typically samphire flats, intertidal areas, of mangrove swamps alluvial/colluvial plains of low lying areas	Dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND	Above 5 %S
302	Bore Log and/or core photo Assessment	south of coastal dunes and adjacent samphire flats	SILTY CLAY, high plasticity, pale grey; with some gravel, sub-angular to sub-rounded, fine grained; trace of sand; very soft, at 4.20m, becoming dark brown, firm	not tested
312	Bore Log and/or core photo Assessment	samphire flats adjacnet intertidal flats	CLAY/Clayey SAND, dark grey, wet (CORE PHOTOS ONLY)	not tested
402	Bore Log and/or core photo Assessment	intertidal flats	CLAY/Clayey SAND, brown, (CORE PHOTOS ONLY)	not tested
409	Bore Log and/or core photo Assessment	intertidal flats	CLAY/Clayey SAND, brown to dark brown (CORE PHOTOS ONLY)	not tested
410	Bore Log and/or core photo Assessment	intertidal flats	(CL) CLAY, low plasticity, brown; with trace of sand, fine to medium grained, with trace of gravel, fine; very soft	not tested
412	Bore Log and/or core photo Assessment	fringing coastal dunes adjacent intertidal flats	(CL) SANDY CLAY, low to medium plasticity, pale green brown mottled pale blue orange; very stiff, becoming very soft	not tested
			(SC) CLAYEY SAND, fine to medium grained, green brown; clay is low plasticity, with some gravel, fine to coarse, sub-angular, cemented sand	not tested
			(CL) SANDY CLAY, low plasticity, dark green / dark brown; sand is fine to medium grained, trace of gravel, fine to medium grained, sub-angular, cemented sand; very soft	not tested
			(GC) CLAYEY GRAVELLY SAND, fine to medium grained, dark grey; gravel is fine to coarse grained, sub-angular to sub-rounded, cemented sand	not tested
417	Bore Log and/or core photo Assessment	adjacent intertidal flats	(CL) CLAY, low plasticity, brown mottled dark grey; trace of sand, fine to medium grained, with some silt, trace of organics (roots); very soft to soft	not tested
			(SC) CLAYEY SAND, fine to medium grained, dark grey mottled brown; with some silt	not tested
			CLAYEY SAND, fine to medium grained, dark brown mottled grey	not tested
418	Bore Log and/or core photo Assessment	adjacent intertidal flats	(CL) CLAY, low plasticity, pale blue to pale grey; trace of sand, fine to medium grained; very soft	not tested
419	Bore Log and/or core photo Assessment	Beach adjacent tidal creek	(SP) SAND, fine grained, pale grey brown; with trace of gravel, angular, fine shell fragments	not tested
503	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	(CH) CLAY, high plasticity, grey; organic odour, soft	not tested
504	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	(CH) CLAY, high plasticity, grey; with some sand, fine to medium; firm	not tested
	Bore Log and/or core photo Assessment		(CH) CLAY, high plasticity, grey brown; with some sand; with some gravel, fine to coarse, sub-angular to sub-rounded, cemented sand; very soft	not tested
505	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	(ML) SILT, blue grey mottled yellow; with some gravel, fine; very soft, gypsum crystals	not tested
506	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	CLAY/Clayey SAND, dark grey (CORE PHOTOS ONLY)	not tested
B-101	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	CLAY, brown (Core Photo Only)	not tested
B-103	Bore Log and/or core photo Assessment	south of fringing coastal dunes. (underlying marine muds)	CLAY, brown grading black (Core Photo Only)	not tested
201	Bore Log and/or core photo Assessment	samphire flats	ORGANIC SAND, fine to medium grained, black; with some fines	not tested
	Bore Log and/or core photo Assessment		(CL) CLAY, medium plasticity, grey; with some sand; very soft grading to Clayey SAND	not tested
319	Bore Log and/or core photo Assessment	samphire flats	Silty CLAY/Clayey SAND, dark grey to black, wet, high organics (CORE PHOTO ONLY)	not tested
224	Bore Log and/or core photo Assessment	samphire flats	CLAY/Clayey SAND, drak grey grading light grey (CORE PHOTOS ONLY)	not tested
B-109	Bore Log and/or core photo Assessment	samphire flats	CLAY, dark grey (CORE PHOTOS ONLY)	not tested
B-114	Bore Log and/or core photo Assessment	samphire flats	CLAY/Clayey SAND, dark brown (CORE PHOTOS ONLY)	not tested
301	Bore Log and/or core photo Assessment	samphire flats	CLAY/Clayey SAND, dark grey (CORE PHOTOS ONLY)	not tested

PASS Mapping Assessment Criteria

Criteria	High Potential for generating acidity	Typical Landform	Soil Type	Sulfide Content
site id	Location and type of assessment	Typically samphire flats, intertidal areas, of mangrove swamps alluvial/colluvial plains of low lying areas	Dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND	Above 5 %S
303	Bore Log and/or core photo Assessment	samphire flats	CLAY/Clayey SAND, brown, (CORE PHOTOS ONLY)	not tested
318	Bore Log and/or core photo Assessment	claypan are adjacent samphire flats	Silty CLAY/Clayey SAND, dark grey to black, wet, high organics (CORE PHOTO ONLY)	not tested
Golder (2010) PASS Investigation Review				
A462	Review of field tests, analytical results and bore review	fringing dunes		5.32
A469	Review of field tests, analytical results and bore review	alluvial/colluvial		7.12
A470	Review of field tests, analytical results and bore review	alluvial/colluvial		10.58
A919	Review of field tests, analytical results and bore review	samphire flats	Silty CLAY , clayey SAND	6.81
A920	Review of field tests, analytical results and bore review	samphire flats	Clayey SILT, Silty CLAY, Sandy CLAY SAND, sandy CLAY	6.31
A921	Review of field tests, analytical results and bore review	samphire flats	Silty CLAY , clayey SILT, SAND	6.44
A925	Review of field tests, analytical results and bore review	samphire flats/alluvial/colluvial	Silty CLAY, SAND	11.15
A929	Review of field tests, analytical results and bore review	samphire flats/alluvial/colluvial	CLAY, Organic CLAY, Silty CLAY, Clayey SAND	7.3
A932	Review of field tests, analytical results and bore review	alluvial/colluvial	Silty CLAY, SAND	9.58
ES115	Review of field tests, analytical results and bore review	alluvial/colluvial	Sandy CLAY	8.26
ES118	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY, SAND	12.9
ES120	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY	10.72
ES121	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY, Silty SAND	8.2
ES122	Review of field tests, analytical results and bore review	alluvial/colluvial	Silty CLAY, Silty SAND	16.34
ES123	Review of field tests, analytical results and bore review	alluvial/colluvial	Silty CLAY	7.48
ES124	Review of field tests, analytical results and bore review	alluvial/colluvial	Silty CLAY	6.85
ES125	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	8.86
ES141	Review of field tests, analytical results and bore review	alluvial/colluvial	Clayey SAND	5.59
ES144	Review of field tests, analytical results and bore review	alluvial/colluvial	Silty CLAY , Silty SAND	7.51
ES150	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY	8.39
ES152	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY	8.28
ES154	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY, Silty SAND	11.69
ES215	Review of field tests, analytical results and bore review	claypan adjacent supratidal salt flats	CLAY	5.26
ES53	Review of field tests, analytical results and bore review	samphire flats	Silty CLAY	6.99
ES56	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY, organic CLAY	6.99
ES70	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY, SAND	5.59
ES72	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY	7.1
ES74	Review of field tests, analytical results and bore review	supratidal	Organic CLAY, SAND	6.84
ES78	Review of field tests, analytical results and bore review	supratidal falts	CLAY	5.08
ES90	Review of field tests, analytical results and bore review	-	Organic CLAY, Sandy CLAY	8.31
ES99	Review of field tests, analytical results and bore review	samphire flats	Sandy CLAY	5.48
ES163	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	6.57
ES164	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	7.38
ES171	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	8.11
ES184	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	8.33
ES181	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	9.40
ES215	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	5.26
ES230	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	5.51
ES231	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	6.38
ES246	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	7.45
ES232	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	8.05
ES233	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	8.96

Criteria	Moderate Potential to Generate Acidity	Landform	Soil Type	Sulfide Content
Site ID	Location and type of assessment	Typically samphire flats and clayey plains, and chenier formations, alluvial/colluvial plains of low lying areas	Dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND	1-5%S
Environmental Programme (URS, 2010)				
E019	Onslow	fringing dunes and beach, unstable and mobile sand units	CLAY, grey	**1.34**
	Fringing and Coastal Dunes	Significant surface shell deposition	CLAY, grey	**1.26**
	Aerial Photography (Landgate,2007)	spit located parallel to ocean and moderately vegetated fringing dune.		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Spit look temporary from recent storm surge and heavy rainfall events		
	Ashburton North Area	Adjacent dunes approximately 3-4 m in height		
	Groundtruthing (March-June, 2009)			
E018	Onslow	South of coastal dunes, low lying broad plains with sandy surface	CLAY, cream brown with yellow mottles	**1.26**
	Alluvial/Colluvial Plains	No discernible drainge pattern although slight landform gradient toward the north, increasing with proximity to		
	Aerial Photography	coastal dunes.		
	Aerial Photography (Landgate,2007)	moderatley vegetated with spinifex		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)			
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
PASS INVESTIGATION REVIEW (Golder, 2010)				
A914	Review of field tests, analytical results and bore review	clayey plains/samphire	CLAY	1.48
A916	Review of field tests, analytical results and bore review	clayey plains/samphire	Silty CLAY to CLAY	4.96
A917	Review of field tests, analytical results and bore review	clayey plains/samphire	Silt	1.29
A918	Review of field tests, analytical results and bore review	clayey plains/samphire	Clayey SILT, silty CLAY, clayey SAND, silty SAND	1
A926	Review of field tests, analytical results and bore review	alluvial/colluvial	Silty CLAY, SAND	2.57
A930	Review of field tests, analytical results and bore review	alluvial/colluvial	Clayey SAND, SAND	4.78
A934	Review of field tests, analytical results and bore review	clayey plains	CLAY, SAND	3.69
A935	Review of field tests, analytical results and bore review	clayey plains	Silty SAND	3.57
ES111	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY, Sandy CLAY	1.94
ES114	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY, Sandy CLAY	4.94
ES116	Review of field tests, analytical results and bore review	alluvial/colluvial	Sandy CLAY	3.15
ES117	Review of field tests, analytical results and bore review	alluvial/colluvial	Sandy CLAY	3.96
ES119	Review of field tests, analytical results and bore review	alluvial/colluvial	Sandy CLAY	3.06
ES146	Review of field tests, analytical results and bore review	supratidal	Silty SAND	4.44
ES148	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY, silty SAND	3.25
ES158	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	1.96
ES160	Review of field tests, analytical results and bore review	supratidal	Clayey SAND	1.7
ES50	Review of field tests, analytical results and bore review	clayey plains/samphire	Silty CLAY	4.11
ES57	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY	4.25
ES62	Review of field tests, analytical results and bore review		CLAY	1
ES73	Review of field tests, analytical results and bore review	supratidal	Silty CLAY	1.87
ES75	Review of field tests, analytical results and bore review	supratidal	SAND	2.59
ES77	Review of field tests, analytical results and bore review	supratidal	Sandy CLAY	1.7
ES82	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY	4.29
ES88	Review of field tests, analytical results and bore review	alluvial/colluvial	Organic CLAY, Clayey SAND, SAND	4.8
ES89	Review of field tests, analytical results and bore review	-	Organic CLAY	1.91
ES167	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	2.42
ES177	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY to Sandy CLAY	4.77
ES180	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	4.03
ES188	Review of field tests, analytical results and bore review	claypan	CLAY	1.71
ES189	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	1.76
ES190	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	2.20
ES229	Review of field tests, analytical results and bore review	alluvial/colluvial	Sandy CLAY	3.69
ES238	Review of field tests, analytical results and bore review	alluvial/colluvial	Sandy CLAY	1.58

Criteria	Location and type of assessment	Landform	Soil Type	Sulfide Content
Site ID	**Low potential to Generate Acidity**	Typically Supratidal Flats	Dark grey to dark brown, low to high plasticity CLAY/Organic CLAY and SILT to brown to dark grey, fine to medium grained, clayey SAND/SAND	0.03 to 1.0%S
ENVIRONMENTAL PROGRAMME (URS, 2010)				
E012	Littoral/Onslow Boundary	Occasional salt scalding and black algal mottling		
	Intertidal Flats, Tidal Creek and Mangrove Swamps	moderately vegetated, broad flat flats with alluvial/colluvial plains to north		
	Aerial Photography (Landgate,2007)	Broad flat mud flats, some surface shell evident	SAND, fine grained, dark grey	**0.66**
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Tidal creek approximately 80m wide @ low tide, dense mangrove	CLAY, dark brown, high plasticity	**0.47**
	Ashburton North Area	along eastern side of creek. Light to sparse on western boundary.		
	Groundtruthing (March-June, 2009)	Algal mud flat approx. 1km from mouth of tidal creek		
		salt crusting is only a thin veneer (~1mm) over clay rich sand		
		Approximately 300m to 1000m in width.		
E038	Littoral	Salt encrusted, broad, flat area, very low lying	sandy CLAY, fine grained, low plasticity, light brown	
	Supratidal Salt Flats	connected to mangroves, no noticeable historical storm surge	clayey SAND, fine to medium grained, low plasticity, light brown	
	Aerial Photography (Landgate,2007)	Black mottling associated with algal mats and potentially MBO		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	No noticeable drainage lines or gradient		
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E027	Bore Log and/or core photo Assessment	Adjacent Supratidal Salt Flats	Clay: Yellow - grey. very sticky, soft, mod - high plasticity, minor sand.	not tested
E010	Onslow	Adjacent longitudinal dunes to west and marginal to intertidal flat to east	CLAY, brown to grey	**0.11**
	Alluvial/Colluvial Plains	slope is 1-2 degrees.		
	Aerial Photography (Landgate,2007)	soil surface is not hardset, bleached light brown with some coherence.		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)			
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
PASS INVESTIGATION REVIEW (Golder, 2010a)				
A456	Review of field tests, analytical results and bore review	supratidal	silty CLAY	0.58
A936	Review of field tests, analytical results and bore review	saline flats	CLAY	0.54
ES113	Review of field tests, analytical results and bore review	alluvial/colluvial	Clayey SAND	0.73
ES143	Review of field tests, analytical results and bore review	supratidal	Sandy CLAY	0.27
ES159	Review of field tests, analytical results and bore review	supratidal	SAND	0.99
ES162	Review of field tests, analytical results and bore review	supratidal	CLAY	0.64
ES191	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	0.78
ES193	Review of field tests, analytical results and bore review	intertidal	CLAY	0.86
ES194	Review of field tests, analytical results and bore review	intertidal	CLAY	0.26
ES206	Review of field tests, analytical results and bore review	supratidal	Gravelly SAND	0.05
ES60	Review of field tests, analytical results and bore review	alluvial/colluvial	Gravelly SAND and SAND	0.04-1.0
ES61	Review of field tests, analytical results and bore review	alluvial/colluvial	SAND	0.1
ES63	Review of field tests, analytical results and bore review	supratidal	CLAY	0.32
ES86	Review of field tests, analytical results and bore review	alluvial/colluvial	SAND	0.59
ES165	Review of field tests, analytical results and bore review	supratidal	CLAY, Sandy CLAY	0.50
ES168	Review of field tests, analytical results and bore review	claypan	CLAY, Sandy CLAY	0.85
ES173	Review of field tests, analytical results and bore review	claypan	CLAY	0.68
ES176	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY and SAND	0.36
ES183	Review of field tests, analytical results and bore review	claypan	CLAY	0.80
ES185	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY, Sandy CLAY	0.66
ES191	Review of field tests, analytical results and bore review	intertidal	CLAY and SAND	0.78
ES193	Review of field tests, analytical results and bore review	intertidal	CLAY	0.86
ES194	Review of field tests, analytical results and bore review	intertidal	CLAY	0.26
ES206	Review of field tests, analytical results and bore review	claypan	Gravelly SAND	0.05
ES218	Review of field tests, analytical results and bore review	claypans	Clayey SAND	0.32
ES220	Review of field tests, analytical results and bore review	claypan	Sandy CLAY	0.03
ES234	Review of field tests, analytical results and bore review	alluvial/colluvial	CLAY	0.51

PASS Borrow Area Investigation (Golder, 2010b)-Borrow Area 4 only				
BP4-1	Review of field tests, analytical results and bore review	longitudinal dunes	Silty SAND	0.15
BP4-2	Review of field tests, analytical results and bore review	alluvial colluvial	Silty Clayey SAND and Gravelly Clayey SAND	0.03-0.19
BP4-3	Review of field tests, analytical results and bore review	alluvial colluvial	SAND	0.21

Criteria	Assessment Type	Landform	Soil Type	Sulfide Content
Site ID	**Below DEC 0.03%**	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation) and alluvial colluvial	Red earths sands/clays	Non-detect
ENVIRONMENTAL PROGRAMME (URS, 2010)				
E002	Dune	Bare, Claypan, dry, hard cracking -2-5mm	silty sandy CLAY, low plasticity, red brown	non detect
	Claypans	Surrounded by Alluvial/Colluvial-vegetated with spinifex	silty SAND, red brown	
	Aerial Photography (Landgate,2007)	Depressed area	silty SAND, limestone fragments	
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	circular, discontinuous, 100-200 m radius		
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E003	Dune	interdunal swale between dunes.	Sand/Calcaerous SANDSTONE	non detect
	Longitudinal Dunes and Interdunal Swales	undulating topography with slopes of 10-15 degrees		
	Aerial Photography (Landgate,2007)	moderately vegetated with spinifex and low shrubs		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	calcareous cobbles on surface adjacent site		
	Ashburton North Area	sparse shell		
	Groundtruthing (March-June, 2009)			
E004	Dune	As above	SAND, light brown	non detect
	Longitudinal Dunes and Interdunal Swales		SANDSTONE	
	Aerial Photography (Landgate,2007)			
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)			
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E005	Dune	interdunal swale between dunes.	silty SAND, red brown, fine to medium grained	non detect
	Longitudinal Dunes and Interdunal Swales	site is marginal to the slope of the ridge, in a basin between two ridges	gravelly SAND, brown, fine to medium grained	
	Aerial Photography (Landgate,2007)	adjacent plains to the east	sandy GRAVEL, light grey, fine to medium grained	
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	surface soils is slightly hard set sands.	silty sandy GRAVEL	
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E006	Dune	marginal slope to water drainage area on west of dunes area	SAND, very fine grained, brown	not tested
	Alluvial/Colluvial Plains	slope of site 5 degrees to base of dune		
	Aerial Photography (Landgate,2007)	site is flat to 1-3% slope to W-SW		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	adjancet dune ~10-12m in height		
	Ashburton North Area	moderately vegetated with hummock grasses (spinifex)		
	Groundtruthing (March-June, 2009)	soil surface structure amrphous (no structure)		
E007	Dune	moderately to densely vegetated with spinifex and other shrubs.	silty Clay, red/brown, high plasticity	non detect
	Alluvial/Colluvial Plains	Elevatation of ~3m greater than adjacent plains and at base of adjacent dunes	Sandstone, well cemented (unable to sample)	
	Aerial Photography (Landgate,2007)	small dunal ridge (looking south) of ~10m in height		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	Marginal slope to former intertidal flood zone		
	Ashburton North Area	downslope is 3-5 degrees (looking north)		
	Groundtruthing (March-June, 2009)	some trees 1-3 m in height		
E008	Dune	marginal edge to longitudinal dunes and alluvial/colluvial plain	SAND, red brown	non detect
	Longitudinal Dunes and Interdunal Swales	slope is generally flat to 2 degrees of general surrounds	silty SAND, red brown	
	Aerial Photography (Landgate,2007)	soil surface is loose, fraibel incohernat sand.		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	moderately vegetated spinifex. Sparse shrubs		
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E009	Dune	Interdunal swale, marginal to longitudinal dune	silty SAND red/brown	non detect
	Longitudinal Dunes and Interdunal Swales	sand dune within saddle area. Intertidal area to the north west	SANDSTONE	
	Aerial Photography (Landgate,2007)	downslope is 3-5 degrees (looking north west)		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	surface soils are very fine -fine (silty sand), friable (light finger pressure)		
	Ashburton North Area	sparse vegetation of hummock grasses and weeds. Very sparse shrubs		
	Groundtruthing (March-June, 2009)	no organised or incised drainage patterns		
E015	Dune	undulating interdunal swale, soil red, saddle between ridges	SAND, fine grained, well sorted, red/brown	non detect
	Longitudinal Dunes and Interdunal Swales	moderately vegetated with spinifex and saprsely with acacia	clayey SAND, red brown	
	Aerial Photography (Landgate,2007)	ridges are 6-7 m in height		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	drainge is through soil, no discernible drainage lines		

Criteria	Assessment Type	Landform	Soil Type	Sulfide Content
Site ID	**Below DEC 0.03%**	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation) and alluvial colluvial	Red earths sands/clays	Non-detect
	Ashburton North Area	sand has no cohesion when disturbed		
	Groundtruthing (March-June, 2009)			
E016	Dune	Interdunal swale, site is in a saddle marginal to longitudinal dunes of 2-3 m in I	SAND, red brown	non detect
	Longitudinal Dunes and Interdunal Swales	moderately vegetated with hummock grasses and low shrubs.	silty SAND, red brown, fine to medium grained	
	Aerial Photography (Landgate,2007)	groundwater not intercepted		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)	surface soils are fine, red sands		
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E017	Onslow	Broad relatively flat plain, slightly undulating (adjacent longitudinal dunes)	clayey SAND, red/brown	non detect
	Alluvial/Colluvial Plains	Moderately to densely populated with spinifex and other species	sandy CLAY, red/brown	
	Aerial Photography (Landgate,2007)	shallow groundwater encountered.	clayey sandy GRAVEL	
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)		silty SAND	
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E036	Littoral	very flat, broad, moderately to densely vegetated (~0.5m in height) broad sand	silty SAND, very fine grained, tight, red/brown	non detect
	Alluvial/Colluvial Plains	Mainland remnant dunes visible to north, no surface salt scalding		
	Ashburton North Area			
	Groundtruthing (March-June, 2009)			
E037	Alluvial/Colluvial Plains	Base of mainland remnant dunal. Slight gradient of about 5-10 degrees	silty SAND, very fine grained, tight, red/brown	non detect
	Aerial Photography (Landgate,2007)	vegetation dense (0.5-1.0 m in height), surface silty sand, with no scalding		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)			
E039	Alluvial/Colluvial Plains	vegetation dense (0.5-1.0 m in height), surface silty sand, with no scalding	silty SAND, red brown, fine to medium grained	non detect
	Aerial Photography (Landgate,2007)	Located on "island" adjacent supratidal salt flats		
	3m-Hillshade Interpretation-Lidar Dem (Nov, 2008)			
GEOTECHNICAL BORE REVIEW (Coffey, 2009)				
E011	Bore Log and/or core photo Assessment	Beach		no
E013	Bore Log and/or core photo Assessment	Beach		no
E020	Bore Log and/or core photo Assessment	Beach	SILTY SAND: Light orange brown loose sand with 5% minor silt, fine to medium grained sand, sub rounded, moderately sorted, quartz major with ironstone, sandstone grains, several 3-5mm shell fragments, large (20mm) pieces of dolerite	no
E021	Bore Log and/or core photo Assessment	Beach		no
E014	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta	SAND: Silty, red-brown, well sorted, subrounded, mainly quartz.	no
E022	Bore Log and/or core photo Assessment	Plant and surrounds		
E023	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta, West of Bechtel Plot Plan	SAND: Clayey with gravel, some shell fragments, red, brown, soft, well sorted, well rounded, mostly quartz, mica, increasingly compact and filled with more clay content.	no
E024	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta	GRAVELLY CLAY: Same fine grained sand, 30% gravel ± 20mm. Sun angular to angular, low to moderate plasticity, loose to medium to tight, red, brown.	no
E025	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta	SAND: Red sand, fine grained, siliceous, well sorted, mature.	no

Criteria	Assessment Type	Landform	Soil Type	Sulfide Content
Site ID	**Below DEC 0.03%**	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation) and alluvial colluvial	Red earths sands/clays	Non-detect
E026	Bore Log and/or core photo Assessment	Coastal Dunes east of Ashburton River Delta	SAND: Siliceous, red brown, approximately 90% fine grained sand with minor silt (approximately 10%). Well sorted, sub-rounded quartz grains dominant with minor organic material. Minor gravel at 3 m	no
E028	Bore Log and/or core photo Assessment	Longitdunal Dune Network	SANDY CLAY: Fine to medium grained, loose, red, brown, low plasticity, loose to moderately tight.	no
E029	Bore Log and/or core photo Assessment	Longitdunal Dune Network	SAND: Siliceous, red brown, approximately 90% fine grained sand with minor silt (approximately 10%). Well sorted, sub-rounded quartz grains dominant with minor organic material.	no
E030	Bore Log and/or core photo Assessment	Longitdunal Dune Network	SAND: Red brown, well sorted, fine grained with cemented pebbles.	no
E031	Bore Log and/or core photo Assessment	Longitdunal Dune Network	SAND: Clayey sand; brown- yellow (around 50 % clay) siliceous. SAND: Siliceous; red - brown, qtz - rich, moderately sorted, medium grained, sub - rounded grains. Minor clay content.	no
130	Bore Log and/or core photo Assessment	CUCA Condensate Tank	visual interpretation of core logs	no
202	Bore Log and/or core photo Assessment	Train 2	visual interpretation of core logs	no
204	Bore Log and/or core photo Assessment	Train 2	visual interpretation of core logs	no
212	Bore Log and/or core photo Assessment	Train 1	visual interpretation of core logs	no
225	Bore Log and/or core photo Assessment	Train2 - CUCA	visual interpretation of core logs	no
226	Bore Log and/or core photo Assessment	Train 2 - CUCA	visual interpretation of core logs	no
231	Bore Log and/or core photo Assessment	Train 2 - CUCA	visual interpretation of core logs	no
232	Bore Log and/or core photo Assessment	Train 2 - CUCA	visual interpretation of core logs	no
233	Bore Log and/or core photo Assessment	Train 2 - CUCA	visual interpretation of core logs	no
305	Bore Log and/or core photo Assessment	P/R (Marine Flare)	visual interpretation of core logs	no
306	Bore Log and/or core photo Assessment	Dom Gas	visual interpretation of core logs	no
309	Bore Log and/or core photo Assessment	Dom Gas	visual interpretation of core logs	no
316	Bore Log and/or core photo Assessment	P/R (Cryog. Line)	visual interpretation of core logs	no
320	Bore Log and/or core photo Assessment	DomGas - CUCA	visual interpretation of core logs	no
325	Bore Log and/or core photo Assessment	Slug-Catcher- CUCA	visual interpretation of core logs	no
328	Bore Log and/or core photo Assessment	Slug-Catcher- CUCA	visual interpretation of core logs	no
413	Bore Log and/or core photo Assessment	Onshore MOF	visual interpretation of core logs	no
501	Bore Log and/or core photo Assessment	Levee @ 400 m (Shoreline Buffer)	visual interpretation of core logs	no
502	Bore Log and/or core photo Assessment	Levee @ 400 m (Shoreline Buffer)	visual interpretation of core logs	no
802	Bore Log and/or core photo Assessment	Roadway	visual interpretation of core logs	no
B-107	Bore Log and/or core photo Assessment	West of Bechtel Plot Plan	visual interpretation of core logs	no
B-128	Bore Log and/or core photo Assessment	West of Bechtel Plot Plan	visual interpretation of core logs	no
B-131	Bore Log and/or core photo Assessment	West of Bechtel Plot Plan	visual interpretation of core logs	no
B-142	Bore Log and/or core photo Assessment	East of Bechtel Plot Plan	visual interpretation of core logs	no
PASS Borrow Area Investigation (Golder, 2010b)-Borrow Area 4 only				
BP4-4	Field test results and bore logs	alluvial colluvial	SAND and Silty SAND	not tested
BP4-5	Field test results and bore logs	alluvial colluvial	SAND and Silty SAND	not tested
BP4-6	Field test results and bore logs	longitudinal dunes	SAND and Silty CLAY	not tested
BP4-7	Field test results and bore logs	alluvial colluvial	SAND, sandy CLAY, silty sandy CLAY	not tested
BP4-8	Field test results and bore logs	alluvial colluvial	Silty SAND and clayey silty SAND	not tested
BP4-9	Field test results and bore logs	alluvial colluvial	SAND, silty SAND and silty clayey SAND	not tested
BP4-10	Field test results and bore logs	alluvial colluvial	SAND, silty SAND and clayey sandy GRAVEL	not tested
BP4-11	Field test results and bore logs	alluvial colluvial	SAND and sandy CLAY	not tested
BP4-12	Field test results and bore logs	dunal	SAND	not tested
BP4-13	Field test results and bore logs	alluvial colluvial	Silty CLAY, silty clayey SAND and silty clayey GRAVEL	not tested

Criteria	Assessment Type	Landform	Soil Type	Sulfide Content
Site ID	**Below DEC 0.03%**	Fringing, Coastal and Longitudinal Dunes and Interdunal Swales (unless underlying Chenier formation) and alluvial colluvial	Red earths sands/clays	Non-detect
BP4-14	Field test results and bore logs	alluvial colluvial	Silty SAND, Silty sandy CLAY, silty clayey SAND, silty sandy CLAY amd clayey silty GRAVEL	not tested
BP4-15	Field test results and bore logs	alluvial colluvial	SAND, silty SAND, silty sandy CLAY	not tested
BP4-16	Field test results and bore logs	alluvial colluvial	SAND and silty clayey SAND	not tested
BP4-17	Field test results and bore logs	longitudinal dunes	SAND and silty clayey SAND	not tested
BP4-18	Field test results and bore logs	longitudinal dunes	SAND and silty SAND	not tested
Domgas Study Area-Geotechnical Memo (Golder, 2010c)				
DG01	Field test results and bore logs	alluvial colluvial	CLAY	not tested
DG02	Field test results and bore logs	alluvial colluvial	silty SAND and CLAY	not tested
DG03	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG04	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG06	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG07	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG08A	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG09A	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG10	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG11	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG12	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG13	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG14	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG15	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG16	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG17	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG18	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG19	Field test results and bore logs	alluvial colluvial	Silty SAND and Gravelly SAND	not tested
DG20	Field test results and bore logs	alluvial colluvial	Silty SAND and Gravelly SAND	not tested
DG21	Field test results and bore logs	alluvial colluvial	Silty SAND and Gravelly SAND	not tested
DG22	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG29	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG30	Field test results and bore logs	alluvial colluvial	Silty SAND and Silty Gravelly SAND	not tested
DG31	Field test results and bore logs	alluvial colluvial	Gravelly silty SAND	not tested
DG32	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG33	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG34	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG35	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG36	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG37	Field test results and bore logs	alluvial colluvial	Silty Gravelly SAND	not tested
DG38	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested
DG39	Field test results and bore logs	alluvial colluvial	Silty SAND and gravelly silty SAND	not tested
DG40	Field test results and bore logs	alluvial colluvial	Silty SAND and sandy GRAVEL	not tested
DG41	Field test results and bore logs	alluvial colluvial	Gravelly silty SAND	not tested
DG42	Field test results and bore logs	alluvial colluvial	Silty SAND and sandy GRAVEL	not tested
DG43	Field test results and bore logs	alluvial colluvial	Silty SAND and gravelly silty SAND	not tested
DG45	Field test results and bore logs	alluvial colluvial	Gravelly silty SAND	not tested
DG46	Field test results and bore logs	alluvial colluvial	ironstone/lateritie	not tested
DG47	Field test results and bore logs	alluvial colluvial	silty SAND, calucitrite	not tested
DG48	Field test results and bore logs	claypan	silty SAND, sandy GRAVEL and CLAY	not tested
DG49	Field test results and bore logs	claypan	silty SAND, calucitrite	not tested
DG50	Field test results and bore logs	claypan	Silty SAND and clayey GRAVEL	not tested
DG53	Field test results and bore logs	alluvial colluvial	silty SAND, calucitrite	not tested
DG54	Field test results and bore logs	alluvial colluvial	Silty SAND	not tested





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