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Port Spencer Marine Baseline Quantitative Surveys

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REPORT

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Executive Summary

Centrex Metals Ltd proposes to develop Port Spencer on the east coast of the Eyre Peninsula, South Australia (the Site). Port Spencer will handle iron ore and grain for export from South Australia. The key marine structure of the Port will consist of a 25 m wide and 515 m long jetty, with a 55 m wide and 345 m long berthing jetty at the seaward extent (Golder 2011).

For managing Centrex's environmental obligations, a formal development application and a request for *Guidelines* to be issued for the Stage 1 works (which include the construction of the jetty) was submitted in December 2010. In June 2011, the Development Assessment Commission requested that Centrex prepare a detailed Public Environmental Report regarding the proposal, and the accompanying *Guidelines* requested that quantitative studies be undertaken to detail the type, extent and condition of marine communities at the Site.

In July and August 2011, Golder Associates undertook quantitative and qualitative assessments of the key marine habitats at the Site.

These key habitats (as identified during previous marine surveys (Golder 2009 and 2011)) are as follows:

- intertidal rocky shores
- subtidal rocky reefs dominated by mixed macroalgal communities
- subtidal seagrass meadows of *Posidonia angustifolia, P. sinuosa* and *Amphibolis Antarctic*, and
- subtidal sandy substrates interspersed with sparse *Heterozostera nigricaulis* (seagrass) and *Pinna bicolor* (Razorfish).

The approach to these surveys was developed in consideration of the following key elements:

- DAC issued *Guidelines*
- current understanding of the approach to construction and operation of the Port
- current understanding of the Site conditions, and
- the potential for impacts based on the understanding of the nature, extent and duration of the disturbances.

The findings of these surveys indicate that the habitats at the Site are representative of those founds in the region. No threatened species were identified as occurring at the Site, however a naturally rare leucosiid crab (*Cryptocnemus vincentianus)* and a marine pest (*Musculista senhousia*) were identified as occurring in the seagrass habitat.

The information obtained during the current study has been used to further document the baseline conditions at the Site and to develop a more comprehensive understanding of the potential for impacts to occur from the construction and operation of the proposed jetty.

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1.0 INTRODUCTION

Centrex Metals Ltd (Centrex) proposes to develop Port Spencer on the east coast of the Eyre Peninsula, South Australia (the Site) (refer to Figure 1, Appendix A). Port Spencer will handle iron ore and grain for export from South Australia. The key marine structure of the Port will consist of 25 m wide and 515 m long jetty, with a 55 m wide and 345 m long berthing jetty at the seaward extent (Golder 2011). Panamax[1] and Cape class[2] vessels are expected to berth at the jetty. Initially, approximately 20 vessels will be loaded with grain and hematite[3] per year. This is an approximate frequency of one vessel every 18 days. When magnetite[4] ore is processed at the mine, a predicted 50 Cape class vessels will increase the frequency of berths to seven vessels each month (Golder 2011). Conveyors will be used to transport ore and grain to the jetty.

For managing Centrex's environmental obligations, a formal development application (DA) and a request for *Guidelines* to be issued for the Stage 1 works (which include the construction of the jetty) was submitted in December 2010. In June 2011, the Development Assessment Commission (DAC) requested that Centrex prepare a detailed Public Environmental Report (PER) regarding the proposal, and the accompanying *Guidelines* requested that quantitative studies be undertaken to detail the type, extent and condition of marine communities at the Site.

Golder Associates Pty Ltd (Golder) has previously undertaken preliminary qualitative and some semi-quantitative marine studies for the port, which were targeted at identifying the habitats present at the Site, as well as considering the potential ecological effects from the construction and ongoing use of the proposed jetty. The studies have included a literature review, a preliminary baseline assessment, and, more recently, a targeted assessment within, and immediately surrounding, the footprint of the proposed jetty, which focused on describing the habitats and marine sediments present in this area. The findings of the preliminary survey work are presented in Golder (2009 and 2011) and briefly described in Section 5.0.

Targeted quantitative surveys were then undertaken in August and September 2011 (the current survey) to quantify the marine species present at Port Spencer. The findings of these surveys have been used to better understand the potential impacts from the construction and operation of the proposed jetty. The findings of these more detailed baseline surveys are presented in this report.

[1] Typically vessels carry up to 65,000 to 90,000 tonnes (dead weight) and are maximum dimension of 295m long, 32m beam (wide), 13m draught (hull depth).

[2] Typically vessels carry up to 165,000 to 200,000 tonnes (dead weight)

[3] Iron oxide, Fe_2O_3, ferrous iron – valence 2.

[4] Iron oxide, Fe_3O_4, ferric iron – valence 3.

2.0 RELEVANT MARINE GUIDELINES

The *Guidelines* detailed below have been addressed as part of the present study. Some key tasks identified in the *Guidelines* may have been previously addressed; however, where appropriate, Golder has updated the work already completed to reflect the results of the quantitative surveys.

Table 1: DAC issued Guidelines relevant to the marine baseline studies

Item	Task
Coastal and Marine	
5.3.1	Investigate the potential effect of the development on the terrestrial, coastal and marine environment, both on and around the Site (including the Lipson Island Conservation Park).
5.3.2	Describe the impact of the proposed jetty construction on the foreshore[5], seabed and benthic communities.
5.3.4	Describe the impact of blasting and pile driving activities on marine communities, especially turbidity and disturbance.
5.3.7	Describe the impact of incidental ore or grain spillage during ship loading operation on the marine environment, especially water quality.
Native Vegetation (Terrestrial and Marine)	
5.3.28	Quantify and detail the extent, condition and significance of native vegetation (individual species and communities) that currently exist on site.
5.3.29	Quantify and detail the extent, condition and significance of native vegetation (individual species and communities) that may need to be cleared or disturbed during construction and the ability of communities or individual species to recover, regenerate or be rehabilitated.
5.3.30	Calculate the level of clearance for individual community types that would be required for the whole site (including ancillary clearance for infrastructure).
5.3.31	Identify measures to minimise and mitigate vegetation clearance, including incorporating remnant stands in the layout design, and to compensate for any loss of native vegetation and habitat.
5.3.32	Describe measures to deliver any significant environmental benefit that is required by the Native Vegetation Act 1991[6].
5.3.33	Identify impact avoidance, minimisation and mitigation measures and their effectiveness.
Native Fauna (Terrestrial and Marine)	
5.3.34	Quantify and detail the abundance, condition and significance of native fauna populations that currently exist on site.
5.3.35	Describe the extent of fauna and/or habitat loss or disturbance during the construction and operation phases (both on and around site) and the ability of communities and individual species to recover, especially for resident or migratory shore birds and threatened or significant species (including those listed under the Commonwealth Environment Protection & Biodiversity Conservation Act 1999 and National Parks & Wildlife Act 1972).
5.3.36	Describe the impacts of introduced species, especially vermin and nuisance species that can be attracted to port facilities.
5.3.38	Outline the effect of noise emissions, vibration and light pollution on fauna, especially nocturnal species.
5.3.39	Identify impact avoidance, minimisation and mitigation measures and their effectiveness.

[5] For the purpose of this report, the foreshore is defined as the part of the shore that lies between the limits for high and low tides.

[6] Refer to Golder (2011). Sheep Hill Port Facility Additional Marine Ecological Studies and Environmental Effects. July 2010 Survey. Ref 107661001-011-R-RevA.

3.0 SCOPE OF WORKS

To meet the requirements of the *Guidelines* and to obtain quantitative data that will support an assessment of potential impacts from the construction of the jetty and ongoing operation of the Port, Golder conducted the following scope of works:

- Assessment of available relevant marine ecological literature, to develop an understanding of the likelihood and extent of potential impacts.
- Survey of intertidal rocky shores. This included sampling at the potential impact location, two control locations and Lipson Island.
- Survey of subtidal rocky reefs and seagrass meadows (using estimates of percentage cover within quadrats, cryptic fish and invertebrate searches and motile fish searches) at discrete distances from the proposed jetty.
- Collection of infaunal samples, sediments (for sediment chemistry and particle size distribution analysis) and water samples.
- Deployment of towed video to obtain information on general habitat characteristics within soft-bottom sandy substrate areas, in both deeper offshore and inshore environments.
- Statistical analysis and interpretation of results and a summary of potential for impacts based on the reported findings.
- Discussion and technical peer review of the quantitative baseline monitoring surveys by Professor Peter Fairweather (Professor of Marine Biology - Flinders University).
- Address items 5.3.1, 5.3.2, 5.3.28, 5.3.29, 5.3.30, 5.3.34 and 5.3.35 of the *Guidelines*, based on the results from baseline studies.
- Address items 5.3.4, 5.3.7 and 5.3.38 of the *Guidelines,* based on the findings of literature reviews.
- Re-assessment of items 5.3.30, 5.3.31 and 5.3.32, to reflect the current understanding of the proposed marine infrastructure and site conditions, and
- Discussion of mitigation and management measures for items 5.3.33, 5.3.36 and 5.3.39, to identify ways to reduce potential impacts to the marine environment and manage potential key risks, including the following:
  - Risks to marine mammals (and potentially other animals considered as being environmentally, socially or economically important).
  - Risks to key habitats (namely intertidal rocky shores, subtidal macroalgae and seagrass meadows), and
  - Risks from translocation of marine pests.

Golder gratefully acknowledges the contribution of Professor Peter Fairweather to this report by providing technical guidance and review.

4.0 CURRENT UNDERSTANDING OF THE PROPOSED PORT FACILITY

The proposed marine structures that will be constructed as part of the Port consist of 25 m wide and 515 m long jetty, with a 55 m wide and 345 m berthing jetty which extends south from the approach jetty. Construction of the marine structures is expected to extend over an 18 month period.

The approach jetty will be constructed using end over end construction methodology. Construction will commence at the foreshore end of the approach jetty and proceed in a seaward direction. It is anticipated that approximately 64 piles (number subject to final design) along the length of the approach jetty structure will be installed. As the piling process progresses out to sea it will be followed by the installation of approach jetty deck structure and road structure. This will provide continual access from shore to the piling operation for transport of permanent materials, temporary materials and construction plant.

The construction of the berthing jetty and dolphins will involve the installation of approximately 120 piles (number subject to final design) and this will be undertaken using a jack up barge.

During the pile driving process, pile fabric filtering will be used around each pile in order to minimise turbidity effects.

5.0 PREVIOUS MARINE SURVEYS

Prior to the current (August/September 2011) marine ecological survey, Golder undertook two assessments of the marine environment at the Site (one in October 2008 and one in July 2010, refer to Golder 2009 and Golder 2011, respectively). These surveys were used to develop a preliminary understanding of the marine communities present in the vicinity of the proposed jetty.

The October 2008 survey (Golder 2009), involved a preliminary review and assessment of the potential environmental impacts associated with the Port development. The review included an assessment of existing information regarding the marine environment (including physical characteristics, habitats and biological communities) in Spencer Gulf and a preliminary field investigation to assess conditions at the Site.

This preliminary survey involved a high-level assessment of intertidal and subtidal habitats, sampling of epibenthic, infaunal and zooplankton assemblages, as well as sediment and water quality sampling and analysis.

The results of this survey were used to undertake a preliminary assessment of potential impacts based on the information available about the concept design for the proposed jetty. This report provided an overview of the regulatory and planning considerations and discussed potential effects of biological resources and the physical environment.

Golder then undertook an additional marine ecological assessment in July 2010 (Golder 2011), which aimed to provide more detailed site-specific information on key habitats within the direct footprint of the proposed jetty (as presented below), and in turn update (where appropriate), the assessment of potential environmental impacts. This assessment incorporated the current concept design for the jetty to better reflect the potential for impact at the Site.

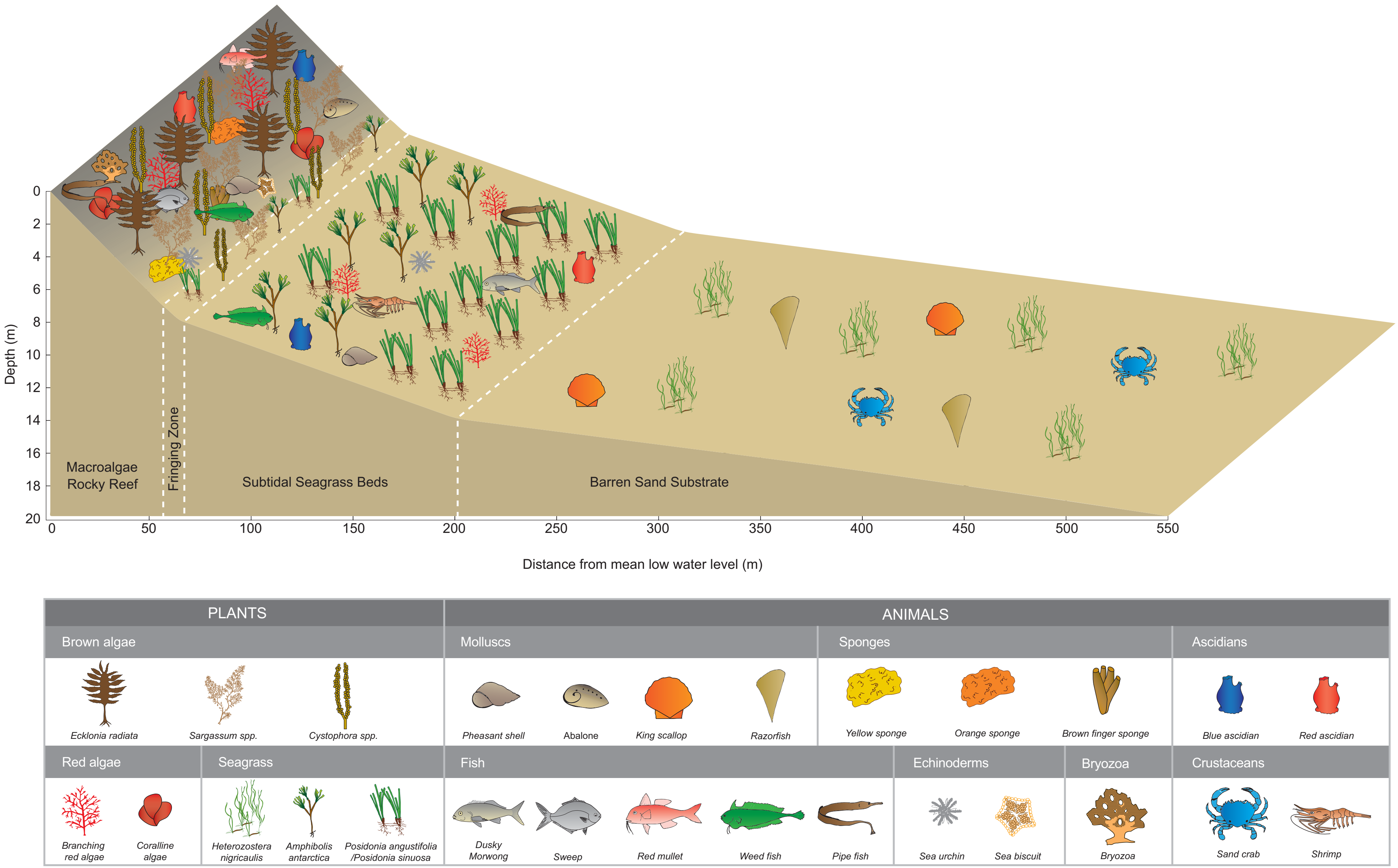
The previous studies identified the following habitats and assemblages at the Site (below), and this information was used to shape the approach to the current study.

- **Intertidal Habitats**
  - Rocky shores: Initial investigations indicated that the assemblages were represented by organisms typical of temperate intertidal rocky reefs in South Australia, and
  - Sandy beaches: The intertidal sandy beaches at the Site were categorised as intermediate/low tide terrace, in morphodynamic type (Short 2001) and were considered to be both widespread and typical for those found in the region. Based on this assessment, infaunal assemblages are considered likely to be similar to those found elsewhere in the region.
- **Subtidal Habitats**
  - Rocky reef: Occurred between approximately 0 to 7 m depth. Assemblages on the reefs were dominated by mixed macroalgal communities and associated vertebrate and invertebrate fauna. Initial qualitative investigations indicated that the taxa present are likely typical of other reefs in Spencer Gulf.
  - Seagrass meadows/sandy substrate: Mixed seagrass meadows of *Posidonia* spp. and *Amphibolis antarctica* occurred between approximately 7 to 10 m depth and dense to patchy seagrass meadows of *Posidonia* spp. occur between approximately 10 to 14 m below sea level (BSL). Assemblages documented as part of the previous studies were consistent with other studies. Infaunal assemblages have previously been described and were considered representative of assemblages in seagrass habitats found more broadly. Previous surveys have made quantitative assessments of infauna, sediment chemistry and particle-size distribution in this habitat, and

- Sandy substrates: Between approximately 14 to 17 m BSL, sandy substrate was interspersed with sparse *Heterozostera nigricaulis*[7] and *Pinna bicolor* (Razorfish). Beyond this depth range (18 to 21 m depth), bare sandy substrate was recorded. Previous surveys have made a qualitative assessment of this habitat (referred to as mid-benthic sandy substrate), as well as quantitative assessments of infauna, sediment chemistry and particle size distribution.

A schematic profile of the marine subtidal habitats present at the Site is shown in Figure 1 on the following page.

[7] *Heterozostera nigricaulis* was reported as *Heterozostera tasmanica* during the 2010 marine survey (Golder 2011). Recent revision (Kuo 2005) suggests that *H. nigricaulis* is the species present at the site.



1. Schematic only, not to be interpreted as an engineering design or construction drawing

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TITLE SCHEMATIC PROFILE OF THE SUBTIDAL MARINE HABITATS AT PORT SPENCER

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6.0 OVERVIEW OF POTENTIAL IMPACTS

The development of Port Spencer has the potential to impact on the marine environment during both the construction phase and ongoing operational phase. Given that the decommissioning phase may not occur for at least 50 years (which is the jetty design life), this has not been considered. These construction and operational phases have been considered separately throughout the report as each will involve different mechanisms for potential impacts to occur. For example, the construction phase will involve short-term disturbance to localised areas; however, this disturbance will cease once construction is complete. Conversely, the operational phase of the Port will involve long-term and ongoing changes to conditions (such as shading and altered hydrodynamic conditions from the marine structures) as well as risks associated with shipping activities, and will include pressures which will continue throughout the life of the Port.

Understanding the nature, extent and duration of the potential disturbances prior to embarking on a monitoring programme is key to obtaining targeted data which can be used in an assessment of potential impacts at the Site.

A number of potential environmental impacts associated with both phases of the Port development have been identified. These are summarised below.

Construction Phase

Based on the information available about the methods to be employed for the construction of the marine structures, it is considered likely that construction-related effects below the high water mark will be transient in nature, generally lasting only as long at the construction activities are underway. These effects are considered likely to be predominantly localised to the area within the immediate vicinity of the jetty but some effects (such as acoustic pollution from pile-driving activities) may be apparent up to 500 m away from the jetty.

A more detailed consideration of the potential for impacts to occur has been provided in the relevant sections throughout the report; however, in summary, impacts may include the following:

- Localised loss or disturbance of marine organisms or habitat directly under individual piles or the jack-up barge. These effects are considered likely to be highly localised as pile driving activities do not typically generate high turbidity or result in extensive habitat destruction. Impacts, should they occur, are considered likely to be restricted to the area in the immediate vicinity of the proposed jetty.
- Introduction of marine pest species' from vessels used during construction period.
- Acoustic pollution from pile-driving activities.
- Sediment disturbance and resuspension. This is considered likely to be negligible as pile driving activities do not typically generate high turbidity, and operational measures (such as pile fabric filtering) will be used to manage turbidity issues should they arise, and
- Accidental contamination of the marine environment through spills. A construction environmental management plan will be utilised to minimise the risk of accidental releases into the marine environment.

Operational Phase

The ongoing operation of the port will create altered conditions at the Site. For some as aspects (for example, water quality), the extent (in terms of magnitude and spatial extent) of changes associated with these altered conditions will depend largely on the operational measures implemented to minimise impacts (such as enclosed conveyors to minimise loss of export material). For other aspects (such as habitat loss), the extent of change is considered likely to be largely restricted to the area directly under the jetty and inshore of it.

A more detailed consideration of the potential for impacts to occur as a result of the ongoing operation of the Port has been provided in the relevant sections throughout the report. However in summary, the potential impacts which have been identified may include the following:

- Loss of macroalgal or seagrass species, or shifts in the composition of the species present under the jetty as a result of shading. Subsequent changes to benthic fauna may also occur as a result of habitat loss/fragmentation.
- Addition of new substrate for colonisation of marine species, including pest populations.
- Introduction of marine pest species.
- Underwater noise from shipping activities.
- Alterations to the local hydrodynamic environment, and subsequent changes to the seafloor profile, including an increase in the number of sand patches within seagrass meadows due to changes into sediment dynamics/stability from habitat fragmentation and increased sedimentation, and
- Changes to water quality.

Quantitative and qualitative assessments of the habitats, sediment and water quality conditions present at the Site has been undertaken as part of this report. These assessments have been used to document baseline conditions and in turn used to consider the potential for impacts to occur at the Site based on the current understanding of the project. Together this information has been used to quantify the extent of potential impacts (where it was feasible to do so). The potential impacts, together with the likelihood of occurrence and potential for rehabilitation, have been discussed and, where appropriate, mitigation measures have been suggested.

It is understood that potential for impacts on the marine environment from surface water run-off is negligible due to on-site management measures. As such, potential disturbances from this source have not been considered herein.

6.1 Overview of Mitigation Measures

A number of mitigation measures will be implemented during both the construction and operational phases of the Port. These measures will assist with minimising the potential impact on the marine environment.

These measures include the following:

- End-over-end construction of the jetty which will assist with minimising impacts of marine habitats.
- Development of targeted construction Environmental Management Plans, which will include measures such as the following:
  - Pile fabric filtering during pile driving and drilling activities to reduce the potential for increase turbidity.

- Spill, erosion and sediment control equipment used for all possible pollutants which are likely to be generated through construction.

- Development of an Emergency Response and Incident Management Plan in conjunction with the Environmental Management Plan prior to the commencement of works. This plan will enable effective response to emergencies to minimise adverse impacts on the environment.

- In-built structural pollution controls (such as enclosed conveyors) to minimise loss of product during ship-loading activities, and

- Development of Environmental Management System (EMS) as part of the ongoing operation of the port. An EMS is a systematic approach which is used by organisations to identify and manage potential impacts on the environment that can occur as a result of its activities.

6.2 Calculation of Extent of Potential Habitat Disturbance

Based on the current understanding of the jetty design and approach to construction, Golder has refined the estimated extent of potential habitat disturbance which may occur as a result of construction activities or as a result of the ongoing operation of the Port.

Two estimates have been calculated for each habitat type for the purpose of estimating the extent of potential habitat disturbance (refer to Figure 2, Appendix A). The first estimate encompasses the area considered likely to be affected either directly by pile-driving activities, the use of the jack up barge or by shading from the jetty. This estimate includes the area under the approach jetty and under the berthing jetty (including the area under where vessels will berth) plus a 5.5 m wide buffer on either side (and therefore covers a 36 m wide passage under the approach jetty and roughly 106 m wide passage under the berthing jetty). It is assumed that at least some level of disturbance will occur in these areas and that some changes to the existing habitats will occur as a result of this disturbance. The extent of these changes will largely depend on the resilience of the species (in particular macroalgal and seagrass species) to reduced light conditions.

The second estimate encompasses the area which has been identified through hydrodynamic modelling as being potentially subject to increased sedimentation. Note that direct impacts from shading and jetty construction are not anticipated to extend to this outer area, but rather the extent of smothering, blow-outs or sand patches within the seagrass meadows may increase as a result of increased sedimentation from altered hydrodynamic conditions, or as result of sediment instability from seagrass loss under the jetty. While these effects may be found more broadly than the immediate footprint of the jetty, the effects (as reported in the sediment transport modelling assessment (ASR 2011)) are predicted to be predominately limited to the area inshore of the berthing jetty. Within this area, the potential for increased sedimentation has been identified, with the predicted accretion rates (above that which are naturally occurring) reported as being in the order of 0.03 to 0.05 m/annum (ASR 2011).

Owing to the ability of seagrass to trap suspended sediments (Edyvane 1999b), and given the region is a moderately high energy coastline, it is possible that the existing habitats will absorb any additional sediment input/movement as a natural process.

7.0 APPROACH TO THE CURRENT SURVEY

Based on the understanding of key habitats and assemblages present (as discussed in Section 5.0), together with the results of the literature review, Golder developed a field survey approach which targeted habitats at most risk from potential impacts from the Port development.

The approach to the current survey was developed in consideration of the following key elements:

- DAC issued *Guidelines* (Section 2.0)
- Current understanding of the approach to construction and operation of the proposed port facility (Section 4.0)
- Current understanding of the Site conditions (Section 5.0)
- Potential for impacts based on the understanding of the nature, extent and duration of the disturbances (Section 6.0).

7.1 Objectives

The objective of the current study was to address the relevant *Guidelines* (as highlighted in Section 2.0), with particular emphasis on the collection of quantitative data to provide a detailed description of marine habitats present at the Site.

A secondary objective of the survey was to obtain data which would also support the longer-term requirements of a monitoring program, through which the assessment of impacts can be assessed. Further discussion regarding appropriate monitoring designs has been provided in Section 23.0.

7.2 Survey Design and Habitats Sampled

The approach to the following targeted marine field studies is largely based on what is termed a 'gradient' style survey design. Gradient designs are well suited to detecting impacts that do not have defined boundaries as they require allocating samples according to distance from the source of the potential impact (in this instance, the proposed jetty), rather than by random placement within randomly-placed blocks (Ellis and Schneider 1996).

Initially Golder proposed a gradient-style survey design which included sampling at five locations, these being a potential impact location (referred to as the Potential Impact Zone) and at north and south near-field and far-field control locations (see Figure 3, Appendix A). The Potential Impact Zone included sampling within the immediate footprint of the proposed jetty, as well at discrete distances (sites) north and south of the jetty. These distances were: 150 m, 300 m and 500 m from the jetty.

Due to extended unfavourable weather conditions over the winter months, the survey design was amended for some components of the survey, namely the subtidal reef and seagrass surveys. The new design (which is detailed below) utilised the gradient design approach (with the exception of sampling at 500 m north and south of the jetty), but focused primarily on obtaining sufficient quantitative data from the Potential Impact Zone to meet the shorter-term requirements for the *Guidelines*. The survey design that was implemented for the subtidal reef and seagrass surveys was as follows:

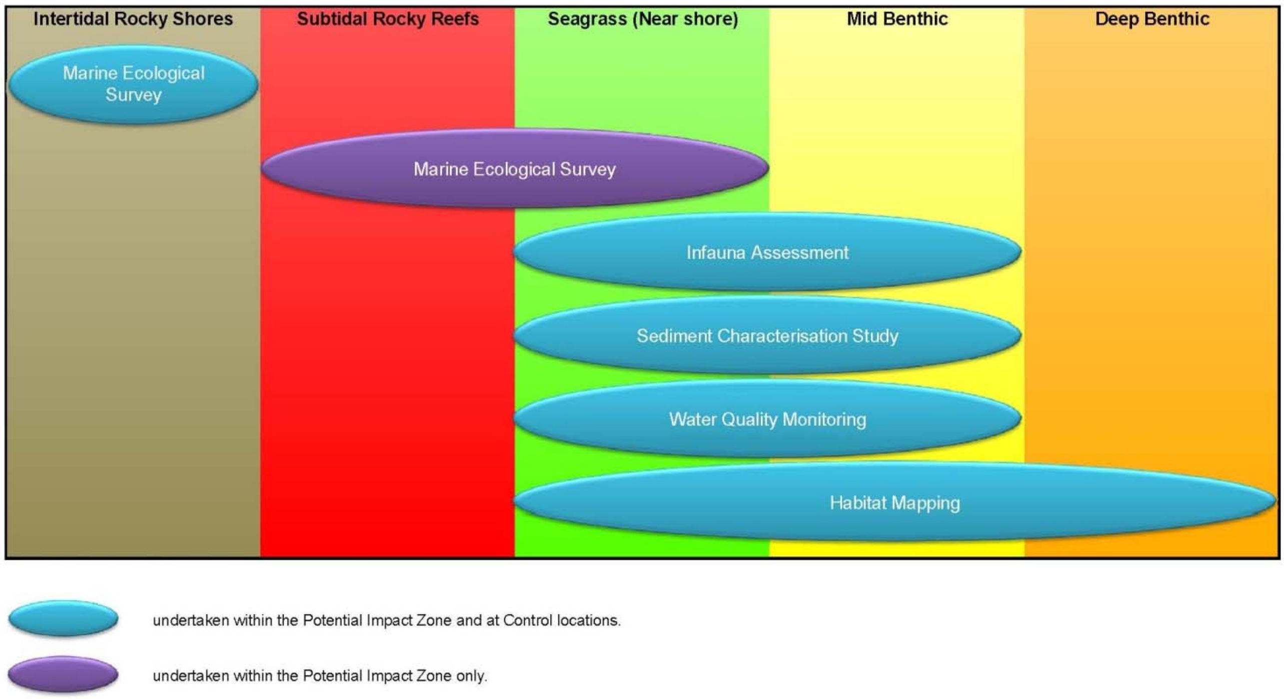
Distance 1 (D1) – within the direct footprint of the proposed jetty

- Distance 2 North and South (D2N and D2S) – 80 to 150 m from the middle of the proposed jetty
- Distance 3 North and South (D3N and D3S) – 230 to 300 m from the middle of the proposed jetty.

Additional sampling (in line with the original survey design which included control locations) was undertaken for the assessments of the intertidal rocky shore, infauna assemblages, sediment chemistry, particle size distribution and water quality. A detailed description of the survey design used for each survey type is provided in each of the relevant sections.

Figure 2 below illustrates the habitats and locations surveyed (including those assessments undertaken as part of the characterisation of the physical environment). Those shaded in blue indicate which components were also undertaken at control locations.

Figure 2: Assessments undertaken as part of the August/September 2011 survey



Towed Video Survey

Towed video footage was collected from all subtidal habitats at the Site (up to 1 km offshore and 500 m either side of the proposed jetty), with the exception of the rocky reefs, which cannot be surveyed using this technique. Video sled footage was also collected from the proposed control locations, to confirm the suitability of these areas for future surveys. The information obtained from the video sled footage has been used to produce an updated habitat map of the Site (see Figure 4, Appendix A).

The video sled footage has provided information about the deep soft-bottom sandy substrate habitat, which had not previously been documented at the Site. A scoping transect between the 1 km offshore and 500 m offshore area was also undertaken to document the habitat between the proposed end of the jetty and the area which may be used for the end of the jetty should the jetty design be altered.

7.3 Quality Control and Quality Assurance

To maintain a consistently high standard for data collection and management, the following quality control measures were employed during the sampling program:

- Each team member read and discussed the work plan with the Task Manager prior to the field survey.
- Discussions were held during morning kick-off meetings and throughout the day regarding sampling techniques and species identifications to ensure consistency between team members.
- The ADAS-qualified scientific divers undertaking the surveys had extensive experience with the identification of temperate marine species, particularly those found in South Australia.
- A site-specific field guide was developed to assist with species identification and to aid with consistent species identification.
- Data sheets were checked for clarity of information at the end of each sampling period and comparisons were made between the data collected by each team member.
- The original data sheets were photocopied at the end of the field survey and the copies were used for data entry purposes.
- The accuracy of data entered into spreadsheets was cross-checked using two people by comparing the records of the data made in the field against that which had been entered. To minimise the chance of repeating mistakes through the misinterpretation of field entries, the person reading off the field sheet was different from the person who had originally entered the data.

7.4 Statistical Analyses

The analytic approach to the data obtained from each sampling method is described in the relevant sections. A brief explanation of each of the main analytic tools is provided here to assist with interpretation of the results. These descriptions are largely based on Clarke and Warwick (2001) and Clarke and Gorley (2006).

The computer software package PRIMER v6 (Plymouth Routines in Multivariate Ecological Research), with the PERMANOVA+ add-on, was used for the majority of analysis of multivariate data arising from community ecology in order to document baseline conditions and to identify differences and/or similarities between each of the sampling locations.

Bray-Curtis Similarity

Community structure is a multivariate function of both the identity of species present and the relative abundance of each species. The community structure between pairs of samples was compared using the Bray-Curtis similarity coefficient. This index compares the abundance of each species between two samples to give a single value of the similarity between the samples, expressed as a percentage with the range from zero (no similarity at all) to 100 (identical).

The Bray-Curtis similarity index was calculated for all possible combinations of sites and transects within sites (and quadrats along transects where used). This resulted in a matrix of pair-wise comparisons, known as a dissimilarity matrix. The dissimilarity matrix is also termed a distance matrix, as it effectively represents distances between samples in hyper-dimensional space (i.e. one dimension per species). The dissimilarity matrix was used for all analyses of community structure in this study.

Prior to some analyses being taken, a number of transformations were applied to the data to examine the relative influence of the more abundant species on the dissimilarity matrix. Transformations included the square root, fourth root, logarithmic and presence/absence. Transformation of data has the effect of down-weighting the influence of highly-abundant species. The extent of the down-weighting is dependent of the type of transformation used, with square root being the least extreme and presence/absence being the most extreme (i.e. all species contribute equally). The use of transformations to define the balance between contributions from common and rarer species to the dissimilarity measure is a commonly-applied approach (Clarke and Warwick 2001).

For the intertidal survey, some replicate samples for the in-situ quadrat counts recorded all variables as zero. To overcome undefined dissimilarities that occur when this is the case, the recommendation by Clarke *et al.* (2006) is to include a dummy variable with a value of 1 for all samples. This approach was adopted as part of the analyses undertaken for the intertidal survey.

Non-metric Multidimensional Scaling (nMDS)

Based on the Bray-Curtis dissimilarity matrix, community differences have been depicted using ordination plots (non-metric multidimensional scaling or nMDS). The purpose of this is to construct a 2-dimensional ‘map’ or visual configuration of the samples, with the degree of dissimilarity between each sample being represented by the relative distance between each point.

As part of the nMDS procedure, a 2-D stress indicator is produced for the plot. This indicator statistic (range 0 to 1) is calculated during the ordination process and indicates the degree of disparity between the reduced dimensional data set and the original hyper-dimensional data set. Increasing stress is generally correlated with increasing numbers of samples. A general guide to interpreting the stress indicator is given by Clarke (1993): < 0.1 is a good ordination with no real risk of drawing false inferences; < 0.2 can lead to a usable picture, although for values at the upper end of this range there is potential to mislead; and > 0.2 is likely to yield plots that can be inappropriate to interpret.

nMDS plots are not typically presented with units on the axis as the numbering is arbitrary (i.e. the units refer only to that plot and no other). These units are only useful for plotting the ordination and cannot be used to further interpret the data.

RELATE

This function in PRIMER tests a hypothesis of no relationship between two dissimilarity matrices by doing a rank correlation and comparing this with results from randomly permuted samples. A common application is to test for the relationship between paired matrices for biotic community structure and abiotic environmental variables.

ANOSIM

This analysis provides "Analysis of Similarities" hypothesis for differences between predefined groups of community samples, using permutation/randomisation methods on a dissimilarity matrix. It returns a global test statistic (R) and significance levels based on random rearrangements of the observed data but can only be applied to very simple sampling designs.

PERMANOVA

PERMANOVA+ is an add-on package to the PRIMER v6 software. In this package, PERMANOVA (permutational multivariate analysis of variance) analyses are based on permutations of raw data or distance measures that require few assumptions about the data, offering a high level of flexibility regarding designs for analyses of environmental impact (Anderson *et al.* 2008).

The PERMANOVA+ package goes beyond ANOSIM in that it allows analysis of complicated multi-factorial or mixed model designs for multivariate data. Factors may be nested within different levels of the survey design (for example, sites within locations) and as such, the nested factors generally represent levels of spatial or temporal sub-sampling. This promotes proper representation and isolation of the natural spatial variation that is occurring at the Site which can, in turn, assist with identifying which changes (if any) may be related to a potential impact. Such nested survey designs are well suited to surveys which aim to detect human impacts on the environment (Downes *et al.* 2002).

Both direct permutation of actual data and Monte Carlo simulations can be done, which is important when there are less than 100 unique permutations. This yields exact probabilities for all levels of the design. An added bonus is the calculation of variance components (analogous to the variance components in "classical" univariate Analysis of Variance (ANOVA)) for all levels of the design for comparing the different factors in this survey design.

SIMPER

Based on the Bray-Curtis similarity matrix, SIMPER (similarity percentages) analysis in PRIMER assists with identifying those species most responsible for particular aspects of the multivariate picture and provides information about the average similarity (expressed as a percentage) within a group of samples (for example, replicate samples within a site) and also the average dissimilarity between paired groups of samples (for example, the dissimilarity between two sites). The results of the SIMPER analysis include the contributions from each of the key species to either the similarity or dissimilarity measure, thus allowing an empirically-based signal of which species might be useful indicators (and how).

8.0 INTERTIDAL ROCKY SHORES

The intertidal rocky shores at the Site comprise small headlands, which lie between intertidal sandy beaches to the north and south. The area is characterised as moderately exposed coastline and beaches (Short 2001).

8.1 Intertidal Rocky Shores of the Spencer Gulf Region

The Port Spencer area is classified as belonging to the Flindersian Province (which extends from south-west Western Australia to southern New South Wales) (Edyvane 1999). The biodiversity of the region is typical of the temperate southern Australian environment and therefore, the Flindersian Province, which, due to a long period of geological and continental isolation (Edyvane 1996 as cited in Edyvane 1999), is characterised by a high level of endemism[8] for many species of algae, marine invertebrates and fish (Edyvane 1999).

The intertidal ecology of Spencer Gulf has most recently been summarised in a general account by Edyvane (1999), which focused on the marine flora that provides the dominant habitat within the gulf region. On coasts of moderate wave energy, particularly those in the southern region of the gulf, the intertidal and subtidal fringe of rocky shores is dominated by the brown algae *Hormosira banksii* and *Cystophora* spp. The upper littoral zone is often dominated by large brown algae, including *Ecklonia radiata*, *Cystophora subfarcinata*, *C. retorta*, *C. polycystidea*, *C. moniliformis*, and other species; *Caulocystis cephalornithos*; *Cystoseira trinodis*; and *Sargassum* spp. (e.g., *S. decipiens* and *S. lacerifolium*), with an understorey of coralline algae (e.g., *Amphiroa anceps*, *Cheilosporum elegans*), *Cladostephus spongiosus* and species of *Caulerpa*.

Important to the Lipson Cove region is Lipson Island, which lies approximately 1.5 km south of the jetty and is on the Register of the National Estate as a Conservation Park. The ecological importance of Lipson Island has been noted as a breeding colony for protected seabirds, including Little Penguins, Black Faced Cormorants, Crested Terns and Fairy Terns (Edyvane 1999).

8.2 Current Understanding of Intertidal Rocky Shores at the Site

Golder (2009) previously undertook a qualitative intertidal survey of the rocky shores at the Site. The findings of this survey indicated that in the upper ranges of the mid-tide zone, the barnacle *Cthamalus antennatus* was found in large numbers as was the gastropod *Austrolittorina unifasciata*. In the mid- to low-tide areas grazing gastropod species such as *Nerita atramentosa*, *Austrocochlea* spp., *Bembicium* spp. and *Cellana tramoserica*, and barnacles such as *Catomerus polymerus* and *Chamaesipho tasmanica* were most dominant. Below the mid-tide zone, the tube worm *Galeolaria caespitosa* formed scattered and sometimes dense encrustations. The rock crab *Ozius truncatus* was also found in areas lower on the shore in crevices in the mid-tide zone and under boulders in the low-tide zone, where it is known to prey on snails such as *N. atramentosa*, *Austrocochlea* spp. and *Bembicium nanum* (Edgar 2000). Predatory gastropods, such as *Dicathais orbita* and *Agnewia tritoniformis* were also found in the mid- to low-tide zones. These molluscs can play an important role on rock platforms as they can control populations of barnacles and other molluscs (Underwood & Chapman 1995).

The lowest levels of the shore were generally dominated by turfing foliose algae such as *C. polycystidea*, *Laurencia* sp. and *Gigartina* sp. The abalone, *Haliotis roei,* and the large chiton *Plaxiphora albida* were also commonly found at the low-tide level, where *P. albida* is known to graze on encrusting algae and *H. roei* on drifting macroalgae (Edgar 2000).

More recently an intertidal survey was undertaken on Lipson Island (DES 2011) in order to document the intertidal habitats and fauna which occur there. The intertidal rocky shore species recorded on the Island are largely consistent with the species recorded during the previous survey undertaken by Golder (2009) at the Site.

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[8] Endemic species are those species of plants & animals which are found exclusively in a particular area. They are naturally not found anywhere else.

8.3 Survey Methods

The methods employed for the current survey are detailed below.

Survey design

For the intertidal survey, Golder employed a survey design that included the following (see Figure 5, Appendix A):

- One impact location, incorporating three separate sites (one central site and one of each site to the north and south of the central site) at 15 m distances between sites
- Two control locations each at a distance of approximately 3.5 km from the central impact location, consisting of one location to the north and south, each with two sites (approximately 15 m between sites), and
- One reference/control location at Lipson Island (consisting of two sites, spaced at approximately 15 m) due to the high conservation value of the region as a National Estate Conservation Park.

Within each location, sampling was undertaken as follows:

- In randomly positioned, 40-60 m wide (along-shore) sites (the difference in site length was due to some locations being more tightly constrained due to limited headland space), and
- In the littoral (intertidal) zone in the area loosely defined as the upper low shore to lower mid shore zone. The mid and low shore zones were not sampled separately due to the nature of the shores in the area, which are typically steep gradients with inaccessible low shore zones.

Location and site selection

Prior to sampling, each location was assessed visually for its suitability for comparison to the other locations. The sites within the potential impact location were largely predetermined by their distance in relation to the proposed jetty.

Considerations which shaped the selection of locations were as follows:

- The distance from the proposed jetty (controls needed to be sufficiently outside of any Potential Impact Zone)
- The limited number of headlands present in the area to choose from
- Lipson Island was a predetermined location; however, finding areas which were comparable to the Potential Impact Location was difficult due to the morphology of the island (steep in some areas, low-lying and cobbles in others)
- Many headlands had steep shorelines and were unable to be sampled. These areas also had faunal assemblages that seemed distinct from those found at the Potential Impact Location (likely due to the vertical nature of the shoreline). This had particular implications for the Control North Location, which was originally proposed to correspond to the Distance 6 North locations for the subtidal sampling. However, due to the steep gradient of the intertidal shores in this area, sampling was unable to be undertaken at this location. Subsequently, the Control North location was moved closer to (but still north of) the Distance 5 North location (Figure 5, Appendix A), and
- A number of headlands were inaccessible from the shore.

Once each location was determined, the sites were haphazardly positioned within the location. The sites were marked using GPS, and field maps and a photographic record of features at each site were made.

Rocky shores typically exhibit natural spatial variability (Underwood and Chapman 1996) and a high degree of spatial variability at the Site and in surrounding areas was noted during site selection process. This variability was also noted between sites within each of the locations. The locations that were selected were considered a 'best fit' from a highly variable shoreline. The results for the physical characteristics of the sites (see Section 0) describe the substrates present at each location, and illustrate differences in the level of complexity across the sites.

Timing of survey

The baseline monitoring was undertaken from 15 to 18 August 2011. The predicted tidal heights for the sampling period were as follows:

- Monday 15th August: 0.36 m
- Tuesday 16th August: 0.32 m
- Wednesday 17th August: 0.33 m, and
- Thursday 18th August: 0.37 m.

Taxonomic Resolution

Organisms were identified to the finest resolution practicable in the field using the following identification guides:

- Identification Factsheets of the Marine Benthic Flora (Algae) of Southern Australia. http://www.flora.sa.gov.au/algae_revealed/index.shtml)
- Australian Marine Life. The Plants and Animals of Temperate Waters, by Graeme Edgar (2000)
- Marine Plants of Australia, by John Huisman (2000), and
- A Field Guide to the Marine Invertebrates of South Australia, by Karen Gowlett-Holmes (2008).

Sampling methods

At each site, three methods were used to sample the area. These were substrate transect sampling, rugosity measures and in-situ quadrat counts. These methods are described below.

Substrate Transect Sampling

Ten randomly-spaced, 5 m long, shore-normal line intercept transects within each site were sampled. Substrate types and percent cover of sessile organisms that occurred in patches greater than 5 cm in length were recorded using the line intercept method. The extent of each substrate was recorded in centimetres, then summed and divided by the total length (5 m) in order to then calculate percent cover estimates. The classifications for substrate were as follows:

- rocks (greater than 1 m at widest point)
- boulders (larger than fist size up to 1 m)
- pebbles, and
- sand.

Each of these substrate types was further classified as follows:

- exposed to air at low tide, or
- submerged (covered with at least 5cm water at low tide)[9].

The categories of sessile organisms that were found on each of these substrates included the following:

- foliose algae
- turfing algae
- encrusting algae
- seagrass
- mussels
- Galeolaria caespitosa worm tubes
- Barnacles, and
- mixed community (which consists of high-density mussel concentrations on mats of turfing algae, where the species ratio is visually observed to approach approximately 20 to 80% in either direction).

The data from the substrate transect sampling were divided into two categories. The first category utilised the information regarding the presence of different substrate types, and together with the rugosity data was used to describe the physical characteristics of the site (see Section 8.4.2). The second category considered the percent cover of sessile organisms along each transect (see Section 0) and was used to describe the biological characteristics of the sites.

Rugosity

Rugosity is a measure of substrate complexity and was undertaken by aligning a 5 m chain (link size = 23 mm) along each transect. The chain was pushed into all cracks and crevices to closely contour the vertical profile of the substrate. The horizontal distance reached by the chain was recorded and used to calculate substrate complexity by the ratio of the measured substrate contour length to the total linear length. Ratios close to one indicate flatter surfaces, while ratios closer to zero are considered highly rugose.

In-situ quadrat counts

At each site, ten replicate 0.25 m^2 quadrats (containing 100 evenly-spaced grid points) were haphazardly deployed and sampled. When a quadrat position was considered unsuitable (for example, on top of a boulder that was outside of the correct tidal height or within a rock pool), the quadrat was re-allocated.

Using the grid points in the quadrats, the percentage cover of bare rock, sessile animals and primary and canopy cover of algae was recorded. In addition to this, all mobile invertebrates were counted. The presence of any species not already counted or measured as percentage cover was noted. These were typically mostly algae or encrusting animals with < 1% cover that occurred at insufficient frequencies, densities or cover to provide analysable data, except as minor contributions in multivariate analyses.

[9] This information was noted as being highly dependent on the timing of the tidal cycle and was therefore not used in the analyses

To avoid overestimates of numerical abundance caused by the edge effects of quadrat sampling, inclusion of individuals for counts were as follows:

- At least 50% of the animal was within the quadrat boundary
- For sessile animals and plants, inclusion was based on the attachment area or holdfast position. Organisms that were attached outside of the quadrat were not counted, and
- For organisms that were positioned on the boundary edge, only two (predetermined) sides of the quadrat were included for counts.

8.4 Results and Discussion

The data collected for each of the sampling methods have been tabulated and are presented in Appendix B.

8.4.1 Summary of assemblages

Overall, 23 faunal taxa and 15 algal taxa were recorded during the survey. The number of taxa recorded at each location varied from 13 at Lipson Island to 33 at the impact location (with 22 and 29 taxa at the North and South Control locations, respectively). Molluscs (gastropod snails, limpets and false limpets) dominated the mid shore areas, with the most commonly recorded invertebrates being *Austrocochlea* spp., *A.unifasciata, Bembicium* spp., *C.tramoserica*, *N.atramentosa, Patelloida latistrigata* and *P. alticostata, Patella chapmani*, *Siphonaria diemenensis* and *S. zelandica*, *Notoacmea* spp. and *Plaxiphora albida.*

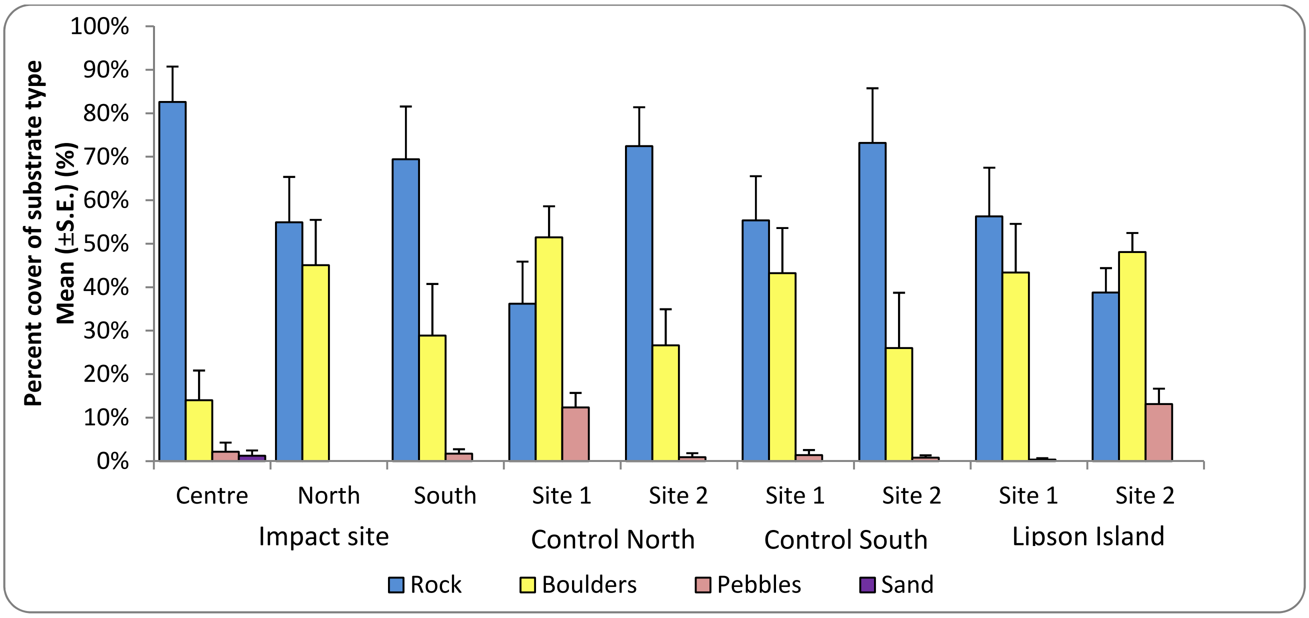
The species recorded were typical of species found on South Australian intertidal rocky shore on moderately exposed coastlines (and more broadly along the warm to cool temperate shores in the Flindersian Province of Australia) (see Edgar 2008, Gowlett-Holmes 2008).

A list of the taxa found is presented in Table 1, Appendix B.

8.4.2 Physical characteristics of the sites

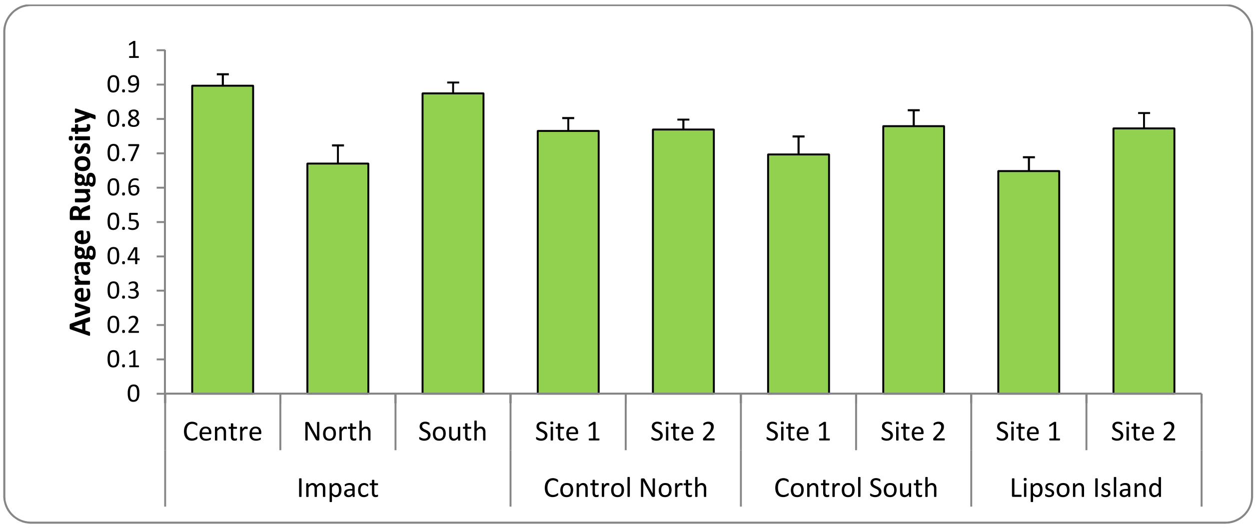
The percentage cover of substrate types was measured at each site using line intercept transects (see Table 2, Appendix B). Figure 3 below demonstrates that all locations were dominated by rocks and/or boulders, with the variability between sites within locations typically being driven by differences in the presence of these two substrates.

Figure 3: Mean (± standard error (S.E.)) percent cover of substrate type at each site within sampling location



In addition to measures of the percentage cover of substrate types, rugosity was measured at each site. Figure 4 represents the average rugosity measures for each site, with ratios close to zero indicate high rugosity and ratios closer to one representing flatter sites. The average rugosity between sites across all locations varied; however, this variation was less than would have been expected based on observations of the seemingly high variability of the rocky shores at the sites. The range of rugosity values (see Table 3, Appendix B) that were recorded across each location better illustrate the variation present, with replicate samples representing relatively flat to highly rugose surfaces (range of measures as follows: Impact 0.45 to 0.99; Control North 0.60 to 0.96; Control South 0.44 to 0.98; and Lipson Island 0.41 to 0.97).

Figure 4: Mean (± standard error (S.E.)) rugosity measures



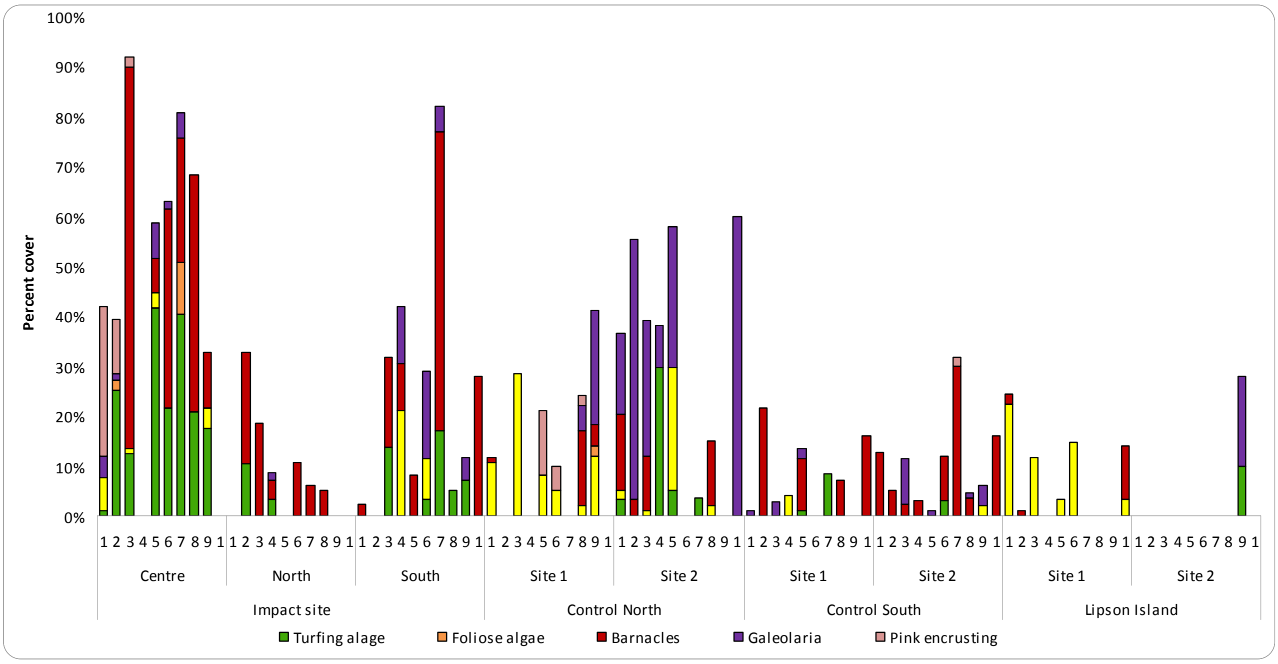
8.4.3 Percentage cover of sessile organisms using LIT

Figure 5 below presents the data from the line intercept transect (LIT) method for the percentage cover of sessile organisms. The dominant percentage cover (mean of 83%) recorded along each of the transects was bare substratum (i.e. no macroscopic organisms). This is not unusual on rocky shore environments, particularly in areas above the low tide mark; however inclusion of this information makes interpreting patterns of distribution and abundance of organisms difficult. For this reason, records of bare substratum have been removed for all analyses of coverage by organisms and the remaining data presented in Figure 5.

As with the substrate transect data, the percentage cover of sessile organisms across the sites was highly variable and this was noticeable between replicates within sites, as well as between sites within locations. For the statistical analyses, an nMDS plot was generated based on the Bray-Curtis similarity matrix[10]. The data were not transformed due to the small ranges recorded for the percent cover of the different taxa.

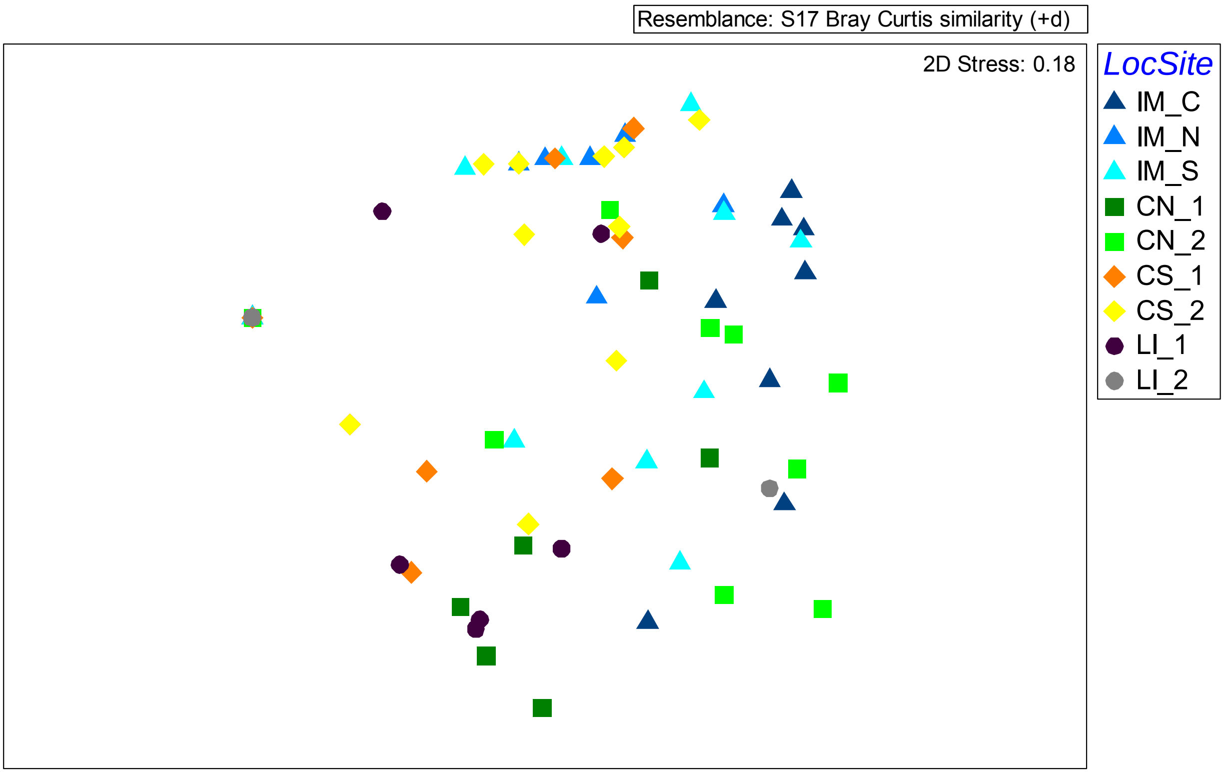
As described in Section 7.4, the dissimilarity is reflected in the distance across the ordination graph, such that two data points that are close together share many species with similar relative abundances; conversely, two points far apart are very dissimilar. The nMDS plot (see Figure 6) had an acceptable stress (0.18) and indicated that the variability between individual replicate transects was often as high as between sites and locations. The tightly-clustered group of sites at the leftmost extent of the plot represented the completely bare replicates, and included seven replicates from the impact location, six and two replicates from the northern and southern control locations, respectively, and 13 replicates from Lipson Island.

Figure 5: Percent cover of sessile organisms (bare substrate removed)



10 Consistent with the data used in Figure 5 the bare substratum percentage cover was also removed from the data set prior to undertaking any statistical analyses.

Figure 6: Non-metric multidimensional scaling (nMDS) ordination plot of percent cover of sessile organisms from line intercept transects.



Site Codes: IM = Impact, CN = Control, LI = Lipson Island. C = Centre, N = North, S = South /, 1 = Site 1, 2 = Site 2

The results of the PERMANOVA test support the nMDS plot interpretation, with the results indicating that there was no significant difference between distances (control versus potential impact), locations within these distances or sites within locations. This is likely explained by the highly variable distribution and abundance of taxa recorded. As a significant difference was not found for any of the factors within this survey design, no further analyses were undertaken on this data set.

8.4.4 In-situ quadrat counts

For the purposes of the analyses, the *in-situ* quadrat count data were divided into the following categories:

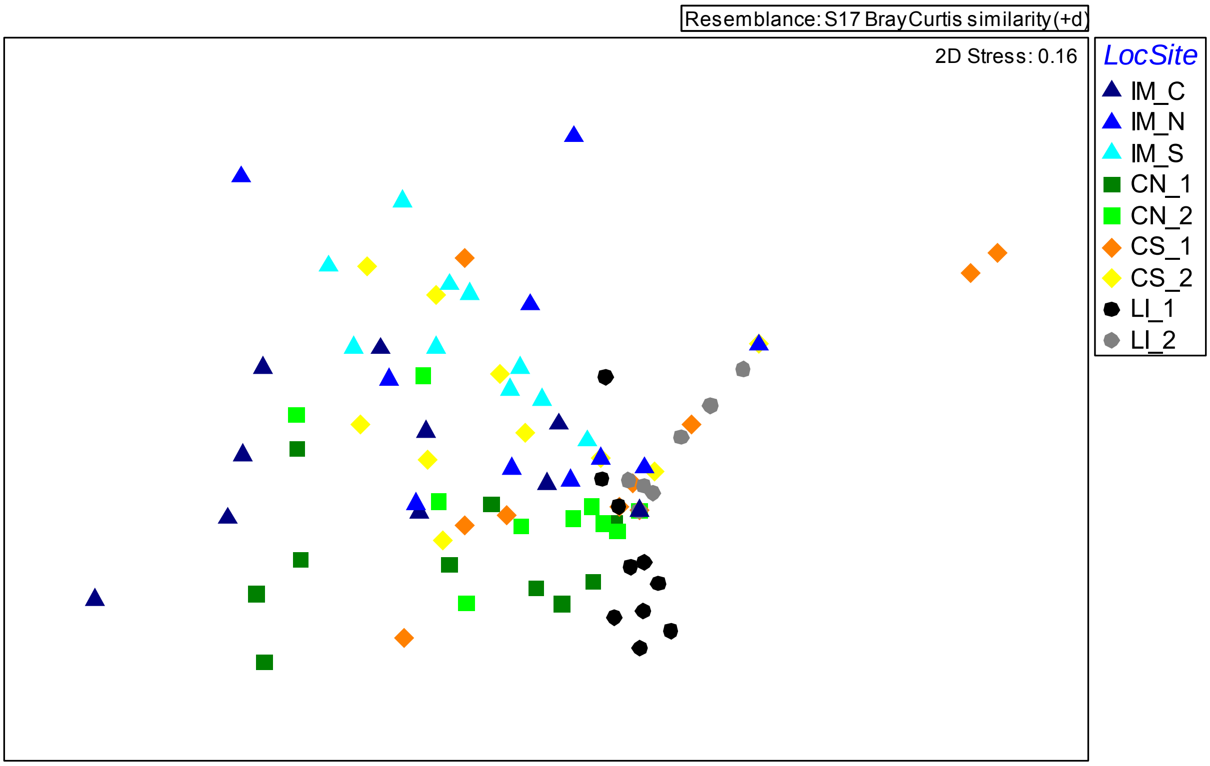
- Percent cover assessment of algae and sessile invertebrates, and
- Counts of mobile animals.

These two data sets were analysed separately using the approach described in Section 7.4 (Bray-Curtis similarity co-efficient, nMDS and PERMANOVA). The data for the quadrat counts are presented in Table 4, Appendix B.

Percent cover of algae and sessile invertebrates

The nMDS plot below (Figure 7) illustrates the similarities (based on untransformed data) detected between replicates from each of the sites.

Figure 7: Non-metric multidimensional scaling (nMDS) ordination plot of percent cover of sessile organisms at each site.



Site Codes: IM = Impact, CN = Control, LI = Lipson Island. C = Centre, N = North, S = South /, 1 = Site 1, 2 = Site 2

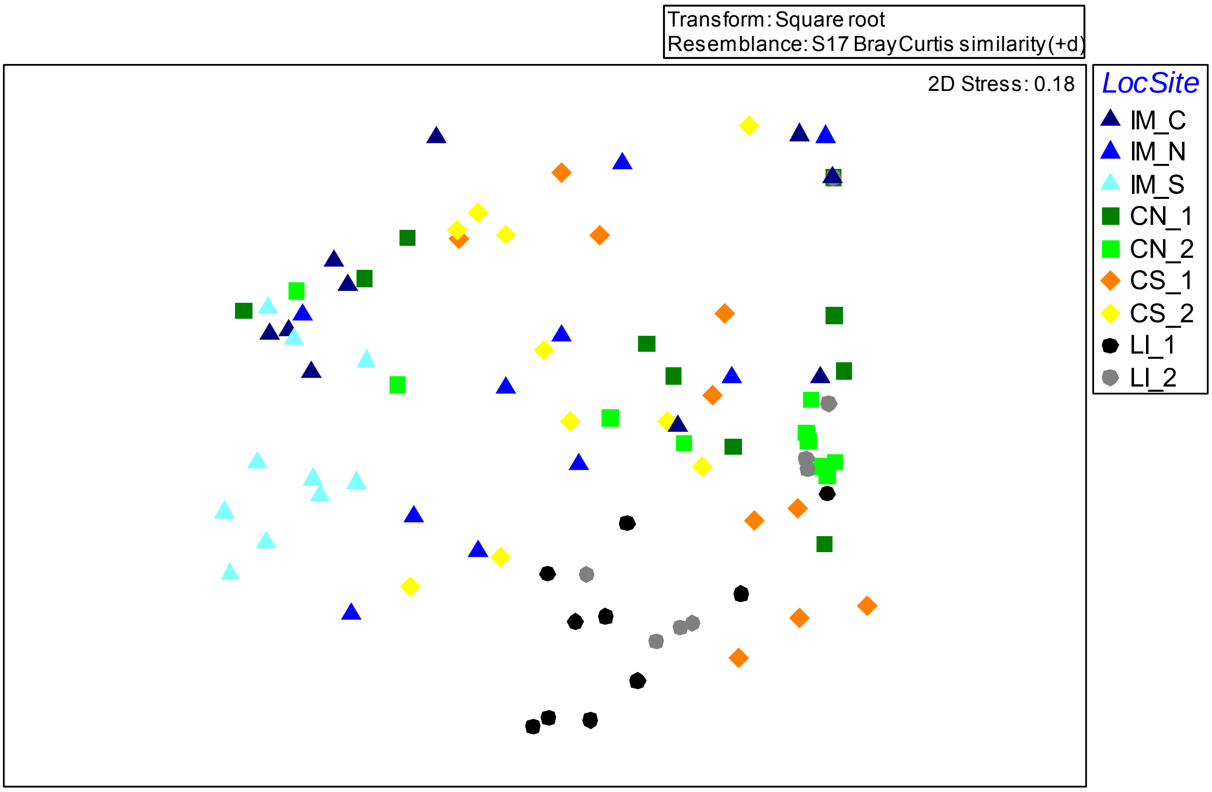
For most sites, the clustering of replicates was generally not tight; however the nMDS plot indicated similarities within some sites and locations (Control North Sites 1 and 2, Impact North and South, Lipson Island Site 1). This was confirmed using the PERMANOVA add-on package, the results of which indicated that both locations and sites are significantly different (P = 0.011 and 0.001, respectively). This suggests that within-site (i.e. between replicates) variability is lower than between-site variability, but that the Impact, Control and Lipson Island reefs are naturally highly spatially variable, even at the small scales such as those covered by sites. Pairwise tests lacked power to show statistically significant results for any combination of locations, but the Monte Carlo simulation showed a significant difference between the Impact and Lipson Island locations (P = 0.014).

Counts of mobile animals

Due to large differences in the abundances of mobile animals, the data for the counts of mobile animals were square-root transformed prior to any analyses being undertaken. This was done so as to down-weight the importance of the highly abundant species, so that similarities depend not only on their values, but also those of less-common species (Clarke and Warwick 2001). A 2STAGE analysis of the default transformations (none, square root, fourth root, log and presence/absence) showed that the square root, fourth root and log transformed data were all similar and that there was a similar difference between these transformed data sets and untransformed data (which gives the most weight to the most common species) as there was with presence/absence transformed data (which gives equal weight to rare and common species).

The nMDS plot (Figure 8) illustrates the similarities (and in turn the dissimilarity) between sites within each of the locations. The stress value was acceptable.

Figure 8: Non-metric multidimensional scaling (nMDS) ordination plot representing quadrat counts of mobile animals at each site.



Site Codes: IM = Impact, CN = Control, LI = Lipson Island. C = Centre, N = North, S = South /, 1 = Site 1, 2 = Site 2

The nMDS illustrates some clear clustering of replicates within some sites (particularly for Lipson Island, Site 1 and the Impact Location, southern site). The results of the PERMANOVA test indicated that both locations and sites were significantly different (P = 0.003 and 0.002, respectively), whilst within-site variability was low. This again supports the interpretation of spatial variability, which indicates that the assemblages at the sites were highly variable, even at small spatial scales such as those covered by sites. Notwithstanding this, the counts of mobile animals reflect lower variability across sites than the percent cover of sessile organisms.

This data set helps to illustrate how variable assemblages were even at small spatial scales such as within sites (which were 40 to 60 m wide) and between sites (which were approximately 15 to 20 m apart), prior to any impact occurring.

This information is important to an impact assessment as such variability can infer disturbance if not adequately documented prior to a potential impact occurring.

High variability between sites is commonly reported for temperate intertidal rocky shores (for examples, see Underwood and Chapman 1998; Meconi *et al.*, 1999), with large spatial and temporal fluctuations in patterns of abundance and distribution usually reported. As a means of exploring this variability, many studies in eastern Australia have investigated the patterns of distribution for intertidal molluscs; particularly in regard to the more common marine snails such as *B. nanum* and *N. atramentosa* (see Underwood and Chapman 1996 and Underwood 2004 for examples). Other studies (see Creese 1982; Lasiak 2006) have investigated patterns of distributions of limpets.

Underwood (2004) demonstrated that small-scale differences are found at the scales of centimetres to <1–2 metres, and for many species on many shores, these accounted for most of the variability in abundances from place to place. Underwood (2004) proposed that these are likely to be determined by behavioural responses to small-scale patches of microhabitat. Large-scale differences in abundance were also found in most species at the scale of hundreds of metres alongshore. These are likely to be due to variation in recruitment and/or mortality because of the limited dispersal by adults of these species (Underwood and Chapman 1996). Small-scale topography has also been found to explain small-scale variation in numbers of very early recruits of intertidal gastropods (Underwood 2004). The observed differences in the presence and abundance of the intertidal mollusc species, both within and between the individual sites, are therefore likely to be linked to the composition of different substrates types and to localised recruitment events.

8.4.5 Rare and/or threatened species and communities

The species recorded as part of the intertidal surveys represent organisms which are typically found on intertidal shores in South Australia. The presence of any rare species was not noted during the intertidal survey.

8.5 Potential for Impacts on Intertidal Rocky Shores

Intertidal assemblages are adapted to a dynamic environment and exhibit naturally high temporal and spatial variation (Underwood 2004). Inspection of aerial photographs of the Site indicate that sand movement occurs on the intertidal areas, with low-lying rocky outcrops being exposed and then covered over time.

The species recorded during the field surveys were typical of species found on South Australian intertidal rocky shore on moderately exposed coastlines (and more broadly along the warm to cool temperate shores in the Flindersian Province of Australia) (see Edgar, 2008; Gowlett-Holmes, 2008). There were no species of conservation significance or concern recorded as part of these surveys.

Construction activities and shading from the jetty structure are considered the most likely potential causes of impacts on the intertidal rocky shores. Increased sand movement and sedimentation is not predicted to deposit on the intertidal rocky shore (ASR 2011).

Changes which may occur are considered likely to be from the loss of species that depend upon high light levels. Subsequent changes in the faunal assemblages may occur if they are dependent on specific algal species. Minor changes in the mobile and sessile invertebrate assemblages may occur as a result of construction activities; however, because these populations are typically naturally highly spatially and temporally variable, these organisms are likely to re-establish during subsequent settlement events.

If impacts from construction activities or shading occur, they are considered likely to be restricted to the immediate vicinity around the proposed jetty (the main headland). The next closest intertidal rocky shores are approximately 250 m to the north and 430 m to the south of the proposed jetty and these areas are considered likely to be outside of the extent of potential construction and shading effects.

8.5.1 Mitigation measures

As part of the construction environmental management plan (CEMP), measures should be developed and implemented which ensure that on-land construction activities do not impact on the intertidal rocky shore (for example, sediment run-off).

In order to minimise impacts to the intertidal rocky shore habitat, the CEMP should include consideration of the likely construction activities required to be undertaken in this area. Construction activities should be restricted to those which cannot be implemented elsewhere; materials should be stored elsewhere (where feasible to do so); and any items which have to the potential to spill should be stored well away from the land/sea interface.

Drilling activities associated with pile installation may generate material which could impact water quality (i.e. turbidity or contaminants). Mitigation measures to manage such material should be implemented as part of the construction CEMP.

Good management practices will assist with reducing the impacts on the intertidal shores. However it is also anticipated that if physical disturbance to the rocky shore is limited, these assemblages will recover quickly from localised impacts which may occur during the construction phase.

8.5.2 Extent of potential disturbance

The extent of potential disturbance or clearance to the intertidal rocky shore has been estimated at approximately 429 m^2 (refer to Figure 2, Appendix A). However, as only a very small component of this area (the area which fringes the subtidal zone) supports algal assemblages, this figure is considered to be an overestimate of the area potentially affected by the port development. An upper estimate of 11,796 m^2 has also been calculated to represent the broader area which may be influenced by increased sediment movement and scour through the area. However, given sediment is not expected to settle on the intertidal rocky shore, it is not anticipated that impacts will be detected in this area.

8.6 Conclusions

This report has presented the approach to, and findings from the initial baseline monitoring for the intertidal rocky reefs at the Site for the proposed jetty, Lipson Island and two control locations. The species recorded during the survey were typical of those species recorded in South Australia (and more broadly along the warm to cool temperate shores in the Flindersian Province of Australia) on moderately exposed coastlines (see Edgar, 2008; Gowlett-Holmes 2008).

There were no endangered, threatened or rare species noted during the surveys.

The results of the descriptive and analytical interrogation of the data suggest that for most measures, there is a high level of variability, not only between locations, but also between sites within locations. High spatial variability is commonly reported for temperate intertidal rocky shores (for examples, see Underwood and Chapman 1998, Meconi *et al.* 1999), with large spatial and temporal fluctuations in patterns of abundance and distribution usually reported.

The implications of this high variability is that detecting changes that result from an impact will be more difficult as any changes will need to be demonstrated as occurring above that which could be attributed to natural variation (unless the sampling is able to isolate this). The need for a complex (nested) sampling design (as has been applied during this survey) is of key importance to any ongoing studies (should they be required). Amendments to the sampling design to improve statistical power may require an increase in the number of sites at each location; however, as the sites are heavily constrained for available sampling space, this may be logistically impractical. Based on this survey, the area can be described as highly spatially variable but typical of rocky shores in the region.

9.0 INTERTIDAL SANDY BEACHES

Sandy beaches and bays typically comprise the following: the dry upper beach zone; the swash zone that is wetted during high tide; the surf zone; and the nearshore zone in deeper water. Often boulders and pebbles are found in the fringing areas between the bays and the intertidal reef platforms.

Sandy beaches are dynamic environments that experience natural physical disturbance from a range of processes (wave energy being one of them). The plants and animals that inhabit sandy beaches are adapted to one of the harshest environments on Earth (Edgar, 2001). These organisms must be able to tolerate the pressures imposed by an intertidal habitat (such as desiccation, extreme temperature changes, salinity and oxygen saturation) as well being able to withstand the physical disturbance from waves which continuously rearrange and bury the sediment in which they live (Edgar 2001).

In spite of this, sandy beaches can support a rich but cryptic biodiversity (Jones and Short 1995). The animals that live within the sand are generally referred to as meiofauna (<0.5 mm) and macrofauna (>0.5 mm). Crustaceans (amphipods, isopods and crabs), polychaetes (worms) and molluscs (pipis/clams and snails) are the macrofauna that tend to dominate sandy areas; however, the species present depends largely on the wave energy of the coast.

Studies have shown (Savidge and Taghon 1988; Schoeman *et al.* 2000) that changes in benthic community structure caused by physical disturbance can be short-lived; however, the extent of time taken for benthic communities to recover is correlated to the intensity (Dernie *et al.* 2003) and probably the spatial extent of the disturbance.

9.1 Intertidal Sandy Beaches of the Lower Spencer Gulf Region

Unvegetated soft bottoms, such as sandy shores and mudflats, remain the least studied marine habitats in Australia (PIRSA 2010). Sandy beaches in South Australia are best known along the Encounter Bay and Coorong coastlines (Dutton et al 2008). Studies regarding intertidal sandy beaches in the Lower Spencer Gulf region could not be found during the literature review undertaken as part of this report.

9.2 Current Understanding of the Intertidal Sandy Beaches at the Site

During the 2008 baseline survey (Golder 2009), a qualitative survey of the intertidal sandy beaches at the Site was undertaken. The sandy beaches were described as sandy shores that were interspersed with rocky outcrops and fringed by pebbles, cobbles and boulder habitat.

Larger boulders or cobbles occurred higher on the shore within the supratidal zone, with a gradual decrease to pebbles and then sand moving down-shore. The presence of amphipods beneath rocks was noted.

A noticeable feature of sandy beach habitats was the presence of isolated outcrops of granite, basalt and other boulders in intertidal areas. A range of rocky shore fauna was found growing on these outcrops including *Nodilittorina unifasciata*, *Nerita atramentosa*, *Catomerus polymerus* and *Chamaesipho tasmanica* as well as dense beds of the mussel *Xenostrobus pulex*. *Ozius truncatus* was also observed in crevices of these rocky outcrops. Algal species were similar to those found in rock pools and low-tide areas of the main rocky shore areas.

No significant intertidal shellfish beds, marine mammal haul out sites or seabird habitats were noted during intertidal investigations.

9.3 Potential for Impacts on Intertidal Sandy Beaches

To date, no quantitative sampling has been undertaken for this habitat type. A study on the organisms associated with the sediment would need to be undertaken to fully assess the potential impacts that the Port development may have on these benthic communities. However, Golder does not consider that such studies are required for the following reasons:

- These beaches are categorised as intermediate/low tide terrace in morphodynamic type (Short 2001) and are considered common around the SA coastline.
- These types of beaches are typically associated with reasonably low biodiversity (Benkendorff *et al.* 2008).
- Potential changes to the sediment profile of the beach to the north of the Site have been identified (ASR 2011) and ongoing beach profile monitoring has been proposed (ASR 2011) in order to assess these changes. However, changes (impacts) to the infaunal assemblages associated with such habitats are unlikely to be detected due to this environment being subject to a high natural level of disturbance and assemblages being highly spatially and temporally variable (Edgar 2001), and
- There are currently no relevant listings under state or federal legislation for the organisms likely to present in the sandy beaches at the Site.

9.4 Conclusions

Studies regarding intertidal sandy beaches in the Lower Spencer Gulf region could not be found during the literature review undertaken as part of this report.

During the 2008 baseline survey (Golder 2009), a qualitative survey of the intertidal sandy beaches at the Site was undertaken. The sandy beaches were described as sandy shores which were interspersed with rocky outcrops and fringed by pebbles, cobbles and boulder habitat. No significant intertidal shellfish beds, marine mammal haul out sites or seabird habitats were noted during these intertidal investigations.

To date, no quantitative sampling has been undertaken for this habitat type. A study on the organisms associated with the sediment would need to be undertaken to adequately assess the potential impacts that the port development may have on these benthic communities. However, Golder does not consider that such studies are required based on the current understanding of the Site and the proposed extent of the development.

10.0 SUBTIDAL ROCKY REEFS

Temperate subtidal rocky reefs differ from tropical reefs in that they are formed by geological (rock) rather than biogenic (coral) substrate, with a dominant cover of habitat-forming macroalgae These canopy-forming species, together with crevices within the substrate, provide microhabitats for a diversity of understorey macroalgae, sessile and mobile invertebrates (e.g. sponges, bryozoans, ascidians, echinoderms, molluscs, crustaceans) and predominantly resident demersal fish.

Temperate reefs provide a number of life-supporting and ecosystem services, resources and products, and recreational and cultural services (McLeod and Leslie 2009). The macroalgal assemblages associated with reefs in South Australia are regarded as being highly productive, with primary production rates being comparable to that of cereal crops or sugar cane stands (Cheshire *et al.* 1998).

The temperate reefs of southern Australia are unique for both habitat and species diversity, and the levels of endemism within the reef communities (Cheshire *et al.* 1998; Edyvane 1999a). A number of inter-related biotic and abiotic factors influence the composition and structure of reef assemblages, including depth, wave exposure, light availability, competition and predation (Turner *et al.* 2006). Such processes operate over a variety of temporal scales ranging from years (e.g. growth and development) to hours (e.g. larval settlement), and spatial scales from thousands of kilometres (e.g. temperature) to less than a metre (e.g. light and substrate), creating a complex mosaic of reef compositions and structures.

Temperate reef systems are also subject to a number of threats, including increased sedimentation, nutrient enrichment, the invasion of exotic taxa and extractive resource use (Turner *et al.* 2006).

Growing awareness of the need to understand reef systems has prompted a number of research and monitoring programs, particularly on the Adelaide coast (e.g. Cheshire *et al.* 1998; Cheshire and Westphalen 2000; Westphalen *et al.* 2005a,b; Gorgula and Connell 2004; Russell *et al.* 2005; Turner *et al.* 2007; Connell *et al.* 2008), but also in systems considered to be in better condition (e.g. Fleurieu and Yorke Peninsulas; see Turner *et al.* 2007). The establishment of the Natural Resource Management Boards and the declaration of 19 Marine Parks in South Australian waters have also seen increased interest in reef habitats with a number of regional surveys being undertaken around the State (e.g. Edgar *et al.* 2005; Friends of Sceale Bay 2009).

On subtidal reefs throughout South Australia, the macroalgal canopy layers tend to be dominated by brown algae from the orders Laminariales and Fucales (McClatchie *et al.* 2006). The Common Kelp, *Ecklonia radiata*, is the sole member of the Laminariales found in south-western Australia and is particularly common on exposed oceanic shores, while *Sargassum* and *Cystophora* represent two of the major canopy-forming genera in southern Australia (McClatchie *et al.* 2006).

As reported in Edgar (2001), a characteristic feature of reef communities is their extreme patchiness. Much of the variation in reef communities may be due to chance events, particularly the probability that the larvae of a species are swimming nearby when bare space is available, and whether they are then able to establish themselves in that space ahead of others (Edgar 2001).

10.1 Subtidal Reefs of the Lower Spencer Gulf Region

The Site falls within the Spencer Gulf marine bioregion (Edyvane 1999b) and is characterised by a moderate wave energy coastline (Baker 2004).

The key ecological components of rocky reef ecosystems are as follows:

- macroalgae
- invertebrates, and
- fish.

These are discussed in more detail below.

Macroalgae

Reef algal communities of the Spencer Gulf bioregion are typically dominated by the following: Corkweed (*Scaberia agardhii*), particularly in shallow waters; species of *Sargassum* and *Cystophora*; mixed red macroalgae including *Osmundaria* and the brown lobed alga, *Lobophora variegata,* in the understorey (Baker 2004).

Reefs near Tumby Bay are described by Baker (2004) as dominated by *Sargassum* species, with *Scaberia* and species of *Cystophora* also in the canopy, and an understorey comprising mainly *L. variegata*, some green algae (*Caulerpa* spp.), articulated corallines (e.g. *Metagoniolithon* spp. and *Jania* sp.) and encrusting corallines.

Branden and Shepherd (1983) reported that the coastline extending approximately 100 km northwards from Tumby Bay is exposed to the prevailing southerly swell, with dominant macroalgae being *Cystophora moniliformis, C. subfarcinata* and *Sargassum* spp. Edyvane and Baker (1996) reported that subtidal communities on moderately-exposed reef at Port Neill were dominated by *E. radiata* and mixed fucoids, comprising *Sargassum linearfolium*, *S. paradoxum, S. spinuligerum, S. lacerifolium*) with species of *Cystophora* (*C. expansa, C. monoliformis*, and *C. brownii*) as subdominants and understorey dominated by encrusting and articulated coralline algae (e.g. *Amphiroa*) and *L. variegata*.

On the eastern side of Lipson Island, to 3 m depth, Branden and Shepherd (1983) reported *E. radiata, C. moniliformis* and *C. subfarcinata* and *Sargassum* sp. in the canopy, with *Jania* sp. in the understorey. At a location on or near the Sheep Hill site (1.5 km north of Lipson Island), to 3 m depth, they reported a canopy dominated by *E. radiata* and *C. subfarcinata* with an understorey of the green algae *Caulerpa brownii* and *C. papillosa*, the brown alga *Zonaria spiralis*, the red algae *Osmundaria prolifera* and red articulated coralline algae including *Amphiroa anceps*, *Metagoniolithon* spp. and *Jania* sp..

Invertebrates

No epifaunal invertebrate surveys are known to have been undertaken in the region, with the exception of surveys for *Haliotis roei* in the shallow subtidal reef (to 2 m depth), with several hundred individuals recorded during 30 minute searches at sites in the region (Branden and Shepherd 1983). Grazing invertebrates were also recorded, including the abalone *Haliotis scalaris* and the Purple Urchin (*Heliocidaris erythrogramma)* at Lipson Island and the gastropods, *Turbo undulatus* and *T. torquatus*, at or near the Sheep Hill site.

Species that are rare, threatened or have limited distribution listed by Baker (2004) for the Tumby Bay area that may use reef habitat are the nudibranch, *Sclerodoris trenberthi,* (recorded at 3-6 m depth only from Tumby Bay around to Elliston) and the Velvet Octopus (*Grimpella thaumastocheir)* (found in a few locations on southern Eyre Peninsula and Yorke Peninsula).

Fish

Few published surveys of reef fish are known to have occurred in the region, with the exception of surveys for Blue Groper (*Achoerodus gouldii)* (Shepherd and Brook 2007). During these surveys, Blue Groper were recorded north of Tumby Bay, and therefore these fish are unlikely to be present at the Site.

Species that are rare, threatened or have limited distribution listed by Baker (2004) for the Tumby Bay area that may use reef habitat include the Leafy Seadragon (*Phycodurus eques)*, Weedy Seadragon *(Phyllopteryx taeniolatus)* and Short-headed Seahorse (*Hippocampus breviceps)*, which inhabits macroalgae along the margins of seagrass (Kuiter 2000; Moreau and Vincent 2004). These species are Listed Marine Species under the Commonwealth *EPBC Act 1999* and are protected under the South Australian *Fisheries Management Act 2007*.

10.2 Current Understanding of the Subtidal Reefs at the Site

The macroalgal reef system was previously investigated as part of the 2010 marine ecological survey. The qualitative visual observations undertaken during the survey indicated that the shallow subtidal rocky reefs at the Site are dominated by macroalgae species inhabiting a low to medium profile reef system made up of a complex of medium to large boulders, vertical slabs, broken horizontal platforms and crevices. This habitat type occurs from 0 to 7 m below sea level at the Site.

Within this habitat type, the visually most-dominant flora was the brown algae that form the canopy layers, while smaller red and green algae were present as understorey. The brown algae *E. radiata*, *Sargassum* spp., *Caulocystis cephalornithos* and *C. brownii*[11] were the dominant species present. In the understorey, smaller brown seaweeds such as *Z. spiralis* and *L. variegata* were present, as well as red macroalgae such as *Asparagopsis armata*, *Laurencia* sp., *Amphiplexia hymenocladioides*, *Echinothamnio hystrix*[15], *Pterocladia* sp., *Jania* sp. and other coralline algae species.

The deeper fringing areas of the reef were interspersed with sand patches, smaller individual boulders (with associated algal cover) and mixed moderately-dense seagrass beds of *Posidonia* and *Amphibolis*. Within this fringing area the additional presence of the brown alga *Scaberia agardhii* was also noted, which is typical of the species as it is usually found near the edge of seagrass beds (Edgar 2008). Abundance of *Sargassum* spp. and *Scaberia agardhii* as dominant macroalgal canopy species on the reefs is a known characteristic of the Spencer Gulf bioregion (IMCRA Technical Group 1998).

The most common invertebrates observed during the 2010 survey were molluscs (primarily gastropods, i.e., abalone *Haliotis laevigata* and *H. scalaris*, *T. undulatus*), the Purple Seastar (*Meridiastra gunnii*[12]*)* and a variety of sponges. Other commonly observed invertebrates included solitary and stalked ascidians, the anemone *Isaurus cliftoni*, the sea cucumber *Australostichopus mollis* and the urchin, *H. erythrogramma.*

During the underwater visual inspections of the rocky reef during the 2010 survey, the most-commonly observed fish were Red Mullet (*Upeneichthys vlamingii)*, Banded Sweep (*Scorpis georgiana)*, Sea Sweep (*Scorpis aequipinnis)*, Senator Wrasse (*Pictilabrus laticlavius)* and Horseshoe Leatherjacket (*Meuschenia hippocrepis)*.

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[11] Denotes where the genus of algae is considered to be correct but there is some uncertainty about the accuracy of the species identified.

[12] Previously known as *Patiriella brevispina*

10.3 Survey Methods

The sites were predetermined according to the gradient-sampling design, with the focus for the survey being to document baseline conditions within the potential impact location of the proposed jetty. For the reef surveys, sampling was undertaken at the following sites:

- Distance 1 (D1), which lies 0 to 35 m north and south from the middle of the proposed jetty
- Distance 2 North and South (D2N and D2S), which lie 80 to 150 m from the middle of the proposed jetty, and
- Distance 3 North (D3N), which lies 230 to 300 m north of the middle of the proposed jetty (there is no reef present at Distance 3 South).

These sites are detailed in Figure 6, Appendix A. The surveys were undertaken over two sampling events (July 8 to 12, and August 11 and 12 2011) during the winter period.

The sampling methods used for the subtidal reef surveys were based on those described by Barrett and Buxton (2002) and have been used to undertake reef surveys across southern Australia since 1992. Similar methods have been designed for use by trained community divers since 2008 (Reef Life Survey 2009). These methods are non-destructive and permit the collection of large amounts of data on a broad range of species and hence a number of different ecosystem processes (Edgar *et al.* 2005).

The Barrett and Buxton (2002) methods are based on a number of contiguous 50 m transects, each with multiple passes for a 10 m-wide belt-transect fish survey, a 1 m-wide belt-transect invertebrate and cryptic fish survey, and five 0.25m^2 quadrats for surveying layered macroalgal communities and sessile invertebrates. Further details on the sampling methodology can be found in Barrett and Buxton (2002).

For this survey, a number of variations to the Barrett and Buxton (2002) methods were employed. These were as follows:

- Using spatially separated, haphazardly-located, 50 m transects rather than four contiguous 50 m transects, as for the Reef Life Survey (2009) method. This was necessary given the limited extent of reef at the predetermined site locations, but also provided independent replicates, allowing some statistical comparison between sites to be undertaken for fish and invertebrate communities and increasing the number of replicates for the overall impact area.
- Doubling the area of invertebrate search (as it could be efficiently incorporated into the modified method), and
- Placing individual quadrats at pre-determined random locations, allowing each quadrat to be used as a genuine replicate.

Golder Associates employed specialist sub-consultant marine biologists (James Brook and Dr Simon Bryars) to assist with the reef (and seagrass) surveys. Mr Brook and Dr Bryars are experienced with the identification of southern Australian species and have extensive experience with the above survey methods (having undertaken several hundred surveys collectively).

During the surveys, organisms were identified to the finest possible taxonomic resolution that is able to be repeatedly achievable in the field. In very general terms, this resulted in species-level identification for fishes, invertebrates and many macroalgae, and genus level for other macroalgae. To maintain consistency, sessile invertebrates were identified to phylum level only (sponges, ascidians and bryozoans), even where there were isolated opportunities to record them at a lower taxonomic level.

10.4 Results and Discussion

The data for the subtidal reef surveys are provided in Appendix B. A summary list of the species recorded during the survey is provided in Table 5, Appendix B.

Discussion pertaining to the results from each of the reef survey components (macroalgae and sessile invertebrates; mobile invertebrates and cryptic fish; and pelagic fish) is provided below.

10.4.1 Macroalgae and sessile invertebrates

There were 25 macroalgal and sessile invertebrate taxa recorded across the four sites within the Potential Impact Zone, varying from 15 taxa at the Distance 1 site to 20 taxa at the Distance 2 North site. Taxa included the following:

- 10 canopy-forming species (*E. radiata*, 5 species of *Cystophora*, 3 species/subgenera of *Sargassum*, and small quantities of *S. agardhii* and *C. cephalornithos*)
- understorey brown algal species (mainly *L. variegata* and *Z. spiralis*, with a small patch of *Dictyota* sp.)
- articulated coralline algae (*Metagoniolithon*, *Amphiroa*, *Haliptilon* and small patches of *Jania*)
- various turfing algae and crustose coralline algae
- sessile invertebrate groups (sponges, bryozoans and ascidians), and
- a small patch of seagrass.

The data for each site, transect and quadrat is presented in Table 6, Appendix B. The major canopy-forming macroalgae and understorey groups are shown in Figure 9 and Figure 10 respectively. Both figures illustrate that there was considerable variability between transects at sites other than at Distance 1.

At the site level, the Distance 2 North site had some notable differences in species composition from the other sites. At this site, the major canopy-forming species were *C. subfarcinata*, *C. expansa* and *S. decipiens*, whereas the other three sites were dominated by *E. radiata* and *Sargassum* species of the subgenera *Arthrophycus* and *Sargassum*. Below the canopy, the Distance 2 North site was more abundant in articulated coralline algae than sites other than Distance 2 South, but less abundant in *Z. spiralis* and crustose coralline algae than the other sites.

Of the four sites, the Distance 2 North site had a north-east aspect, compared with the generally south-west aspect of the other three sites (see Figure 6, Appendix A), and is therefore likely to be less exposed to the prevailing southerly swell. This site had at least two dominant species typical of sheltered to moderately exposed reef (*S. decipiens, C. expansa*), while the dominant species at the other sites were mainly typical of moderately exposed to sub-maximally exposed reef (Edgar 2008; Womersley 1987).

The nMDS ordination plot (Figure 11) provides an indication of the variability between the four sites within the Potential Impact Zone. These sites were spread over hundreds of metres (minimum distance between two sites was approximately 50 to 120 m (between Distance 1 and each of the two Distance 2 sites), maximum distance was approximately 330 to 400 m (between Distance 3 North and Distance 2 South), while the transects (two per site) were spaced tens of metres apart within a site. The quadrats (five per transect) were spaced metres apart along the transect line. The plot suggests that the following:

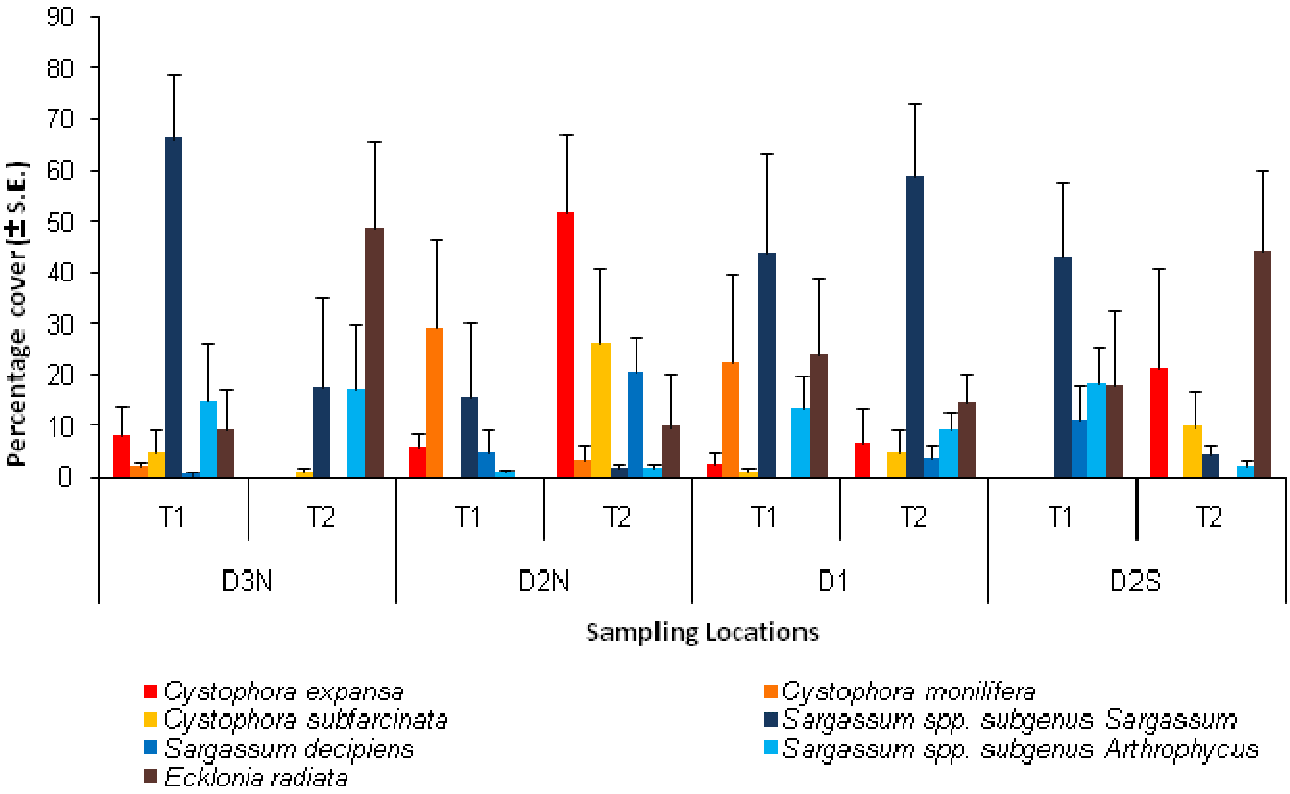
- The Distance 2 North site was of distinctly different character from the other sites and variable in composition

- There were several different assemblages that were represented at each of the other sites, including an *Ecklonia*-dominated assemblage and a *Sargassum* (subgenus *Sargassum*)-dominated assemblage, and
- There is some level of distinction between transects within most sites (except at Distance 1).

A nested, two-factor PERMANOVA analysis showed that there were overall significant differences between transects within sites (P = 0.002), and these differences overrode the between-site variability, with no significant differences seen between sites (P = 0.36). The eight transects were each placed along an approximately-consistent depth contour within a range from 3.5 m to 6 m. A RELATE analysis showed that there was no significant correlation between the macroalgal community structure and the quadrat (transect) depth (Rho = -0.092, P = 0.91).

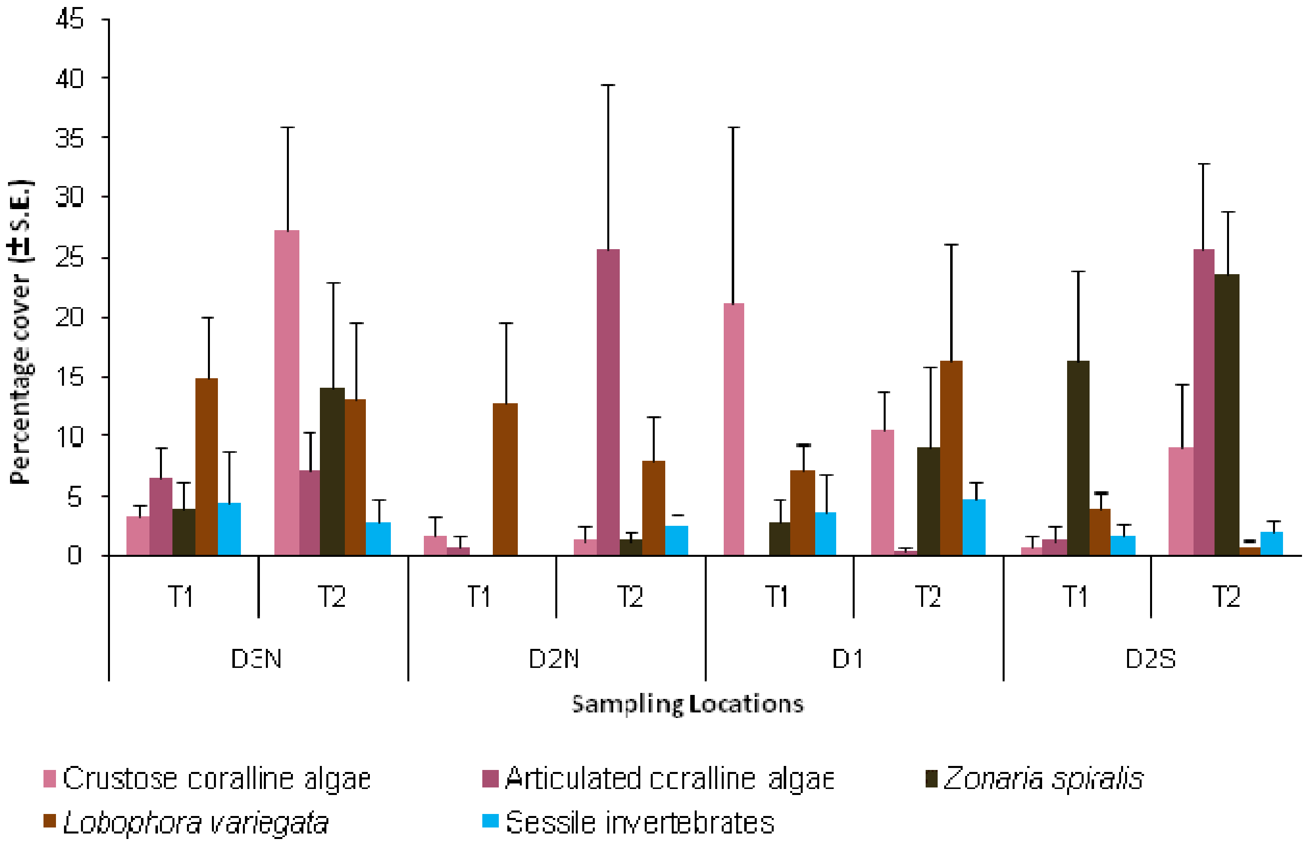
This high variability at small spatial scales is consistent with the reported typical patchiness of subtidal reefs in temperate waters (Edgar 2001).

Figure 9: Dominant canopy-forming macroalgae for each transect (mean of five quadrats plus standard error (S.E.)) at each potential impact site.



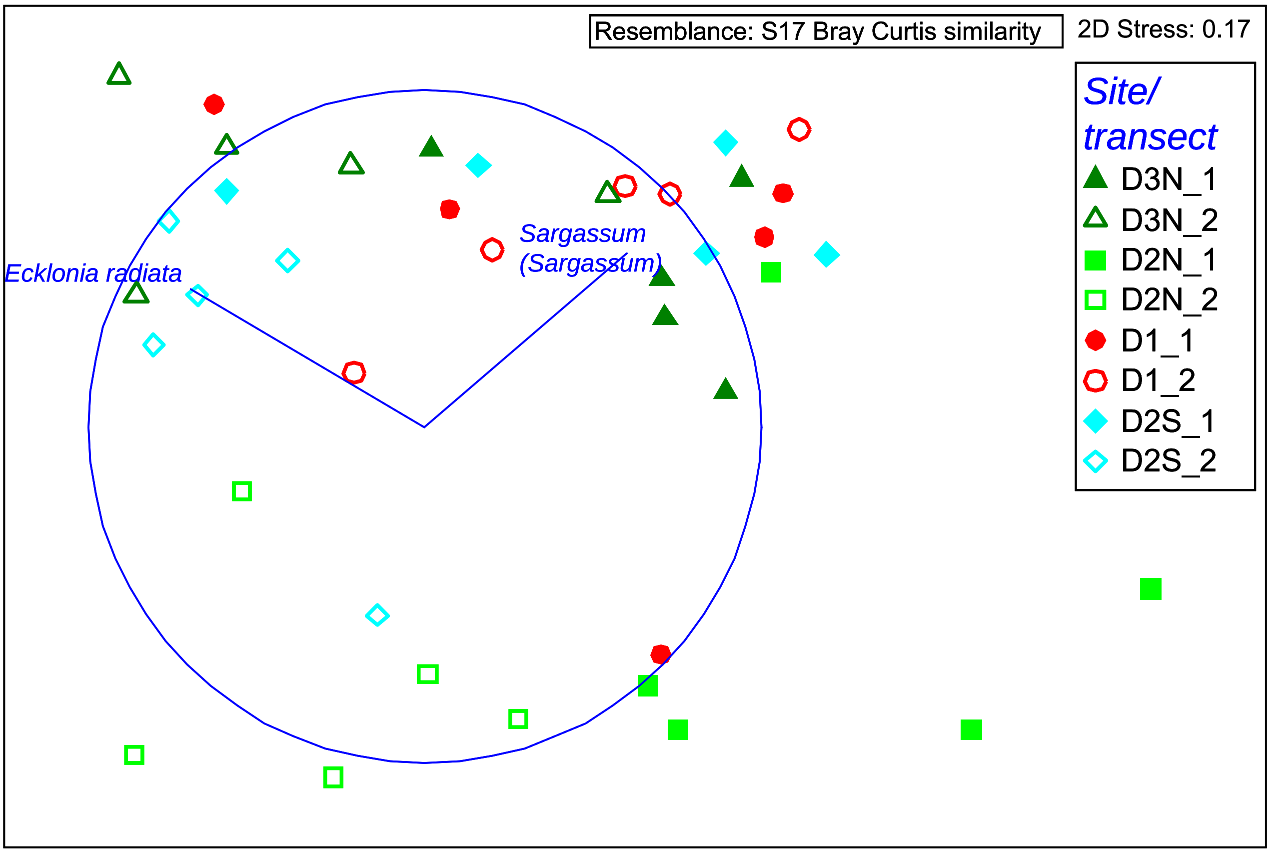
Site codes: D = Distance, N = North, S = South, T = Transect.

Figure 10: Dominant understorey groups for each transect (mean of five quadrats plus standard error (S.E.)) at each potential impact site.



Site codes: D = Distance, N = North, S = South, T = Transect.

Figure 11: Non-metric multidimensional scaling (nMDS) ordination plot for individual quadrats (5 quadrats per transect, two transects per site).



Vectors show species most strongly correlated with the ordination axes (Rho > 0.7). Circle corresponds to Rho = 1.

Site codes: D = Distance, N = North, S = South, T = Transect.

10.4.2 Mobile invertebrates and cryptic fish

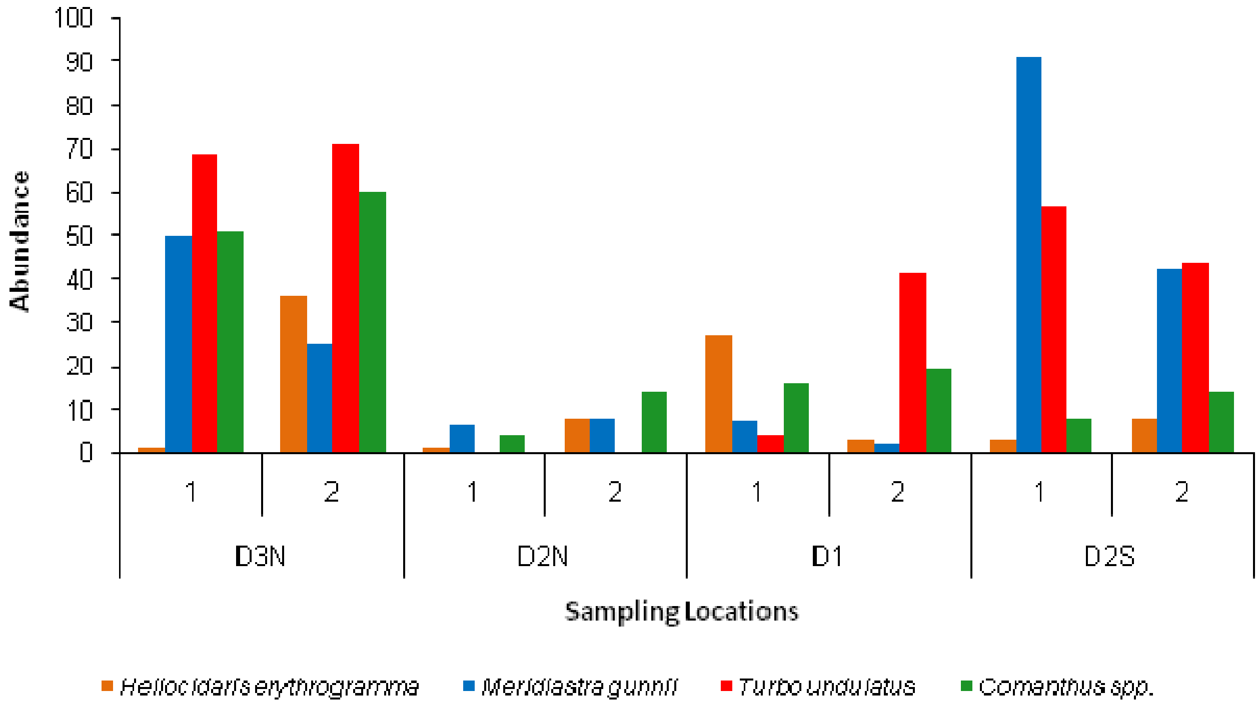
There were 35 species recorded on the invertebrate and cryptic fish transects across the four sites, varying with 10 species at Distance 2 North, 19 species at Distance 2 South, 21 species at Distance 1 and 24 species at Distance 3 North. The data for this component of the survey are presented in Table 7, Appendix B.

The number of individuals varied from approximately 50 at Distance 2 North to 450 at Distance 3 North (total more than 1,000), and was strongly influenced by the abundance of the gastropod *T. undulatus*, the crinoids *Comanthus trichoptera* and *C. tasmaniae*, the asteroid *Meridiastra gunnii,* and the Purple Urchin (*H. erythrogramma)*. Cryptic fish included the Common Threefin *(Trinorfolkia clarkei)* and Crested Threefin (*T. cristatus)*, the Weedfish (*Heteroclinus tristis)* and another undifferentiated weedfish species were recorded.

The most abundant species recorded during the cryptic fish and invertebrate survey are shown in Figure 12. The abundance of *H. erythrogramma* was variable between transects and sites. For the other species, most variability was between sites, with each site appearing to have distinct character. Apart from the low overall abundance of mobile invertebrates, one feature distinguishing the Distance 2 North site from all other sites was the absence of the gastropod *T. undulatus*. This could be the result of the relatively low abundance of the kelp *E. radiata*, which it inhabits, although it has been recorded elsewhere in South Australia in high numbers despite a lack of *Ecklonia* (e.g. Edgar *et al.* 2005; Tanner and Bryars 2007). Differences between the Distance 2 North site and other sites could be due to the differing site aspect discussed above. The Purple Urchin, *H. erythrogramma,* and crinoids, *C. trichoptera* and *C. tasmaniae,* are typical of sheltered and moderately-exposed reefs (Edgar 2008; and see Friends of Sceale Bay 2009; Edgar *et al.* 2005). The gastropod, *T. undulatus,* is more typical of exposed reefs (Edgar 2008). The asteroid, *M. gunnii*, is typically found in sheltered reef and seagrass (Edgar 2008).

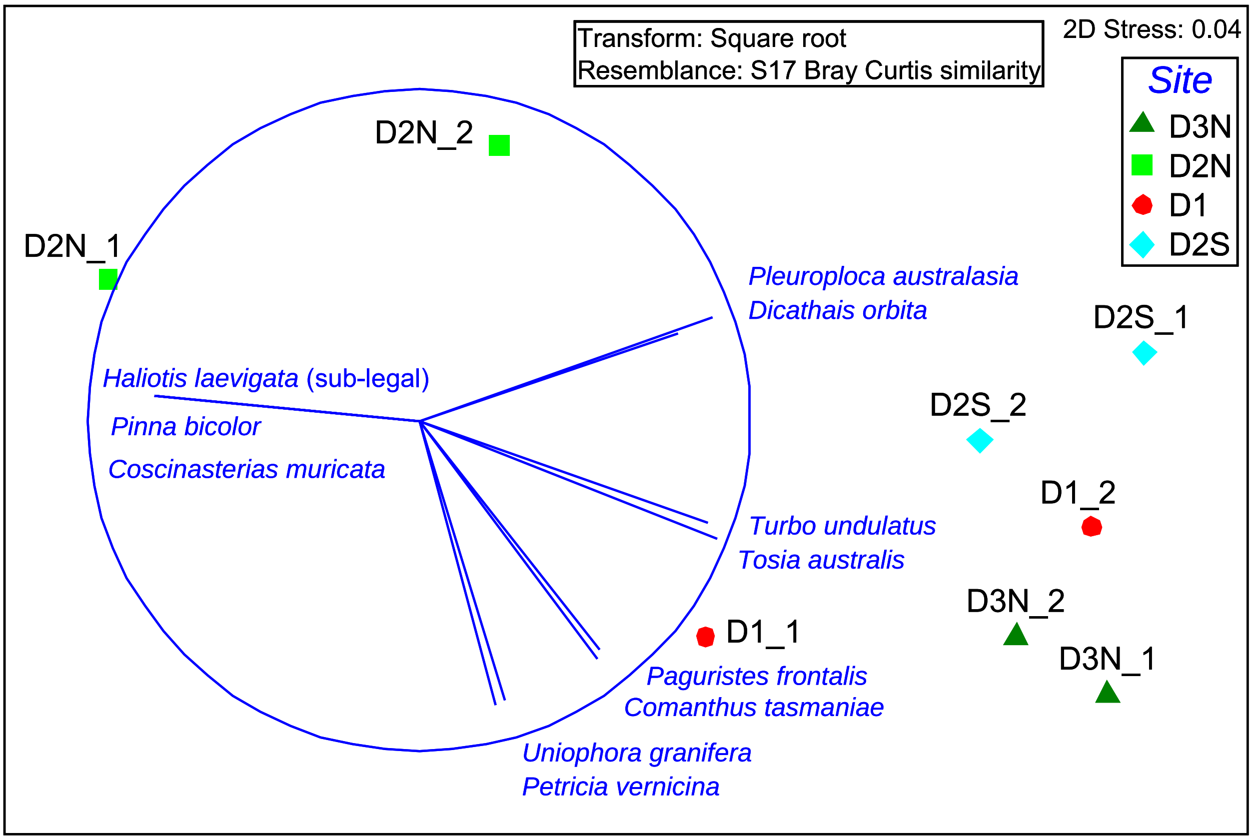
The nMDS plot in Figure 13 shows that the Distance 2 North site was of distinctly different character from the other sites, while for other sites the dissimilarity between transects from the same site was similar to the dissimilarity between transects from different sites. A single factor PERMANOVA test confirmed that there were significant overall differences between sites ($P = 0.009$), but there was an insufficient number of permutations available (i.e. replicates) to show significant differences between any pair of sites (even using a Monte Carlo simulation). An ANOSIM test confirmed the overall significant difference between sites. Although this test had the same limited power to detect significant pair-wise differences, the R values were 1 for each pair that included the Distance 2 North site. This is indicative of complete difference between the pairs of sites (Clarke and Warwick 2001).

Figure 12: Most abundant species recorded during the invertebrate and cryptic fish survey.



Site codes: D = Distance, N = North, S = South

Figure 13: Non-metric multidimensional scaling (nMDS) ordination plot of invertebrate and cryptic fish survey transects (two transects per site).



Vectors show species most strongly correlated with the ordination axes (Rho > 0.7). Circle corresponds to Rho = 1.

Site codes: D = Distance, N = North, S = South.

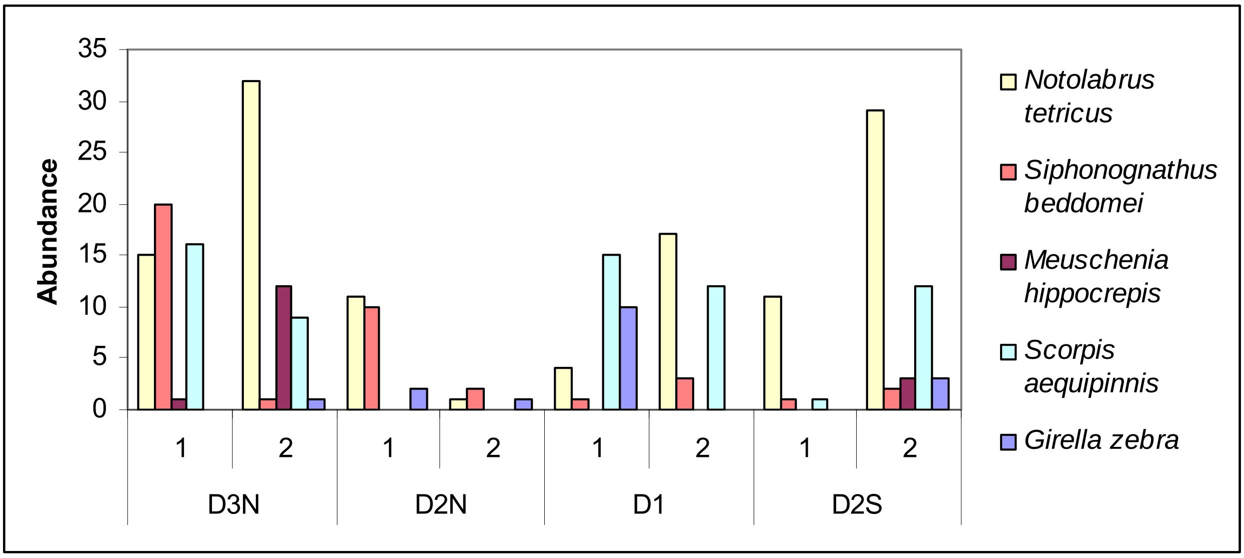
10.4.3 Demersal fish

There were 15 species recorded on the fish transects across the four sites, varying from 5 species at Distance 2 North to 10 species at sites Distance 3 North and Distance 2 South. The number of individuals varied between 31 at Distance 2 North and 122 at Distance 3 North, with a total of 288 individuals recorded. The number of species (on average) and the number of individuals was higher for the three transects undertaken during the second sampling period for the field surveys, when visibility was greater than 10 m, compared with the first trip, where it was only 4-5 m. The Blue Throated Wrasse (*Notolabrus tetricus)* and the Pencil Weed Whiting (*Siphonognathus beddomei)* were observed the most frequently, and the Blue Throated Wrasse and Sea Sweep (*Scorpis aequipinnis)* were the most abundant. The data for this component of the survey are presented with the cryptic fish and mobile invertebrate data in Table 7, Appendix B.

The most abundant species recorded during the fish survey are shown in Figure 14, and varied across transects within and between sites. The higher abundances of the Blue Throated Wrasse and presence of the Horseshoe Leatherjacket (*Meuschenia hippocrepis)* at sites Distance 3 North and Distance 2 South are likely to be due to both or one of their transects, respectively, being undertaken during the second sampling period when visibility was greater. Poor visibility can influence counts by limiting a diver's ability to detect species and by causing mobile species to actively avoid divers (Barrett and Buxton 2002). The absence of Sea Sweep from the Distance 2 North site could reflect the more sheltered aspect of this site (see above), as this species is typically found on exposed reef (Edgar 2008).

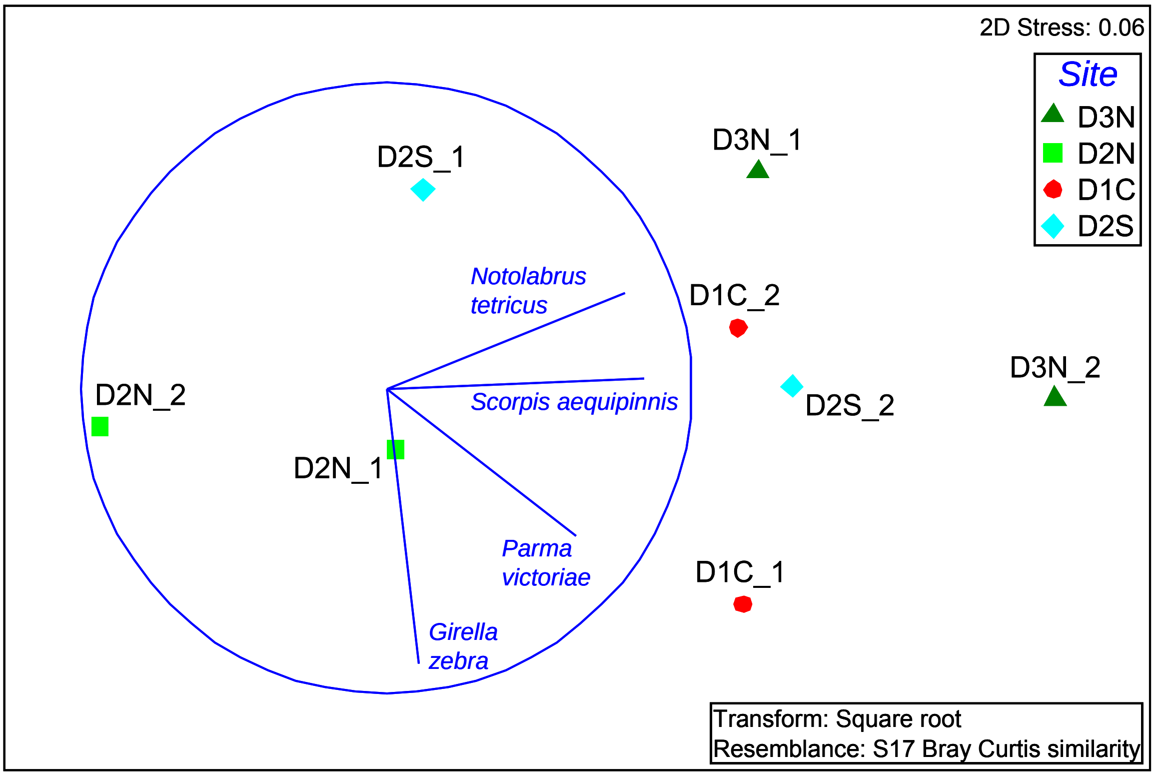
The nMDS plot in Figure 15 suggests that the fish assemblage at Distance 2 North was different from the other sites, and also shows the variability within sites was similar to the variability between them. Neither a single factor PERMANOVA test nor ANOSIM test were able to show a significant difference between sites (*P* = 0.23 and 0.27, respectively). The sites from the second trip were all plotted towards the right hand extent of the nMDS plot. However, a single-factor PERMANOVA resulted in no statistically significant difference between the trips.

Figure 14: Most abundant species recorded during reef pelagic fish surveys.



Site codes: D = Distance, N = North, S = South.

Figure 15: nMDS ordination plot for species recorded during the pelagic fish surveys (two transects per site).



Vectors show species most strongly correlated with the ordination axes (Rho > 0.7). Circle corresponds to Rho = 1.

Site codes: D = Distance, N = North, S = South.

10.5 Other Findings

10.5.1 Recreationally and commercially-significant species

Regulated commercial and recreational fishing species recorded during the surveys included the Greenlip Abalone (three individuals below legal size), Razorfish (one individual) and Sea Sweep (65 individuals). A further species taken recreationally and commercially is the Blue Throated Wrasse (120 individuals recorded).

10.5.2 Rare and/or threatened species and communities

Two rare molluscs and three protected syngnathids were identified as possibly occurring at the site (Baker 2004); however none of these species were observed during the current survey. A male/female pair of the Crested Threefin (see Figure 16) (which is endemic to South Australia (Edyvane 1999a; Baker 2009)), was recorded at the Distance 3 North site. This species has been recorded at a number of locations between Ceduna and Victor Harbor. Although Edgar (2008) described this species as rare, Baker (2009) noted that it has been commonly recorded, and appears not to be rare within its known range.

Figure 16. Male (right) and female Crested Threefin (*Trinorfolkia cristata)*

10.6 Potential for Impacts on Subtidal Rocky Reefs

10.6.1 Construction Phase

Potential impacts from construction activities may result from the direct impacts of pile-driving activities. Loss of habitat will occur directly under each pile; however the extent of this loss is anticipated to be minor.

Pile-driving activities will also generate high levels of underwater noise and this has the potential to impact marine animals. An assessment of the potential impacts from acoustic pollution has been undertaken, the detail of which are provided in Section 17.0. In summary, no effects on marine mammals are anticipated; however some localised effects (up to approximately 500 m from the source) may be experienced by some fish species. Notwithstanding this, no measurable effects are expected and no effects at the population level are anticipated. Golder notes that site-associated reef fish species are likely to be the most susceptible to pile-driving activities and ongoing monitoring should continue to include assessment of these species.

The likelihood of sediment plumes and sediment deposition from construction activities is considered to be low due to the construction method and mitigation measures which have been proposed.

10.6.1.1 Mitigation measures

Drilling activities associated with pile installation may generate material which could impact water quality (i.e. turbidity or contaminants). Operational measures to manage such material should be implemented as part of the CEMP. The use of pile fabric filtering has been proposed for use during construction activities. This operational measure will assist with minimising impacts on rocky reef communities by reducing the potential for sedimentation plumes from pile driving and drilling operations.

10.6.2 Operational Phase

The potential impacts from the ongoing operation of the Port may include effects from the presence of infrastructure (such as shading from the jetty) or reduced water quality associated with the export of materials and shipping activities.

The impacts of shading from the proposed jetty may depend on the tolerance of macroalgal species to reduced light, and the amount of light that is able to penetrate beneath the jetty. The depth ranges of plants reflect the different light-trapping abilities of different species (Edgar 2001). Therefore, as the depth to which macroalgal species can occur may be a useful indicator of the light tolerance of species, this information has been compared with the maximum depth of reef at the Site (i.e. 8 m). However, the survival of species under the jetty may be a result of more complex interactions which could also include changes in water clarity (Edgar 2001).

The major canopy-forming species at the Site have been recorded to occur at a range of depths. The kelp *E. radiata* can tolerate low-light conditions and is found at depths to 44 m, and *S. agardhii* and *C. monilifera* and *C. moniliformis* extend to a similar depth (Edgar 2008). Species from the *Sargassum* and *Arthrophycus* subgenera have maximum depths varying from relatively shallow (5-12 m) to relatively deep (approximately 40 m) (Edgar 2008; Womersley 1987). *Cystophora expansa* and *Sargassum decipiens* have maximum depths of approximately 12 m (Edgar 2008). Species which may be near their tolerance of light based on their maximum depth are *C. brownii* (4 m), *C. subfarcinata* (7 m) and *C. cephalornithos* (7 m). In the former two cases, however, this may relate to their preference for relatively-exposed conditions (Edgar 2008), as wave exposure, like light, is attenuated with depth (Turner *et al.* 2006). It is possible that there may be minor shifts in macroalgal community structure below the proposed jetty but no overall loss of canopy structure and function would be expected.

The orientation of the proposed jetty will also have an influence on any shading effect and the approximately east-west orientation of the main section of the proposed jetty approaches the maximum shading effect possible due to the east-west movement of the sun. During summer when the sun is at its highest orientation, the shading effect would be greatest as the area directly beneath the proposed jetty would receive reduced light almost all day. Nonetheless, it is unknown if this level of shading will be detrimental to the long-term survival of macroalgae and due to variation in the angle of the sun across seasons, the areas under or to the south of the proposed jetty that receive maximum shading will vary across the year.

Other potential impacts from the ongoing operation of the Port may include increased suspended particulates (and therefore increased turbidity) through loss of export material or accidental releases (if they occur). Operational measures will be implemented to minimise the potential for accidental loss of product and to reduce the risk of accidental releases into the marine environment.

Disturbance to sandy substrates from propeller wash has also been identified as a potential source of impacts in the previous marine ecological assessments undertaken by Golder (Golder 2009 and 2011). In order to minimise turbidity and disturbance to sediments, operational measures have been proposed which will ensure that cargo vessels are not under their own power within 1.5 km of the jetty. Such measures will minimise the potential effects on the sandy substrate habitat.

Sedimentation on the rocky reef areas as a result of altered hydrodynamic conditions is not expected to occur (ASR 2011), although the potential for increased sediment movement (rather than accretion) through this area has been identified (ASR 2011).

10.6.2.1 Mitigation measures

Operational measures (such as enclosed conveyors) will be implemented to minimise the potential for accidental loss of export material and to reduce the risk of accidental releases into the marine environment. These management measures play a key role in mitigating the potential for increased turbidity. Without these measures being effectively implemented, there is the potential for reduced light and sediment deposition to impact reef biota through a combination of smothering, scour, and changing the physical characteristics of the substratum (Airoldi 2003). These impacts can include interference with the filter-feeding of sessile invertebrates (Turner *et al.* 2006), with the feeding apparatus becoming clogged (Irving and Connell 2002). Turner and Cheshire (2002) found a significant reduction in recruitment and slow recovery for a number of canopy-forming taxa (the same or similar species to those at the proposed site) in areas impacted by a sediment plume. A reduction in larger canopy-forming taxa can be followed by, or exacerbate a shift to, organisms with sediment-trapping morphologies (typically turfing species) or opportunistic species (Airoldi 2003; Turner *et al.* 2006).

Ongoing monitoring of reef communities will assist with ensuring that the mitigation measures employed are sufficiently effective to minimise impacts to local reef communities.

10.6.3 Increased fishing pressure

Concerns have been raised regarding the potential for impacts associated with increased fishing pressure by foreign crews accompanying vessels. The concern raised was with particular regard to abalone species; however, reef-associated fish species may also be susceptible to such impacts. Discussion is provided below as to the potential for impacts from increased fishing pressure at the Site.

Reef-associated fish

As reported above, Blue Throated Wrasse were the most abundant fish recorded during the surveys. Reef-associated wrasse species (such as the Blue Throated Wrasse) are of conservation concern, due to fishing-induced impacts on populations that are territorial, site-attached and have vulnerable population dynamics (Baker 2009; Shepherd *et al.* 2010).

Shepherd *et al.* (2010) discussed some of the issues associated with the recreational fishing of Blue Throated Wrasse in parts of South Australia. If increased fishing activities were to occur, some localised impacts may occur, whereby this species becomes absent from the immediate vicinity around the proposed jetty infrastructure.

Abalone

H. laevigata (Greenlip abalone) were found in the reef surveys (and also in the seagrass meadows fringing the reef areas). Abalone, particularly Greenlip, are vulnerable to fishing-induced population declines due to a number of population characteristics, such as their sedentary nature, ease of capture, small “home range”, localised reproduction and limited larval dispersal, variable growth between metapopulations (“stocks”), and variable fecundity and fertility between metapopulations. (Shepherd *et al.* 1992; Rodda *et al.* 1998);

It is anticipated that increased fishing pressure at the Site would lead to some localised impact to the Greenlip abalone (*H. laevigata)* population, whereby this species becomes absent from the immediate vicinity of the jetty.

10.6.3.1 Mitigation measures

Foreign crews will not be permitted to leave the vessels or fish from them while berthed at the Port Spencer facility. To ensure that this is enforced, site security controls will be implemented as part of Port operations.

Fishing by personnel involved with Port operations will not be permitted at the Site.

10.6.4 Extent of potential disturbance

The extent of potential disturbance to the subtidal rocky reefs has been estimated at approximately 1,930 m^2.This area represents the area under, and immediately surrounding the jetty, and includes the area which is expected to be subject to shading (refer to Figure 2, Appendix A). This area accounts for the primary extent of potential impacts from both contruction and operational phases of the project. The current understanding of the project suggests that impacts to subtidal rocky reefs will be limited to the headland where the jetty will be constructed, and that the reefs to the north and south of the Site are outside of the zone of potential impacts. Notwithstanding this, a more conservative upper extent of 52,463 m^2 has also been calculated due to the possibility of impacts occurring from increased sediment deposition. Golder notes however that the current modelling predictions (ASR 2011) indicate that this is not expected to occur.

The composition of macroalgal species in the shallow reef zone at the Site is typical of that described for temperate Australian subtidal reefs, which are characterised by the structural dominance and diversity of large macroalgae and an abundance of sessile and mobile invertebrate assemblages (i.e., sponges, bryozoans, ascidians, echinoderms, molluscs and crustaceans) (Edyvane 1999a; Underwood & Chapman 1995). While this area supports a diverse array of macroalgal species, there were no algal species of conservation significance or concern recorded as part of the surveys.

10.6.4.1 Recovery of Rocky Reefs

Recovery of reef-associated fish communities post-construction is expected to begin following the cessation of pile driving activities. As only a relatively small area is expected to be subject to the potential impacts of pile driving activities, the area will likely be re-populated by local fish communities from adjacent reef areas.

Changes to macroalgal assemblages from shading, if they occur, are considered likely to be permanent, although it is anticipated that many species may be tolerant of decreased light levels. Measures to rehabilitate the area under the jetty are not considered feasible or likely to be successful due to the ongoing effects that will be associated with shading.

Sedimentation is expected to be minimal on the rocky reef areas due to the moderately high wave energy of the coast on which the proposed Port would be situated. As such, macroalgal communities are likely to recover from sedimentation impacts following Port decommissioning.

10.7 Conclusions

The composition of macroalgal species in the shallow reef zone at the Site is typical of that described for temperate Australian subtidal reefs, which are characterised by the structural dominance and diversity of large macroalgae and an abundance of sessile and mobile invertebrate assemblages (i.e., sponges, bryozoans, ascidians, echinoderms, molluscs and crustaceans) (Edyvane 1999a; Underwood & Chapman 1995).

The current surveys generally confirmed the canopy and understorey species composition reported in previous surveys and reports, with the exception that there was a lack of foliose red (i.e. other than coralline reds) and green macroalgal species. There was considerable small-scale variation within the macroalgal communities across the sites. At the site level, Distance 2 North had a distinctly different character, but this was not shown to be statistically significant from other sites.

There are few existing published data to compare with the fish and mobile invertebrate fauna noted within the reef system at the Site. However, the faunal assembles were similar in character to reef communities from elsewhere in South Australia (e.g. Edgar *et al.* 2005; Friends of Sceale Bay 2009). There were few species of recreational or commercial significance, and no threatened or protected species recorded. A male/female pair of Crested Threefin, which is a rare specieis endemic to South Australia (though not protected), was recorded.

11.0 SEAGRASSES

11.1 Seagrasses of the Spencer Gulf Region

The most extensive seagrass meadows of South Australia are found in Spencer Gulf, covering over 5,500 km^2 or 57% of the total inshore coastline of South Australia (DEH 2003), and are therefore some of the largest seagrass habitats in Australia (Edyvane 1999b).

Seagrasses typically colonise sandy and muddy areas in the lower intertidal and subtidal zones. A range of species occupy these zones (Hutchings *et al.* 1993; Edyvane 1999a; DEH 2003;), with the shallow limit of their distribution being determined by the plants' ability to withstand the breaking waves in the intertidal region, while their deeper limit is determined by lower light availability (Kirkman 1997). The intertidal zone is dominated by *Zostera* and *Heterozostera* species (e.g., *Z. mucronata*, *Z. muelleri*, and *H. nigricaulis*), which can form dense, pure masses to about 3-4 m deep (Edyvane 1999b; Seddon 2000 cited in DEH 2003;). *Posidonia* species occupy the subtidal zone, within which *P. australis* dominates the community in the shallower waters but shifting to a greater abundance of *P. sinuosa* and *P. angustifolia* as water depth increases (Seddon 2000 cited in DEH 2003). The growth of *Posidonia* species is particularly vigorous, with high turnover rates and estimated annual leaf blade productivity in excess of 9 kg/m^2 in shallow water (Shepherd 1983).

Amongst these seagrass meadows, *Amphibolis antarctica*, *A. griffithii* and *H. nigricaulis* often occupy edges, blowouts and smaller areas, as well as *Halophila australis,* which is sparse but widespread (Edyvane 1999a). *A. antarctica* also occurs in areas of moderately to fairly strong water movement, often in association with *P. sinuosa* (Edyvane 1999b). *A. griffithii* can form pure stands or mixed communities with *A. antarctica* from low tide to depths of around 5 m, but generally extends into rougher localities and tolerates lower light intensities than *A. antarctica* (Edyvane 1999b). *H. australis* usually grows on sand and mud from low tide level to 23 m deep. Other seagrass species reported from Spencer Gulf include *Ruppia megacarpa* and *R. tuberosa,* which form extensive low turfs in mid and lower eulittoral zones on sandy/muddy tidal flats, and *Lepilaena marina* (DEH 2003). A few macroalgal species also occur in or adjacent to seagrass beds, such as *Caulerpa cactoides* and *C. remotifolia* (Edyvane 1999b).

Estimates of seagrass coverage have been made for the bioregions of South Australia, with seagrass meadows covering an estimated 527 km^2 along Eyre Peninsula, 1,377 km^2 within the Spencer Gulf Bioregion, 4,136 km^2 in northern Spencer Gulf and, for comparison, 2,438 km^2 in Gulf St Vincent (Edyvane 1999a). Thus, by comparison to other areas, the northern reaches of the gulf support the greater amount of seagrass habitat.

Seagrasses have also been noted as important habitats within the Dutton and Jussieu biounits, which include the region of the Site and south of Tumby Bay, respectively (Edyvane 1999b). Within the Dutton biounit (which extends from Salt Creek (Tumby Bay) to Cape Driver (Arno Bay) on the western side of central Spencer Gulf (Edyvane 1999b)), extensive seagrass meadows have been recorded growing on sandy substrates to the south of Port Neill and the north of Lipson Island. Seagrass habitats cover approximately 98% of the inshore coastline of the Dutton biounit. Further south but still in close proximity to the Site, the Jussieu biounit has a number of low energy beaches that are fronted by seagrass beds, covering 37% of the coastline in this biounit.

Seagrass beds perform a range of functions within the marine environment and are most notable for the following reasons:

- They are primary producers forming the basis of coastal food webs.
- They support coastal marine communities and maintain biodiversity.
- They provide nursery, breeding and feeding habitat for many species.
- They support commercial and recreational fisheries production.
- They stabilise nearshore sediments and sandbanks with their root and rhizome system.
- They act as a filter and sediment trap for suspended sediment particles, and
- They support the production of carbonate sediments from the skeletal biota inhabiting the beds.

Seagrass habitats support a diverse range of infauna and epiphytes, as well as providing resources for a variety of economically-important fish and crustacean species. The most abundant invertebrate taxa residing amongst the plants are polychaete worms, as well as molluscs, crustaceans, and echinoderms. *Zostera* beds are reported to support the highest density of invertebrate fauna, but with low species richness (Hutchings *et al.* 1993). The tanaid crustacean, *Tanais dulongi* and the cosmopolitan polychaete, *Capitella capitata,* have been recorded as the two most-dominant species occurring almost exclusively in the intertidal zone of *Zostera* beds in northern Spencer Gulf (Hutchings *et al.* 1993). The polychaete worms, *Nereis bifida* and *Eunice* sp., have been recorded as the most dominant species of invertebrate fauna found amongst *P. australis* and *P. sinuosa* beds, respectively (Hutchings *et al.* 1993). Hutchings *et al.* (1993) further reported that very few invertebrate species commonly reside in both *Zostera* and *Posidonia* beds, and that these habitats support distinctive marine assemblages. Seagrasses also provide nursery areas, refuge from predators, breeding grounds, and feeding areas for larger, highly mobile, and economically important species such as western king prawn (*Penaeus latisulcatus*), King George whiting (*Sillaginodes punctata*), yellow-fin whiting (*Sillago schomburgkii*), garfish (*Hyporhamphus melanochir*), yellow-eye mullet (*Aldrichetta forsteri*), bream (*Acanthopagrus butcheri*), blue swimmer crab (*Portunus armatus*[13]), southern calamari (*Sepioteuthis australis*), Western Australian salmon (*Arripis truttacea*) and snapper (*Pagrus auratus*), as well as various pipefishes, seahorses and seadragons (including the Leafy Sea Dragon, *Phycodurus eques*) from the family Syngnathidae (DEH 2003 and references therein; Edyvane 1999a; Bell & Pollard 1989, and Howard *et al.* 1989 cited in Edyvane 1999a, b).

11.2 Current Understanding of the Seagrasses at the Site

The distribution of seagrass habitat in the vicinity of the proposed Port has previously been determined using information obtained during the 2008 and 2010 marine surveys.

Species of *Posidonia* and *A. antarctica* are the most common species present at the Site, with sparse, patchy coverage of *H. nigricaulis and H. australis* also recorded. Overall, the seagrass and algal assemblages present in the vicinity of the Site appear to be consistent with descriptions for seagrasses throughout Spencer Gulf (as described in Section 11.1).

[13] *Portunus pelagicus* (Linnaeus,1758), has recently undergone revision. Four distinct species, *P. pelagicus* (Linnaeus, 1758), *P. segnis* (Forskål, 1775), *P.reticulatus* (Herbst, 1799) and *P. armatus* (A. Milne-Edwards, 1861) have been identified. Refer to Lai et al. (2010).

11.3 Survey Methods

The sampling sites were predetermined according to the gradient-sampling design with the focus for the survey being to document baseline conditions within the potential impact zone of the proposed jetty (refer to Figure 6, Appendix A for sampling positions). For the seagrass surveys, sampling was stratified for depth so as to capture information about the composition of seagrass species in both the shallower (7 m to 9 m BSL) and deeper (11m to 11.5m BSL) extents of the Site. For both depth ranges, sampling was undertaken at the following sites:

- Distance 1 (D1), which lies 0 to 35 m north and south from the middle of the proposed jetty.
- Distance 2 North and South (D2N and D2S), which lie 80 to 150 m from the middle of the proposed jetty, and
- Distance 3 North and South (D3N and D3S), which lie 230 to 300 m from the middle of the proposed jetty.

The surveys were undertaken over two sampling events (July 8 to 12, and August 11 and 12) during winter. The survey methods involved a 50 m transect line which was laid out from a site marker in a northerly direction such that it was parallel to the shoreline and at a consistent depth across its length. The transect line was used as the basis for collecting data using quadrats, a benthic belt transect, and a demersal belt transect. A description for each method is as follows:

- ***Quadrats -*** A single 50 x 50 cm quadrat was placed at randomly-allocated distances at 10 places along the 50 m transect line (10 replicates). Quadrats were constructed with cross-wires so that there were 100 evenly spaced grid points within the quadrat. Counts of benthic cover were made at the intersections of the cross-wires for four categories: *Posidonia*, *Amphibolis*, Zosteraceae, and sand. In some instances substantial amounts of a filamentous red epiphytic alga and a fleshy brown epiphytic alga were observed overlaying the *Amphibolis*; in these instances the algae was scored and noted but the *Amphibolis* underneath the algae was later scored for the percentage seagrass cover analyses.
- ***Benthic belt transect -*** A 1 m wide x 50 m long benthic belt transect was searched by a single diver and scored for the numbers of cryptic fish and large (> 10 mm diameter) sessile and mobile invertebrates found within the seagrass canopy. The cryptic fish and invertebrate surveys were undertaken by marine biologists experienced with underwater surveys and identification of these species in southern Australian waters, and
- ***Demersal belt transect -*** A pair of divers each swam a 5 m wide x 50 m long demersal belt transect for the numbers of fish above the seagrass canopy.

Two parallel transects approximately 10–15 m apart were sampled at each site.

The survey team consisted of a Golder Associates scientific diver and sub-contracted commercial and scientific divers. The specialist scientific sub-consultants included marine biologists (James Brook, Dr Simon Bryars and Shea Cameron). Mr Brook, Dr Bryars and Mr Cameron are experienced with the identification of southern Australian species and have experience with a range of subtidal survey methods.

Taxonomic Resolution

Seagrasses were identified to species or species-group level using Robertson (1984) and Kuo (2005). Field identification of the two *Amphibolis* species (*A. antarctica*, *A. griffithii*) is straightforward, but for the three '*Posidonia australis* group' species (*P. angustifolia*, *P. australis*, *P. sinuosa*) field identification is more difficult. The leaves of *P. angustifolia* and *P. sinuosa* are morphologically similar (Robertson 1984), making their taxonomic discrimination in the field possible only after excavation and examination of the below-ground material. It was evident from random excavations and examination of leaf sheaths that both species were growing sympatrically at the Site. We therefore combined the two species for subsequent surveys and analyses (a practice used in other studies, e.g. Neverauskas 1987, Bryars and Wear 2008). No *P. australis* (which has much wider leaves than *P. angustifolia* and *P. sinuosa*) was observed during the present survey, nor was any *A. griffithii* seen. No species from the '*Posidonia ostenfeldii* complex' were identified at the Site. Field identification of species in the Zosteraceae family can also be difficult and there is still some taxonomic debate about the group (Kuo 2005). While it was evident that *Heterozostera nigricaulis* was present at the Site, the Zosteraceae were a minor component of the seagrass assemblage and not all specimens seen during surveys were collected for identification; thus they were recorded as 'Zosteraceae'. Some specimens of *Halophila australis* were identified at the Site.

Fish and invertebrates were identified to the finest taxonomic resolution possible using the field guides of Edgar (2008), Gowlett-Holmes (2008), and Gomon *et al.* (2008). Sessile invertebrates were identified to phylum level (sponges, ascidians and bryozoans).

11.4 Results and Discussion

This section summarises the results of the seagrass surveys (seagrass cover, cryptic fish and invertebrates, and fish) and provides a discussion of the results in regard to documenting baseline conditions at the Site. The data are presented in Appendix B.

11.4.1 Description of recorded site conditions

Each of the sites appeared superficially similar, generally comprising dense seagrass beds (Figure 17 to Figreu 19). However, there were some subtle differences between shallow versus deep sites and also between some of the shallow sites. The deeper sites comprised solely of *P. angustifolia/sinuosa* (Figure 17), while the shallow sites comprised mainly of *P. angustifolia/sinuosa* and *A. antarctica* (Figure 18 and Figure 19) There appeared to be a species composition shift from north to south in the shallow sites with *A. antarctica* present in substantial amounts to the north where it was mono-specific or mixed in with *P. angustifolia/sinuosa*, but absent to the south of Distance 1. The shallow sites were also characterised by some large sand holes that extended for tens of metres in some cases (see Section 11.4.3). These sand areas were either isolated sand holes within the seagrass beds or finger-like extensions of the sand zone that exists between the fringing coastal reefs/beaches and the seagrass beds further offshore. Small amounts of *H. nigricaulis* were also identified within the *Posidonia* beds at some sites and it was also noted during some of the surveys that an unidentified species of Zosteraceae was colonising the sand zone. Small amounts of *H. australis* were also identified at some sites.

Figure 17: Posidonia at one of the deeper sites

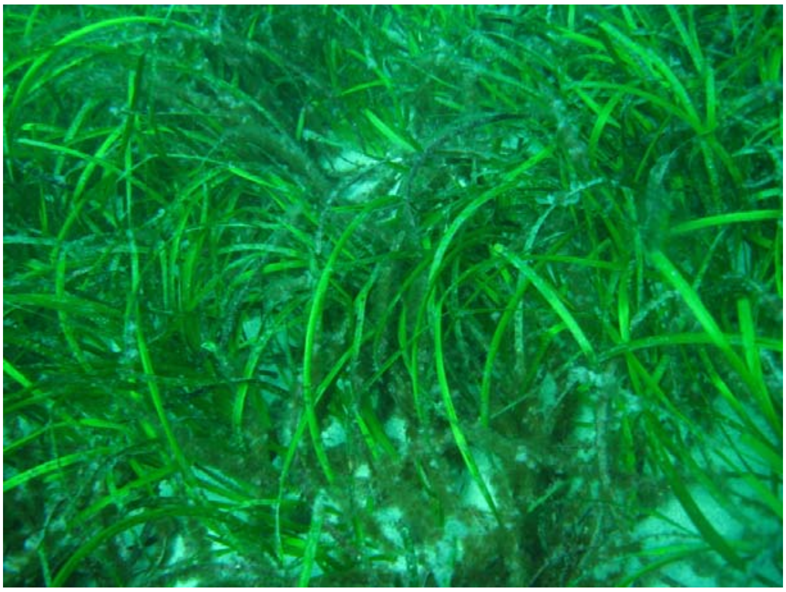


Figure 18: Posidonia at one of the shallow sites

Figure 19: Amphibolis antarctica at one of the shallow sites

11.4.2 Summary of assemblages

The seagrass surveys recorded the following:

- Seagrass cover from quadrats: three seagrass taxa and one substrate type
- Cryptic fish and invertebrates from within-canopy belt transects: 1766 individuals from 32 taxa (mainly invertebrates), and
- Fish from above-canopy belt transects: 21 individuals from two species.

The seagrass beds were dominated by tapeweed (*Posidonia angustifolia*/*sinuosa*) and wireweed (*Amphibolis antarctica*) and could be considered as typical assemblages found in shallow, moderately-exposed locations across much of South Australia. Many of the invertebrate taxa are typical of seagrass habitats but several taxa are more usually associated with reefs, which may have been due to the close proximity of the coastal reefs in the region. Very few fish were observed.

A full list of taxa found at each site is presented in Table 8, Appendix B.

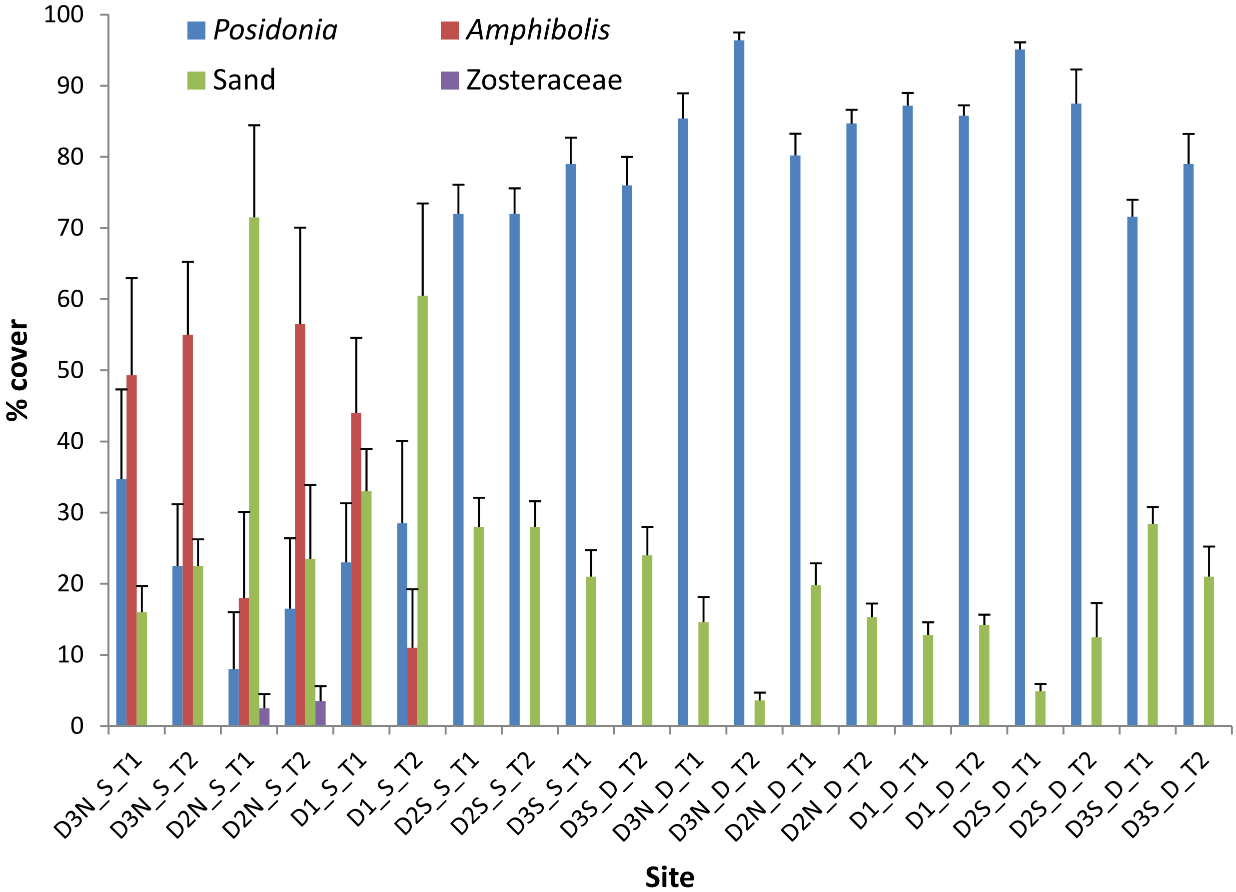
11.4.3 Seagrass cover

The data for seagrass cover are presented in Table 9, Appendix B.

Apparent differences between the sites for the composition of seagrass cover (Figure 20) and seagrass versus sand cover (Figure 21) were confirmed, with both components found to be statistically significantly different across locations (P = 0.001). *A. antarctica* was dominant at some of the northern shallow sites, but was absent from the other shallow sites and the deeper sites which were dominated by *Posidonia angustifolia*/*sinuosa* (Figure 20) This pattern contributed to a significant difference amongst sites within depths for the PERMANOVA (P = 0.001).

Seagrass cover was significantly denser at the deep sites than the shallow sites (P = 0.001, Figure 21). The reason for this result was not so much a difference in actual cover where seagrass was present but because of the high variability between replicates at the shallow sites (see error bars in Figure 21) which varied from 100% seagrass cover to 100% bare sand cover (i.e., seagrass cover was non-uniform across some transect lines due to the presence of large sand holes where seagrass was absent). This patchiness was probably a reflection of the more dynamic conditions and fringing nature of the shallower seagrass beds. In contrast, no large sand holes (i.e. quadrats of 100% sand cover) were recorded at the deeper sites where seagrass cover across transect lines was relatively uniform. Seagrass cover values of > 90% are typically classified as ‘dense’ while values between 40 and 90% are ‘medium’ (Bryars and Rowling 2009). Thus the seagrass meadows at the Site (even when including the sand hole data) would be described as medium to dense cover (Figure 21).

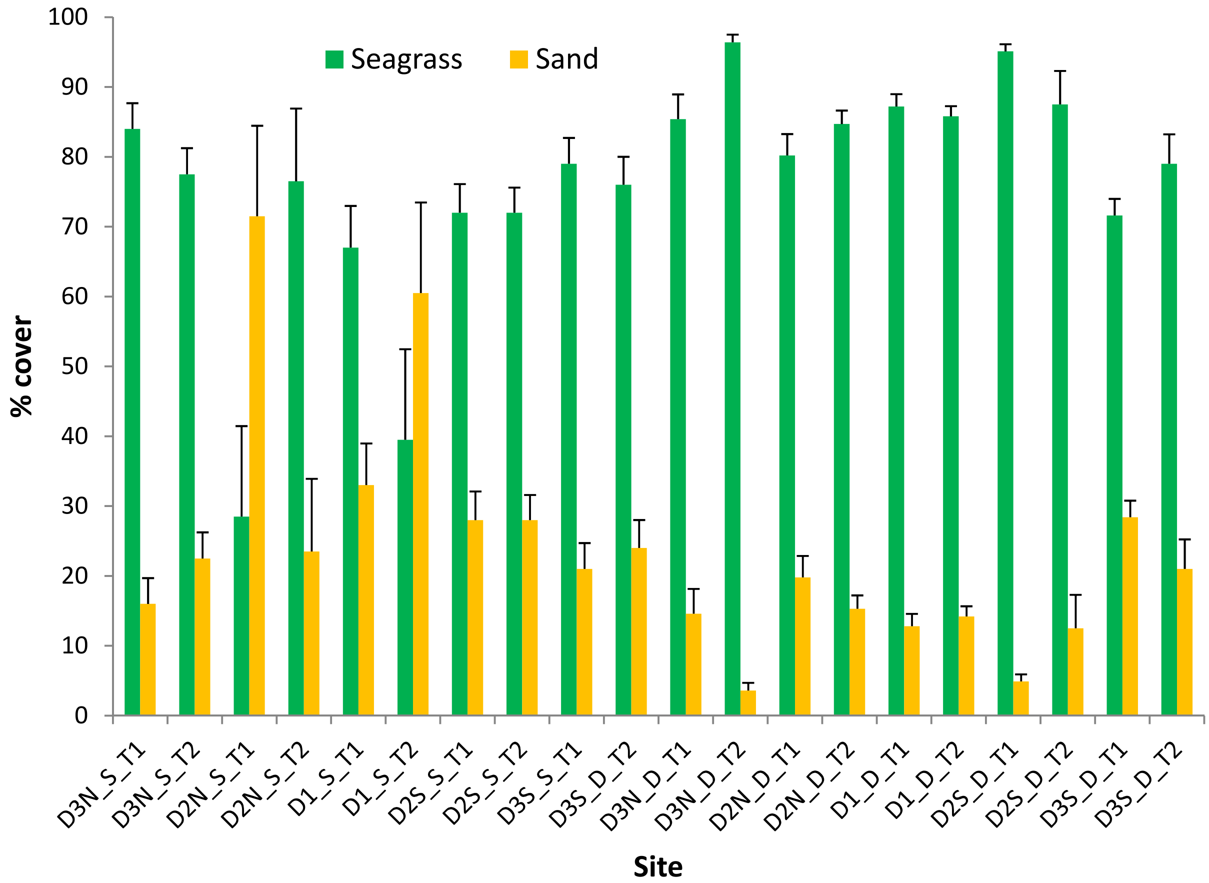
Figure 20: Percent cover of seagrass taxa and sand from quadrat counts across all transects and sites. Values are means (+ standard error (SE)) from the 10 quadrats per transect.



Posidonia = Posidonia angustifolia/sinuosa, Amphibolis = Amphibolis antarctica.

Site codes: D=Distance / N or S =North or South / S or D is shallow or deep / T=transect

*Figure 21: Percent cover of seagrass (*Posidonia, Amphibolis*, Zosteraceae combined) versus sand from quadrat counts across all transects and sites. Values are means (+ standard error (SE)) from the 10 quadrats per transect.*



Site codes: D=Distance / N or S =North or South / S or D is shallow or deep / T=transect

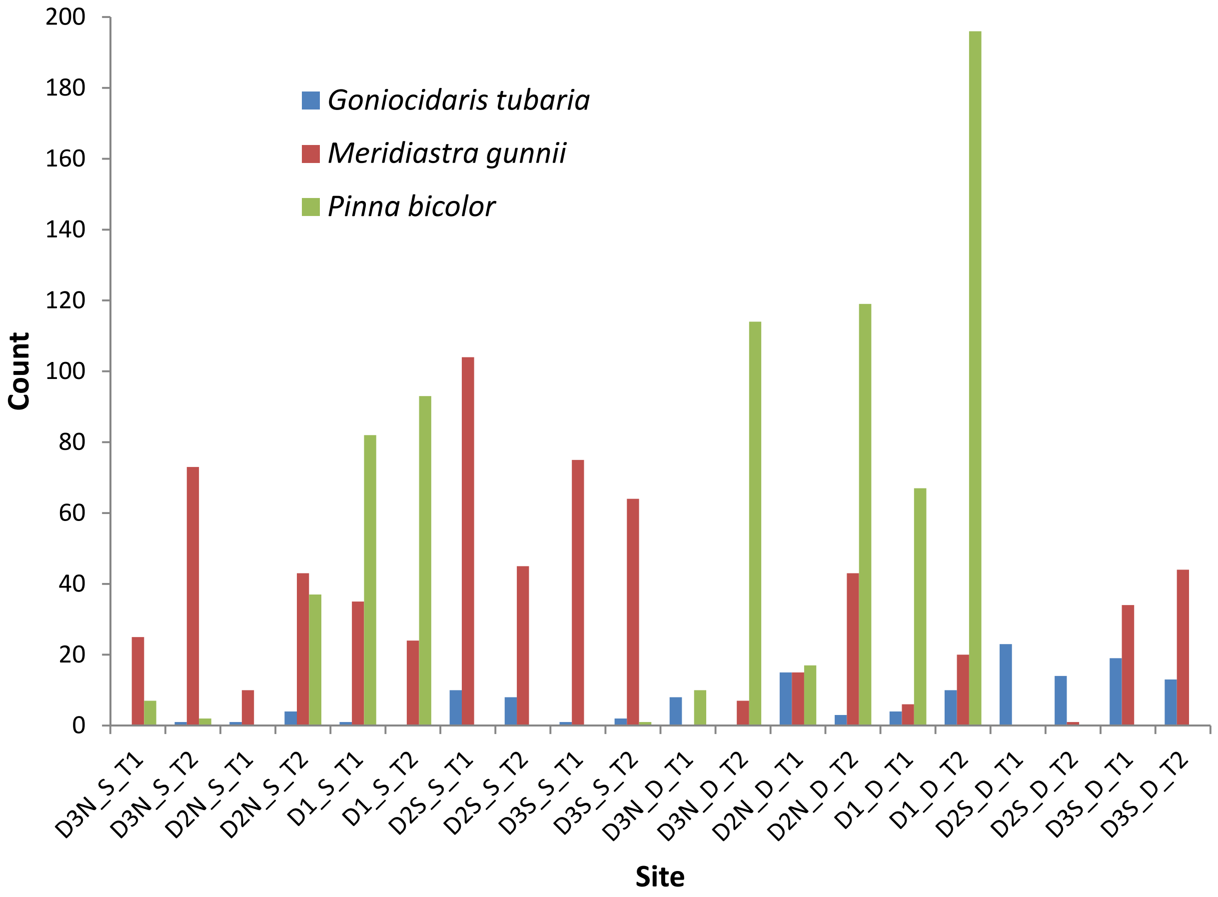
11.4.4 Mobile invertebrates and cryptic fish

A total of 32 taxa were identified and 1,766 specimens counted in the belt transect surveys for cryptic fish and invertebrates (refer to Table 10, Appendix B). Three of these taxa were clearly numerically dominant: the six-armed star (*Meridiastra gunnii*) and the Razorfish (*Pinna bicolor*), and to a lesser extent the Pencil urchin (*Goniocidaris tubaria*) (Figure 22). While *M. gunnii* and *G. tubaria* were present at all sites, *P. bicolor* was virtually absent from the two southern sites (just one individual at Distance 3 South shallow-transect 2 (D3S_S_T2) (Figure 22). The non-uniform distribution of *P. bicolor* is typical of this species as it is long-lived (Edgar 2008), sessile, and has patchy settlement of post-larvae (Butler and Keough 1981). A PERMANOVA showed significant differences between shallow and deep sites (*P* = 0.001), and also between sites within depth classes (*P* = 0.002). This pattern was also apparent in an nMDS plot, but with generally close alignment of transects within sites (Figure 23). A SIMPER analysis indicated that the following seven species contributed to 51% of the differences between the shallow and deep sites (in order of importance): *P. bicolor*, *M. gunnii*, Gobiid spp., *G. tubaria*, *Pyura* sp., *Nectocarcinus integrifrons* and *Tosia australis*. Two of these species (*Pyura* sp., and *Gobiid* spp.) were relatively rare but contributed to the significant differences because they were absent from the shallow sites. It is unknown whether this was due to a real spatial pattern or differences in diver searching ability and/or differing search conditions at the deep sites (e.g. a more open seagrass canopy).

While many of the invertebrates at the Site are known to be associated with seagrass beds (Edgar 2008; Gowlett-Holmes 2008), it is unknown how typical the assemblage is of the region or Spencer Gulf in general as similar types of belt transect surveys are rarely conducted in seagrass beds in South Australia (and thus there is a lack of comparable data). The two most common species, *M. gunnii* and *P. bicolor*, are recognised seagrass or sandy substrate inhabitants (Edgar 2008) with *M. gunnii* feeding on drift seagrass and organic material (Gowlett-Holmes 2008). The next most common species, *G. tubaria*, is not generally associated with seagrass but rather with reefs (Edgar 2008; Gowlett-Holmes 2008), but is known to feed on encrusting invertebrates and also scavenges (Gowlett-Holmes 2008).

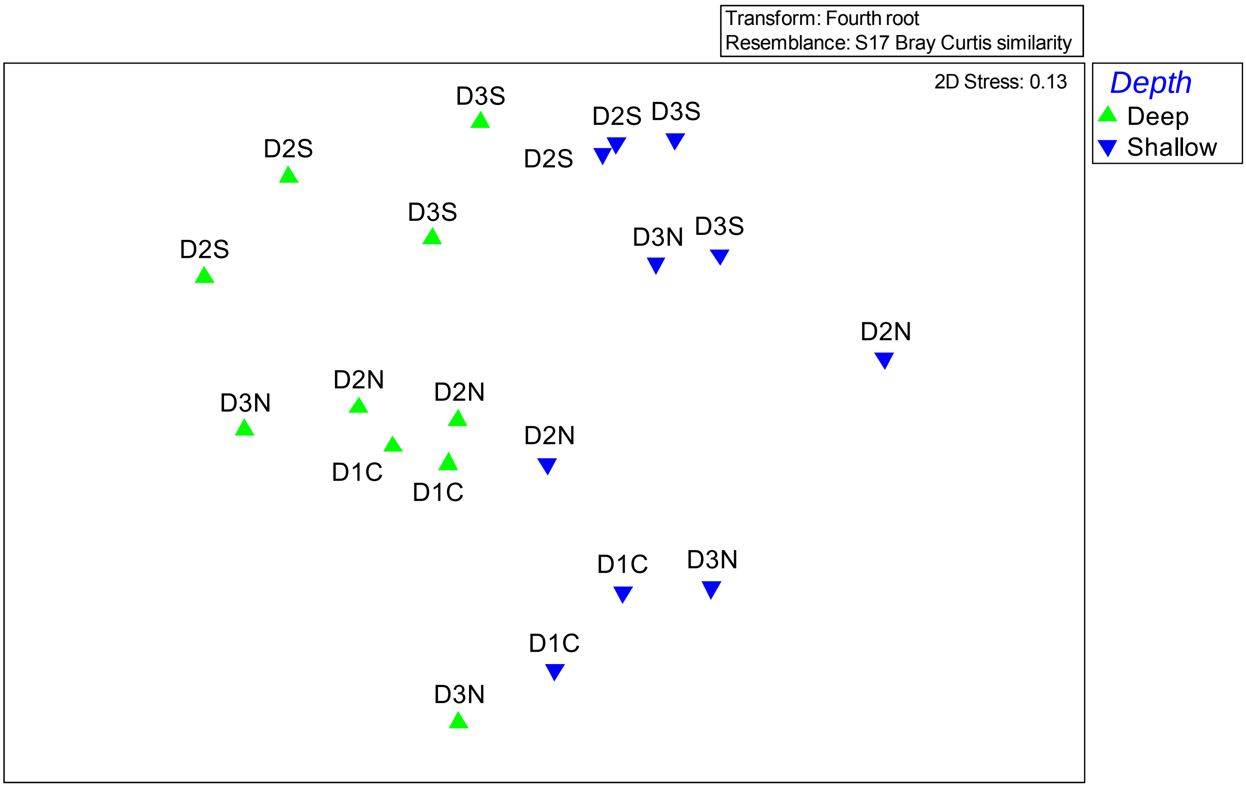
Some other species of note were the Greenlip abalone (*Haliotis laevigata*) and the swimming anemone (*Phlyctenactis tuberculosa*). *H. laevigata* were recorded at several of the shallow sites on sand amongst seagrass leaves, which is unusual as they are usually found on hard reef substrate (Edgar 2008). *H. laevigata* were likely feeding on the red filamentous epiphytic algae that was noticeably present on the *Amphibolis* seagrass; all 12 specimens were recorded only at the shallow sites where *Amphibolis* was found, and drift red algae are one of the preferred foods of *H. laevigata* (Gowlett-Holmes 2008). *P. tuberculosa* is a large, colourful, and highly mobile anemone (Edgar 2008) that was recorded at several sites. Another species of note (not for its presence but rather for its large size) was the pheasant shell (*Phasianella australis*) as most specimens were approaching the maximum height of 100 mm (Gowlett-Holmes 2008); this species is also known to feed on epiphytic algae (Gowlett-Holmes 2008), which were abundant on the local seagrasses. An unusual finding was a square-bodied four-armed specimen of the biscuit star (*Tosia australis*) which normally has five arms although Edgar (2008) reports that they can be relatively common.

Figure 22: Counts of the three most abundant taxa on the seagrass belt transect surveys across all transects and sites.



Site codes: D=Distance / N or S =North or South / S or D is shallow or deep / T=transect

Figure 23: Non-metric mutildimensional scaling (nMDS) ordination plot of cryptic fish and invertebrates from belt transect surveys



Site codes: D = Distance, N = North, S = South

The nMDS ordination plot above shows spatial separation of deep versus shallow sites, and generally close alignment of transects within sites.

11.4.5 Demersal fish

The data for demersal fish are presented in Table 11, Appendix B.

Very few species or individuals of fish were sighted during the fish surveys. Only *Siphonognathus beddomei* (n = 20) and *Haletta semifasciata* (n = 1) were recorded and only on the shallow sites. *Siphonognathus beddomei* is typically found on reefs (Edgar 2008) rather than seagrass and may have been present at the shallow sites due to their close proximity to the coastal reef. *H. semifasciata* is associated with seagrass (Edgar 2008). The low numbers of fish was unsurprising as many seagrass species are highly cryptic and/or avoid divers.

11.5 Other Findings

11.5.1 Recreationally and commercially-significant species

Commercially and recreationally important species recorded during the surveys included the Razorfish (*Pinna bicolor*, n = 745 individuals) and the Greenlip abalone (*Haliotis laevigata*, n = 12 individuals). However, the Razorfish were located in a depth that is not usually fished, i.e., they are normally harvested from intertidal areas.

11.5.2 Rare and/or threatened species and communities

The species recorded as part of the seagrass surveys represent organisms which are typically found associated with seagrass meadows in South Australia. The presence of rare or protected species was not noted during the habitat survey; however, a naturally rare leucosiid crab (*Cryptocnemus vincentianus)* was identified as part of the benthic macro-infauna assessment. More information about the presence of this species at the Site can be found in Section 13.4.2.

11.6 Description of Seagrass Meadows from Video Sled Footage

Video sled footage was collected during the baseline surveys to refine the habitat maps of the Site, and to confirm the suitability of the proposed control locations. For seagrass meadows, the footage provided information about the presence and density of seagrass species, including the extent of their distribution, with footage collected from the Potential Impact Zone (Distance 1 to Distance 3 North and South), as well as the control locations (Distance 5 and 6 North and South).

The methodology used for the video sled has been described later in the report in Section 12.2.

Inspection of the footage indicates that while seagrass meadows were present at all sites, there were some differences in the species present. In particular, these differences were as follows:

- *Amhibolis antarctica*: within the Potential Impact Zone (Distances 1 to 3 North and South), monospecific meadows of *A. antarctica* were present at approximately 7 - 8 m BSL at the northern end of the zone (Distance 1, Distance 2 and 3 North, however were absent from the more southern sites (Distance 2 and 3 South). *A. antarctica* was recorded at Distance 6 South, however it was not recorded at Distance 5 South, Distance 5 North or Distance 6 North. This is possibly due to the depth at which filming started (12-14 m) compared to the other sites. Aerial images of the area indicate that these sites have more extensive subtidal reef areas which extend further offshore, which would account for the lack of seagrass meadows in shallower water (see also Figure 4 - Habitat map, in Appendix A).

- Mixed beds of *A. antarctica* and *Posidonia* spp. occurred within the Potential Impact Zone (Distance 1, Distance 2 and 3 North) from approximately 8 – 9.5 to 10 m BSL. At Distance 6 South (which was the only other site with *A. antarctica* present), mixed meadows were present between approximately 9 – 9.5 m BSL.

- *Posidonia* spp.: from approximately 10 - 10.5 m, monospecific meadows of *Posidonia* spp. were present within the Potential Impact Zone. The density of *Posidonia* spp. became sparse from approximately 14 m BSL and ceased to be present at 15 m BSL. At the southern control sites (Distance 5 and 6 South), *Posidonia* spp. meadows were present between 9.5 m BSL to approximately 13 - 14 m BSL, where they ceased to be present, while in the northern control sites (Distance 5 and 6 North) *Posidonia* was present until 15.9 m and 15.7 m, respectively, and

- *Heterozostera nigricaulis* and *Halophila australis:* these species were present within the Potential Impact Zone and the southern control locations (Distance 5 and 6 South) however they were not recorded at the northern control sites (Distance 5 and 6 North). Where present, these species were reported as sparse. It is noted that while the video footage was not clear enough to determine the species of Zosteraceae present at the Site, visual observations made by divers when collecting sediment samples suggests that *H. nigricaulis* was the species present.

The spatial variability recorded between the Potential Impact Zone and the proposed control sites has implications for the ongoing monitoring to be undertaken at the Site. Quantitatively documenting these habitat differences prior to any impact occurring is a key element to the survey design. Without these ‘before’ data, differences between sites may be perceived as impacts attributable to the construction of the proposed jetty.

11.7 Potential for Impacts on Seagrass Meadows

The potential impacts from the proposed jetty construction on subtidal seagrasses can be separated into those resulting from the construction and operational phases.

11.7.1 Construction phase

During construction it is anticipated that disturbance to seagrass species will be restricted to the footprint of the proposed jetty (and in particular, directly under individual piles) and to those areas which may be used by the jack up barge (up to 5.5 m either side of the proposed jetty). It is expected that the potential for impacts will be from the physical disturbance of habitats (for example, from the jack up barge) rather than from the effects of turbidity and sedimentation (due to the mitigation measures proposed).

Based on this assessment, a conservative estimate for each seagrass association has been calculated. This area is referred to as the construction footprint and it represents what is considered to be the maximum area which *may* be affected by contruction activities. However, as this area includes the entire area under the jetty as well as the 5.5 m buffer either side, the extent of seagrass loss is anticipated to be significantly lower than the estimates provided below. These (coarse) estimates are:

- Mixed meadows of *A. antarctica*, *P. sinuosa* and *P. angustifolia* constitute approximately 1,317 m^2 in the shallower areas of the seagrass habitat at the Port (at approximately 7-9.5 m BSL). The seagrass meadows are moderately dense, consisting of approximately 50% cover and 50% bare sand, and
- Mixed meadows of P. sinuosa and P. angustifolia constitute approximately 3,385 m^2 in the deeper areas of the seagrass habitat at the Port (at approximately 10 to 14 m BSL). In this area, seagrass is dense, proving up to 90% cover and 10% bare sand.

In addition to these areas, very sparse cover *of H. nigricaulis* and *H. australis* is present in the deeper areas of the site (to a depth of about to 17 m BSL). The area where *H. nigricaulis* may be impacted during construction activities is estimated to be approximately 6,520 m^2. However, within this area it is thought that *H. nigricaulis* and *H. australis* cover only approximately 5 to 10% of the total estimated area.

Pile-driving activities will also generate high levels of underwater noise and this has the potential to impact marine animals. An assessment of the potential impacts from acoustic pollution has been undertaken, the detail of which are provided in Section 17.0. In summary, no effects on marine mammals are anticipated; however some localised effects (up to approximately 500 m from the source) may be experience by some fish species. Notwithstanding this, no measurable effects are expected and no effects at the population level are anticipated.

11.7.1.1 Mitigation measures

End-over-end construction of the proposed jetty and pile fabric filtering will assist with minimising impacts on seagrass meadows by reducing the potential for sedimentation plumes and seagrass damage from the use of the jack up barge and from pile driving and drilling operations.

11.7.1.2 Recovery of seagrasses post-construction

The recovery of seagrasses at the site post-construction is thought likely in those areas either side of the proposed jetty, which may be affected by localised physical damage from the use of the jack up barge. While *Posidonia* and *Amphibolis* species can be slow to recover from large-scale losses, recovery can occur more rapidly when a local source of recruitment remains present, as will be the case at the Port.

The areas under the jetty will remain subject to shading, and as such, are discussed further in Section 11.7.2 below. *Heterozostera nigricaulis* and *H. australis* are known to be opportunistic coloniser species, which are seasonally variable. Any loss or disturbance of these species during the construction phase is considered likely to be short-term and therefore recovery is expected to occur.

11.7.2 Operational phase

Potential impacts post-construction are considered likely to be associated with decreased light availability due to shading by the proposed jetty structure, and potentially increased sedimentation due to changes in the local hydrodynamics surrounding the proposed jetty. It was previously reported that increased sedimentation from shipping activities may also be a potential source of impacts; however, Port operational measures will be in place which will ensure that large vessels will not be under their own power within 1.5 km of the jetty. This will ensure that propeller wash will not contribute to increased sedimentation.

The effects of shading are thought likely to be limited to area in the immediate vicinity of the jetty. The most abundant seagrass species at the Site are *Posidonia angustifolia, Posidonia sinuosa* and *Amphibolis antarctica.* The most recent field investigations indicated that *P. angustifolia* is the more dominant of the two *Posidonia* species present at the Site. Sparse, patchy coverage of *Heterozostera nigricaulis* and *Halophila australis* also occurs. These species of seagrass are all endemic to Australia.

P. angustifolia is a widespread species which can live in deeper waters and disturbed environments with low light (IUCN 2011a). The depth range for *P. angustifolia* is from 2-50 m in open near-shore waters. At shallower depths and in relatively sheltered situations, this species occurs sympatrically with *P. sinuosa* and *Amphibolis* spp. (IUCN 2011a). At depths of 35 m it has been observed with sparse *Heterozostera tasmanica* and *Halophila ovalis* (IUCN 2011a). As *P. angustifolia* is adapted to low light conditions, it may prove to be reasonably resilient to the effects of shading from the jetty.

Around Australia, there have been major areas of loss across the range of *P. sinuosa* that have caused significant population declines. Major threats to this species are a decrease in water quality, sedimentation and coastal development (IUCN 2011b). This species is listed as Vulnerable under criterion A2 on the IUCN Red List for Threatened Species. However, while *P. sinuosa* is listed as Native Vegetation under the SA Native Vegetation Act (as are all of the seagrasses present at the Site), it is not listed as endangered, vulnerable or rare under the National Parks and Wildlife Act (1972) or the Environment Protection and Biodiversity Act 1999. This species is considered likely to be more susceptible to the effects of shading from the jetty than *P. angustifolia.*

A. antarctica is a seagrass that dominates (with *Posidonia* spp.) the subtidal environment in western and southern Australia (IUCN 2011c). Overall, its population is thought to be stable (IUCN 2011c). In south-eastern Australia, it forms patches of varying sizes at the mouth of some bays, and occurs in areas dominated by sandy siliceous sediments and exposed to ocean swells. It can be present to depths of 22 m in clear non-polluted water. It is a slow-growing seagrass that is reportedly (Walker 1989, as cited in IUCN 2011) tolerant of very high salinity levels. This species is considered likely to be more susceptible to the effects of shading from the jetty than *P. angustifolia.*

Shading experiments on the *Posidonia* and *Amphibolis* genera have shown that they are remarkably tolerant of shading for prolonged periods (e.g. Mackey *et al.* 2007; Collier *et al.* 2009; Lavery *et al.* 2009). Nonetheless, if the level of shading is sufficiently high and for prolonged periods, then death of these seagrasses can occur. The impacts of shading from the proposed jetty will depend upon the amount of light that still penetrates beneath the proposed jetty and how this varies across the depth gradient of seagrass distribution. If shading is heavy enough, then it is considered likely that the deeper *Posidonia* beds, which appear to be already near their lower light limits, will die before the shallower *Posidonia*.

The orientation of the proposed jetty will also have an influence on any shading effect and the approximately east-west orientation of the main section of the proposed jetty approaches the maximum shading effect possible due to the east-west movement of the sun. During summer when the sun is at its highest orientation, the shading effect would be greatest as the area directly beneath the proposed jetty would receive reduced light almost all day. Nonetheless, it is unknown if this level of shading will be detrimental to the long-term survival of the seagrass and due to variation in the angle of the sun across seasons, the areas under or to the south of the jetty that receive maximum shading will vary across the year; this phenomenon may well assist with persistence of the seagrasses.

In regard to increased sedimentation, hydrodynamic modelling indicates that some sedimentation may occur inshore of the berthing jetty, with increases to seabed levels predicted to be in the order of 0.03 to 0.05 m per annum (ASR 2011). Owing to the ability of seagrass to trap suspended sediments (Edyvane 1999b), and given the region is a moderately high energy coastline, it is possible that the existing habitats will absorb any additional sediment input/movement as a natural process. Notwithstanding this, as seagrass beds are susceptible to decreases in water clarity and sedimentation (Edgar 2001), ongoing monitoring to assess project-related changes to seagrass meadows should form an important component of future ecological surveys. As with the effects of shading, it is considered likely that sedimentation effects (if they occur) will be observed in deeper *Posidonia* meadows (which are already nearing their light limits), before those in shallower areas.

Additionally, scour holes around the individual jetty piles are predicted to form. These scour holes are likely to be approximately 0.3 to 1.4 m in depth with a long-shore length of 0.6 to 2.0 m) (ARS 2011); however, the areas which may be affected by these additional changes will likely be the same as those affected by shading (for scour holes) and sedimentation (for increased sandy patches).

If habitat fragmentation occurs (through complete loss or reduced seagrass cover), these changes may bring about localised changes in the faunal assemblages associated with the seagrasses. Edgar (2001) reports that relatively slight changes in the composition or density of seagrass can produce a disproportionately large change in the faunal assemblages. Tanner (2005) showed fragmentation of seagrass meadows in the Gulf of St Vincent to have a negative effect upon populations of mobile crustaceans (e.g. ghost shrimp, amphipods); however, sessile or sedentary infaunal species (polychaete worms, bivalves) were little affected. The effects of habitat fragmentation, should they occur, are expected to be limited to the area beneath and immediately surrounding the jetty, and therefore the displacement of marine fauna as a result of the installation of the jetty is considered to occur at a relatively small scale compared to the extent of seagrass meadows present in the region.

As discussed elsewhere, other potential impacts from the ongoing operation of the Port may include increased suspended particulates (and therefore increased turbidity) through loss of export material or accidental releases (if they occur). Operational measures will be implemented to minimise the potential for accidental loss of product and to reduce the risk of accidental releases into the marine environment.

Potential impacts to populations of fish from the ongoing operation of the Port are considered likely to be negligible due to their mobility, the extent of nearby suitable habitat and the restricted area that will be utilised by port operations.

11.7.2.1 Mitigation measures

Operational measures (such as enclosed conveyors) will be implemented to minimise the potential for accidental loss of export material and to reduce the risk of accidental releases into the marine environment. These management measures play a key role in mitigating the potential for increased turbidity.

Without these measures being effectively implemented, there is the potential for reduced light and sediment deposition to impact seagrass meadows. As with reef biota, seagrasses are susceptible to decreases in water clarity (Edgar 2001). Increased nutrients and suspended sediments can also impact filter-feeding sessile invertebrates.

Ongoing monitoring of seagrass meadows will assist with ensuring that the mitigation measures are being effectively implemented.

The effects of shading from the jetty are considered likely to result in at least some changes to the composition and abundance of the seagrass meadows. While the immediate effects of shading are anticipated to be restricted to the area under the jetty, Golder note that if seagrass loss does occurs, then localised changes to sediment stability and changes to the faunal assemblages associated with these areas may subsequently occur. If such changes are reported during monitoring surveys, measures to stabilise the sediment may need to be considered.

11.7.3 Potential seagrass disturbance area calculation

The extent of potential disturbance to seagrass meadows has been estimated at approximately 4,702 m^2. This estimate comprises the area immediately under the jetty as well as a buffer of approximately 5.5 m either side to ensure the estimate is more conservative. Within this area, the following seagrass associations occur.

- Mixed meadows of *A. antarctica*, *P. sinuosa* and *P. angustifolia* constitute approximately 1,317 m^2 in the shallower areas of the seagrass habitat at the Port (at approximately 7-9.5 m BSL). The seagrass meadows are moderately dense, consiting of approximately 50% cover and 50% bare sand, and
- Mixed meadows of P. sinuosa and P. angustifolia constitute approximately 3,385 m^2 in the deeper areas of the seagrass habitat at the Port (at approximately 10 to 14 m BSL). In this area, seagrass is dense, proving up to 90% cover and 10% bare sand.

In addition to this estimate, an area of approximately 6,520 m^2 constitutes very sparse cover of *H. nigricaulis* and *H. australis*. Within the latter estimate, these seagrasses are thought to cover only approximately 5 to 10% of the total estimated area.

The areas presented above represent the areas under, and immediately surrounding the jetty that are expected to be subject to shading (refer to Figure 2, Appendix A). The current understanding of the project suggests that the area under the jetty is most likely to demonstrate effects from the development of the Port. Changes to the cover of seagrass species, if they occur, are considered likely to be permanent, although it is anticipated that some species (namely *P. angustifolia* but possibly also *A. antarctica*) may be tolerant of decreased light levels and survive ongoing shading.

While it is considered likely that impacts to seagrass beds will be largely limited to the area under and immediately surrounding the proposed jetty, a more conservative upper extent of 113,406 m^2 has also been calculated due to the possibility of impacts occurring from increased sediment depositionand decreased water quality. The estimate is linked to the area identified by the hydrodynamic modelling as potentially being subject to increased sedimentation over a 50 year period (ASR 2011). As stated above, seagrasses have the ability to trap suspended sediments (Edyvane 1999b) and given the moderately high energy coastline in which the proposed Port is situated, it is possible that the existing habitats will absorb any additional sediment input/movement as a natural process.

The seagrass beds were dominated by tapeweed (*Posidonia angustifolia/sinuosa*) and wireweed (*Amphibolis antarctica*) and could be considered as typical assemblages found in shallow, moderately-exposed locations across much of South Australia. The species recorded as part of the seagrass surveys represent organisms which are typically found associated with seagrass meadows in South Australia. The presence of rare or protected species was not noted during the current survey.

11.7.3.1 Seagrass recovery after Port closure

Seagrass recovery subsequent to the closure of the Port will depend on the extent and nature of the seagrass loss over time, as well as the extent and nature of other (future) pressures which are unrelated to the operation of the Port.

Given the current understanding of the potential for impacts to occur as a result of the operation of the Port, and assuming that the environmental condions in Spencer Gulf remain relatively consistent over time, it is expected that seagrass communities will recover once the Port ceases to operate (and the infrastructure is removed from the marine environment). This is due to the nature of the losses which, if they occur, are expected to be:

- localised (for example, primarily under the proposed jetty, however if they occur more broadly, are likely to be restricted to up to 500 m either side of the proposed jetty); and
- not complete loss of vegetation (for example, an overall reduction in vegetative cover or increased habitat fragmentation/patchiness).

The nature and extent of these losses suggests that localised sources of recruits would remain and these would support the recovery of seagrasses in the area.

11.8 Conclusions

The seagrass beds were dominated by tapeweed (*Posidonia angustifolia*/*sinuosa*) and wireweed (*Amphibolis antarctica*) and could be considered as typical assemblages found in shallow, moderately-exposed locations across much of South Australia. The seagrass cover was found to be significantly higher at the deeper sites compared to the shallow sites. The reason for this result was not so much a difference in actual cover (where seagrass was present) but because of the high variability between replicates at the shallow sites which varied from 100% seagrass cover to 100% bare sand cover. This patchiness was probably a reflection of the more dynamic conditions and fringing nature of the shallower seagrass beds. The seagrass meadows at the Site could be described as medium to dense cover.

Many of the invertebrate taxa that were recorded as part of the surveys were typical of seagrass habitats but several taxa recorded are more usually associated with reefs. This may have been due to the close proximity of the coastal reefs in the region. Very few fish were observed during the surveys.

The current understanding of the project suggests that the area under the jetty is most likely to demonstrate effects from the development of the Port. Changes to the cover of seagrass species, if they occur, are considered likely to be permanent, although it is anticipated that some species (namely *P. angustifolia* but possibly also *A. antarctica*) may be tolerant of decreased light levels. Ongoing monitoring will assist with delineating the extent of impacts, should they occur.

12.0 SUBTIDAL SANDY SUBSTRATE

Subtidal sandy habitats form important components of our marine environment. Despite their visual simplicity in comparison to more physically complex habitats, it has been found that some unvegetated habitats are just as important as seagrass meadows as a nursery habitat for fish (Brown 2001).

Generally, sand and other soft substrates provide habitat for some of the most basic life forms (for example, amoebas and foraminifera) (Baker 2004). The species diversity of groups such as bivalves is rich in sand habitats. Bivalve shells are important secondary producers, particularly in sand and sand-gravel habitats (Baker 2004). Some of the numerous small, sand-dwelling invertebrates are an important food source for sand-dwelling fish species (Baker 2004).

Limited information pertaining to sandy substrates in the Spencer Gulf region was found during the literature search. However, the information found indicated that, in depths greater than 15 m, sandy substrates are typically bare, with coarse sediment with undulations increasing in size with distance from the coast (Baker 2004). Within the region, these habitats are reported to support Blue Swimmer Crabs (*Portunus armatus*), Sand Crabs (*Ovalipes australiensis*), Western King Prawns (*Penaeus latisulcatus)*, Razorfish (*Atrina tasmanica* and *Pinna bicolor*), King (*Pecten fumatus*) and Queen (*Equichlamys bifrons*) Scallops, and Southern Calamari (*Sepioteuthis australis)* (Bryars, 2003).

The species detailed above are consistent with what has previously been identified (Golder 2009 and Golder 2011) as occurring in the habitat at the Site.

12.1 Current Understanding of the Sandy Substrates at the Site

The mid benthic zone was previously defined as between 15 m BSL and 20 m BSL and up to approximately 500 m offshore. This outer extent corresponded to the end of the proposed jetty and was the deepest area considered as part of the previous surveys.

The deep benthic zone was recently identified as requiring consideration due to possible variations in the design of the proposed jetty. For the purpose of the current survey, this zone was defined as the area between 500 m to 1 km offshore in 20+ m water depth.

The above mid benthic and deep benthic classifications were adopted for the following purposes:

- Delineating the extent of the previous surveys (and therefore known habitat conditions) from deeper areas that were potentially different from that which had previously surveyed, and
- Aligning the habitat descriptions with the proposed jetty and berthing area.

The results of the current survey have illustrated that these two ‘zones’ are similar and best described as ‘sandy substrate’ habitat.

12.2 Survey Methods

Underwater video was selected as the most suitable method to obtain habitat information about the mid- and deep benthic zones. While diver visual surveys using self-contained underwater breathing apparatus (S.C.U.B.A) can provide more detailed and quantitative observations of seabed habitats, they can be inefficient when the survey requires large areas to be considered, or where the water depth tightly constrains the diver’s bottom time (and therefore the number of dives that can be completed in a day).

Underwater video has the advantage of being able to survey a more extensive area of the seabed – and this is particularly efficient when the habitat type does not require an intensive quantitative sampling regime.

Underwater video footage was collected between 10 and 12 August 2011. Footage was collected from the Potential Impact Zone (Distance 1 to Distance 3 North and South), as well as the control locations (Distance 5 and 6 North and South).

From previous surveys it was known that the Site was dominated by sand from aproximately 15 m BSL. While the extent of the previous surveys was limited to a depth of 20 m, it was expected that bare sandy substrate would likely be present further offshore. For this reason, and due to the large area from which information was being targeted, towed video sled footage was deemed an appropriate means of collecting descriptive information about this habitat at the Site.

The towed video transects were undertaken by subcontractors Dive Connect Pty Ltd. The equipment used was custom-built specifically to enable large areas of seabed to be filmed in an accurate and efficient manner. The equipment included a water-proof high-definition camera, lighting, depth and temperature gauge and GPS equipment. The equipment was secured to a winged sled arrangement that allowed both low speed tracking along the bottom and high speed travel just above the sea bed, with the sled being tethered to the tow vessel by a 12 mm line and the fibre optic umbilical.

On board the vessel, a hard drive recording and voice overlay was achieved through the vessels built-in monitors, GPS and diver communications systems. The GPS data was communicated by voice to the recorded data, which allowed waypoint reference numbers to identify when a feature was found (i.e. substrate/ habitat change).

The speed of the vessel was adjusted to suit the terrain and abundance of marine life in view, i.e. the flat terrain with minimal marine life could be covered at speeds up to 3.0 knots typically in depths 18 m and greater, whereas in highly diverse areas such as nearshore environments, speed can be as slow as 0.1 knot.

12.3 Results and Discussion

The sandy substrate habitat was assessed as two separate components, these being mid benthic and deep benthic areas. Discussion regarding these areas is provided below.

12.3.1 Description of recorded site conditions

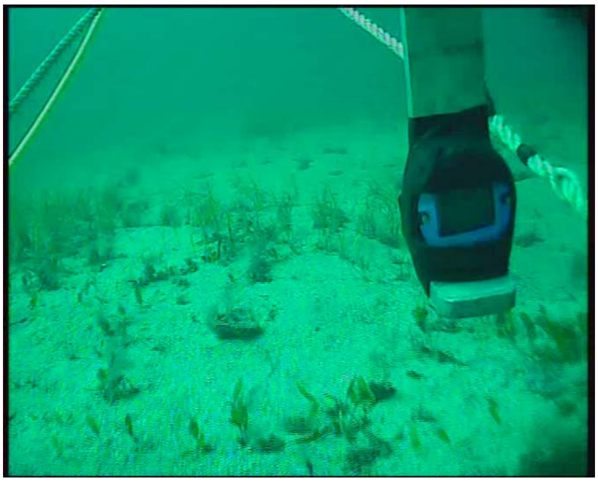
Mid benthic

As described above, the mid benthic zone was previously defined as 15 m to 20 BSL.

The video sled footage demonstrated that *Posidonia* spp. was present at the shallower extent of the depth range (approximately 15 m BSL); however, the cover was patchy and quickly disappeared as depth increased. Occasional small patches or individual shoots of *Heterozostera nigricaulis* and *Halophila australis* were also recorded, with the two species often found as mixed, sparse cover (Figure 24a).

Some differences were noted between the presence of seagrasses in the Potential Impact Zone compared to locations further north or south (Distances 5 and 6, North and South). For example, while *H. nigricaulis* was recorded in the southern control sites, it was present to a larger extent within the Potential Impact Zone, however it was patchy and sparse at all locations. At the Potential Impact Zone, *H. nigricaulis* appeared to be present to a depth of 16 m, which was the deepest record of its presence at any of the locations (Figure 24b).

Figure 24: Photos captured from video footage taken from the Potential Impact Zone



a) A patch of *H. nigricaulis* and *H. australis* (14.9 m deep).

b) Small patches of *H. nigricaulis* (15.7 m deep)

Beyond 17 m BSL, the presence of seagrass was not observed; however, *A. tasmanica, P bicolor*, *P. fumatus*, *Ostrea angasi* (Native Oyster), sponges and ascidians were recorded as present.

With the exception of patchy, and typically sparse, coverage of *Posidonia spp., H. nigricaulis and H. australis,* the mid benthic areas were typically dominated by bare sand.

Deep benthic

The deep benthic zone was previously defined as >20 m and between 500 m to 1 km offshore.

As with the mid benthic zone, the deep benthic zone was dominated by bare sand with *A. tasmanica, P bicolor, P. fumatus*, *O. angasi*, sponges and ascidians noted as being present (albeit infrequently).

At the Potential Impact Zone and the southern control sites, sponges were rarely noted. However, sponges became more abundant and individuals were notably larger at Distance 6 North, (Figure 25).

Figure 25: Photos captured from video footage taken in the deep benthic zone.

a) Photo taken from the Potential Impact Zone (22.5 m deep). Bare sandy substrate.

b) Photo taken from Distance 6 North (22.6 m deep). Sponges are present.

The depth gradient at the Site did not change rapidly, with the change in depth between the outer extent of the mid benthic zone and the outer extent of the deep benthic zone being an increase of 3 m over 500 m (from 20 m to 23 m between 500 m and 1 km offshore).

Overall, the sandy substrate habitat (both mid and deep benthic) was dominated by bare sand. Brown (2001) described unvegetated benthic habitats with increased water velocity (such as that experienced at the Site), as commonly dominated by ascidians, bivalves such as scallops, and other invertebrates such as sea stars, small sponges, sea pens, and bryozoans. This description is consistent with what was found at the Site.

The difference in subtidal habitat from the outer extent of the mid benthic to the outer extent of the deep benthic zone showed no significant habitat changes.

12.4 Other Findings

12.4.1 Recreationally and commercially significant species

The following species have been recorded during previous in-water qualitative surveys of this area (Golder 2011): *O.australiensis, P. bicolor* and *A. tasmanica*, *P. fumatus* and *O. angasi.*

Given the small area that will be used for Port operations, the potential for impacts on these species is considered negligible in regards to recreational or commercial significance.

12.4.2 Rare and/or threatened species and communities

There were no rare, threatened or protected species noted during the surveys of the sandy substrate habitat.

12.5 Potential for Impacts on Subtidal Sandy Substrates

The sandy substrate habitat is characterised by bare substrate that is interspersed with patchy, sparse *H. nigricaulis* and *H. australis.* These species are widespread in southern Australia and are considered common. Potential impacts to this habitat are considered below.

12.5.1 Construction phase

Disturbance to seagrass species is considered likely to be minimal and restricted to the footprint of the proposed jetty and that of the jack-up barge which may be used in areas where these species occur. As these seagrasses are known to be opportunistic coloniser species any loss or disturbance is considered likely to be short-term.

Pile-driving activities will generate high levels of underwater noise and this has the potential to impact marine animals. An assessment of the potential impacts from acoustic pollution has been undertaken, the detail of which are provided in Section 17.0. In summary, no effects on marine mammals are anticipated; however some localised effects (up to approximately 500 m from the source) may be experienced by some fish species. Notwithstanding this, no measurable effects are expected and no effects at the population level are anticipated.

Potential impacts to benthic macro-infauna are discussed in Section 13.5.

Potential impacts to fish from construction and shipping activities have been considered as part of the assessment of acoustic pollution (refer to Section 17.0).

12.5.2 Operational phase

Disturbance to sandy substrates from propeller wash has been identified as a potential source of impacts in previous marine ecological assessments undertaken by Golder (Golder 2009 and 2011). In order to minimise turbidity and disturbance to sediments, operational measures will be implemented that will ensure that cargo vessels are not under their own power within 1.5 km of the jetty. Such measures will minimise the potential effects on the sandy substrate habitat.

Other potential impacts from the ongoing operation of the Port may include increased suspended particulates (and therefore increased turbidity) through loss of export material or accidental releases (if they occur). Operational measures will be implemented to minimise the potential for accidental loss of product and to reduce the risk of accidental releases into the marine environment.

In regard to increased sedimentation, hydrodynamic modelling indicates that some sedimentation may occur inshore of the berthing jetty, with increases to seabed levels predicted to be in the order of 0.03 to 0.05 m per annum (ASR 2011). Increased sedimentation has the potential to interfere with the feeding mechanisms of filter feeding sessile invertebrates (such as the Razorfish, *P. bicolor*), which in turn could lead to increased mortality of the species at the Site.

Over time there may also be the potential for shipping related contaminants to accumulate in the sediment under the berthing jetty and surrounding the jetty. Some chemicals can be acutely toxic to organisms when introduced at concentration above natural background levels, while others can bioaccumulate[14] or biomagnify[15] over time. Given the sediments are sandy, and as the Site is situated on a moderately-exposed coastline, the potential for accumulation is less than if the Site was situated in muddy, sheltered conditions.

Impacts to populations of fish from the ongoing operation of the Port are considered likely to negligible due to their mobility, the extent of nearby suitable habitat and the restricted area that will be utilised by Port operations.

12.5.3 Mitigation measures

As discussed above, operational measures to reduce impacts on the marine environment will include vessel management practices that will reduce the potential for turbidity and increased suspended sediments and enclosed conveyors to minimise loss of export material.

12.5.4 Extent of potential disturbance

The extent of potential disturbance for sandy substrate habitat has been calculated as 47,480 m^2. This estimate encompasses the area directly under and immediately surrounding the proposed jetty. This figure is considered to be an overestimate as potential impacts (if they occur) are considered likely to be restricted to the loss of sparse, patchy seagrasses (*H. nigricaulis* and *H. australis)* under the jetty.

A more conservative figure of 429,584 m^2 has been calculated, and this includes the key areas which have been identified by hydrodynamic modelling as potentially being subject to increased sedimentation (ASR 2011). As above, this figure is also considered an overestimate of the potential extent of impacts as it is based on an aerial extent which does not reflect the likely loss of habitat given the sparse and patchy nature of organisms present within this habitat at the Site.

12.6 Conclusions

The sandy substrate habitat for the purpose of these surveys has been defined as the area where *Posidonia* seagrass meadows cease to exist (approximately 15 m BSL) to 1 km offshore (approximately 23 m BSL). The area is dominated by bare sand, and at times, sparse, patchy *H. australis* and *H. nigricaulis.*

The presence of common species such as *O. australiensis, P. bicolor* and *A. tasmanica*, *P. fumatus* and *O. angasi* has also been reported.

There were no species of conservation significance reported for this habitat type during these surveys

[14] Bioaccumluation occurs when the concentration of a chemical accumulates over time in the tissue of plant and animal.

[15] Biomagnification occurs when chemicals are concentrated as they pass up the food chain. Biomagnification occurs in the tissues of a carnivores as predators eat many times their body weight in prey and retain the persistent chemicals bound within the tissues of that prey (Edgar 2001)

13.0 BENTHIC MACRO-INFAUNA

Macrobenthic infauna (macro-infauna) are defined as the invertebrate fauna that are typically larger than 0.5 mm (Edgar 2001) that predominately live in the sediments (Simpson *et al.* 2005). As these organisms are not very mobile, they are useful indicators of water, sediment, and habitat qualities, and consequently, the ecological implications of long-term changes to these components can be monitored.

Systematic subtidal studies of Spencer Gulf are most prevalent for the northern or upper gulf region (Shepherd 1983; Ainslie *et al.* 1989; Hutchings *et al.* 1993; Ainslie *et al.* 1994), but only a limited number of studies have been carried out in the central and southern region of Spencer Gulf. Hutchings *et al.* (1993) investigated the infaunal community of marine sediments and seagrass beds in the upper Spencer Gulf near Port Pirie, which showed that polychaetes largely dominated the infauna inhabiting seagrass beds both in terms of number of individuals and species.

13.1 Current Understanding of Macro-infaunal Assemblages at the Site

Golder (2009) has previously undertaken macro-infaunal sampling at the Site. Samples were collected from both seagrass and sandy substrate habitats in the vicinity of the proposed jetty. As reported (Golder 2009), all sites contained members of the phyla Annelida, Arthropoda and Mollusca. Diversity was generally greater in the samples collected from sites with denser seagrass than those from areas of less dense seagrass.

The amphipods found in the samples from less-dense seagrass patches were identified to family level and belonged to only three families, Amphilochidae, Corophiidae and Gammaridae. Amphipod diversity in some samples was notably higher, with amphipods from seven families recorded in a single replicate. Similarly for polychaetes, worms from nine families were collected in a single replicate from an area with dense seagrass, whereas a maximum of six polychaete families was recorded in a sample collected from another site (sandy substrate).

Abundance of polychaetes was, however, higher at sites with lower densities of seagrass, particularly polychaetes of the family Spionidae, which were present in high numbers, with a maximum of 69 spionids recorded in one replicate sample. Spionids are generally abundant in fine-grained substrates and are opportunistic, often in response to enrichment and disturbance (Probert *et al.* 2001). Syllidae polychaetes were the second most abundant family, followed by capitellids and terebellids.

13.2 Survey Methods

The sampling locations for the macro-infaunal survey were predetermined according to a reduced version of the gradient-sampling design. Samples were collected from both seagrass and mid benthic sandy habitats, at depths of approximately 11 m and 20 m BSL respectively. The locations (refer to Figure 6, Appendix A) were as follows:

- One impact location (the Potential Impact Zone), which included three separate sites (one central site (Distance 1) and one of each site to the north and south of the central site (Distance 3 North and Distance 3 South).
- Two control locations each at a distance of approximately 3.5km from the central impact location, consisting of one location to the north and south (Distance 6 North and Distance 6 South), and
- Two reference (additional ‘near field’ control) locations. One at Lipson Island (due to the high conservation value of the region as a National Estate Conservation Park) and one approximately 1.5 km north (Distance 5 South and Distance 5 North respectively). At these locations, sampling was restricted to the mid benthic zone due to unfavourable weather conditions).

The survey was undertaken between 8 and 12 July 2011.

Macro-infaunal samples were collected using diver-operated 10 cm diameter polyvinyl chloride (PVC) cylindrical hand corers. At each site (within an area of approximately 10 x 10 m), four replicate corers were inserted into the sediment to a depth of 15 cm and then capped to prevent loss of the sample. Once retrieved, each sample was processed on the research vessel using a 500 µm sieve and transferred to a labelled storage container. The samples were then placed in chilled eskies until the team returned from the day's field trip where they were then preserved using a 10% buffered formalin solution.

On completion of the survey, the samples were transported to a specialist sub-consultancy (Infauna Data) who has expertise with the identification of marine and estuarine invertebrates. The processing of the samples involved the samples being washed with water into 500 µm sieve and then transferred into elongated storage container. The sample was then elutriated and the small debris and light macro-infauna washed, via 500 µm sieve, into a second storage container. The contents of both containers were then sorted and the macro-infauna identified to family level with the use of Lecia MZ6 microscope (6.2 to 40 magnifications). Any macro-infauna that was not easily recognised was placed in a labelled vial for identification at the end of sorting. Any invertebrates that could not be identified by personnel at Infauna Data were then submitted to the Museum of Victoria for identification by specialist taxonomists.

Once identified, all organisms were recorded on a site data sheet, removed from the sample and placed in a labelled 'site vial'. The vial was then filled with 70% ethanol and plugged with cotton wool in preparation for archiving.

Upon completion of the sample processing, the information on the laboratory tally sheets was checked and the information transferred onto a data matrix. The data matrix was checked against the laboratory tally sheets on completion of the data entry for quality assurance purposes.

13.2.1 Taxonomic resolution

Table 12, Appendix B presents the taxonomic resolution used for the macro-infaunal samples.

13.3 Results and Discussion

The data collected for each of the sampling methods have been tabulated and are presented in Table 13, Appendix B.

13.3.1 Description of recorded site conditions

Targeted sampling was undertaken in order to collect information about macro-infauna assemblages within both the seagrass and mid benthic sandy habitats. As marine ecosystems are influenced by the water depth, both habitat types were sampled within a narrow depth range. For the seagrass habitat, sampling was undertaken at approximately 11 m BSL, while samples from the mid benthic sandy habitat were collected from approximately 20 m BSL.

Within the seagrass meadows, shoot densities were noticeably different at each sampling location, with samples from Distance 3 North found to be difficult to collect due to the thick seagrass rhizome mat and a dense layer of shell grit at about 10 cm below the sediment surface. Samples from Distance 6 South were easier to collect than those from other locations, which was likely due to the patchier cover of seagrass.

No noticeable differences were reported for the mid benthic sampling locations.

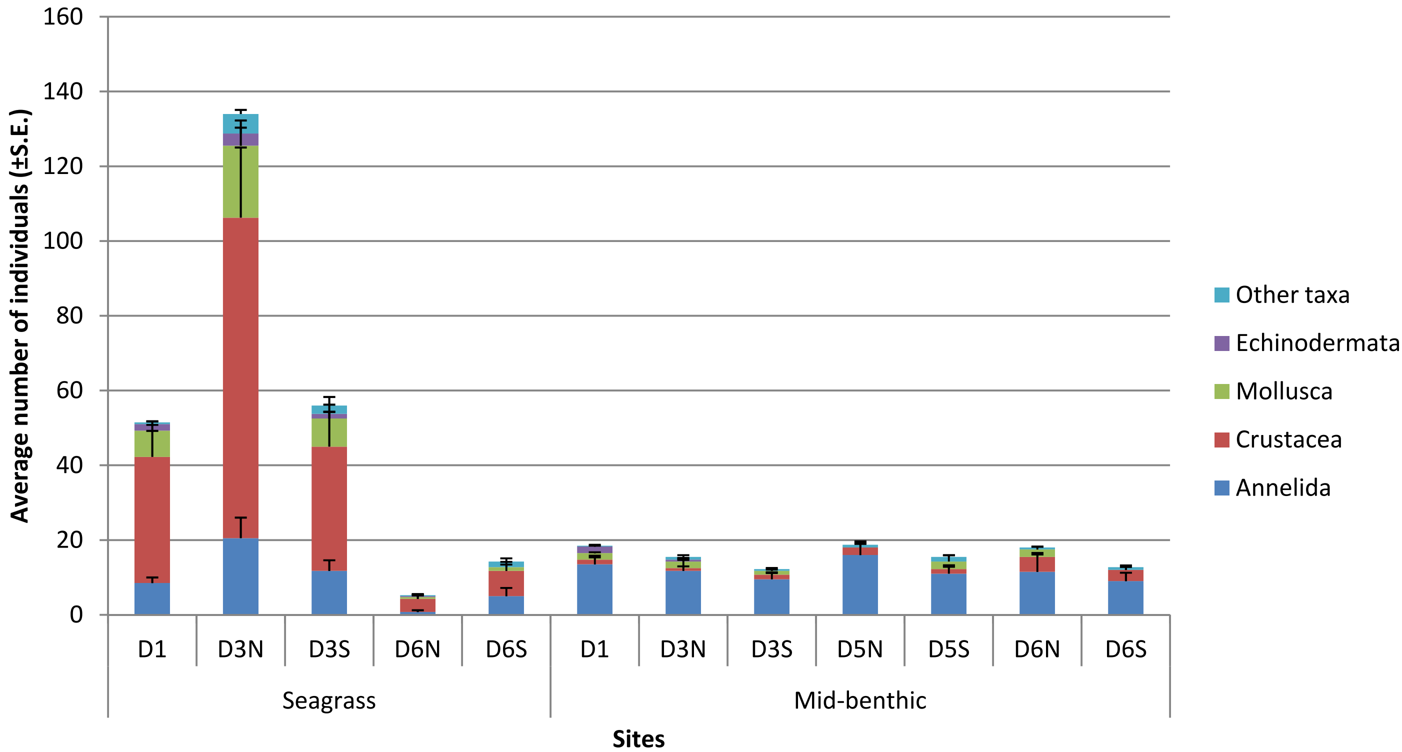
13.3.2 Description of assemblages

The total number of individuals reported for each sampling location varied between sites, with the largest variation in density noted between seagrass sites (range: 21 to 536 individuals for seagrass; and 49 to 75 individuals in the mid benthic habitat). As seen below in Figure 26, the large variation in densities of individuals within the seagrass sites was attributed to larger counts of invertebrates at Distance 3 North, followed by (but at noticeably reduced densities) at Distance 1 and Distance 3 South. The lowest numbers of individuals were from the control locations at Distance 6 North and South.

As shown in Figure 26, the samples from the seagrass habitat are dominated by the presence of crustaceans (for example, amphipods, isopods and crabs), followed by annelids (worms), and to a lesser extent molluscs (for example bivalves and gastropods (marine snails)).

For the mid benthic sandy habitat, the variation in densities of individuals between sites appears to be limited. Annelids (worms) dominated the fauna for all of the mid benthic sites. The differences between the types of fauna reported for the seagrass and mid benthic sandy habitats is considered likely to be due to differences in the above- and below-ground biomass provided by the presence of seagrass shoots and rhizomes.

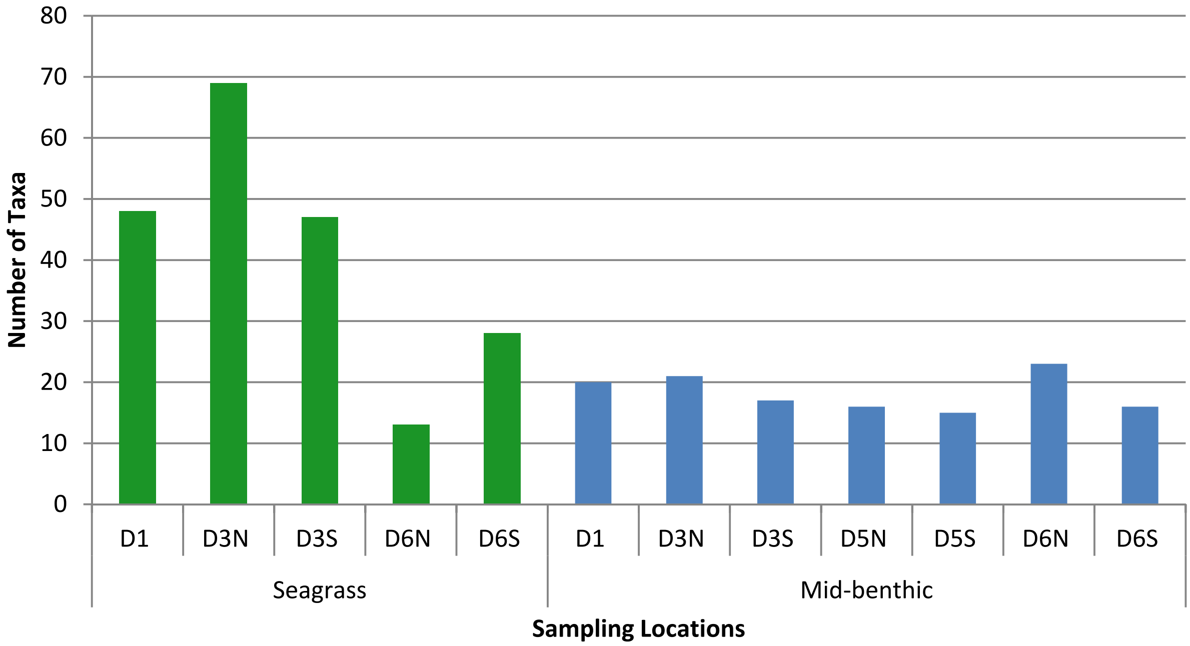
Figure 26: Average Number of Individuals per Site.



Site codes: D = Distance, N = North, S = South

To investigate these differences further, the number of taxa per sampling location was graphed and is shown below in Figure 27. This figure demonstrates that there was a greater diversity of organisms found in the seagrass samples than those collected from the mid benthic sandy habitat. This is consistent with other studies that have investigated the abundance and diversity of macro-infauna assemblages in seagrass compared to those in sandy substrates. Edgar (2001) reports that even relatively slight changes in the density of the plants can produce a disproportionately large change in the fauna.

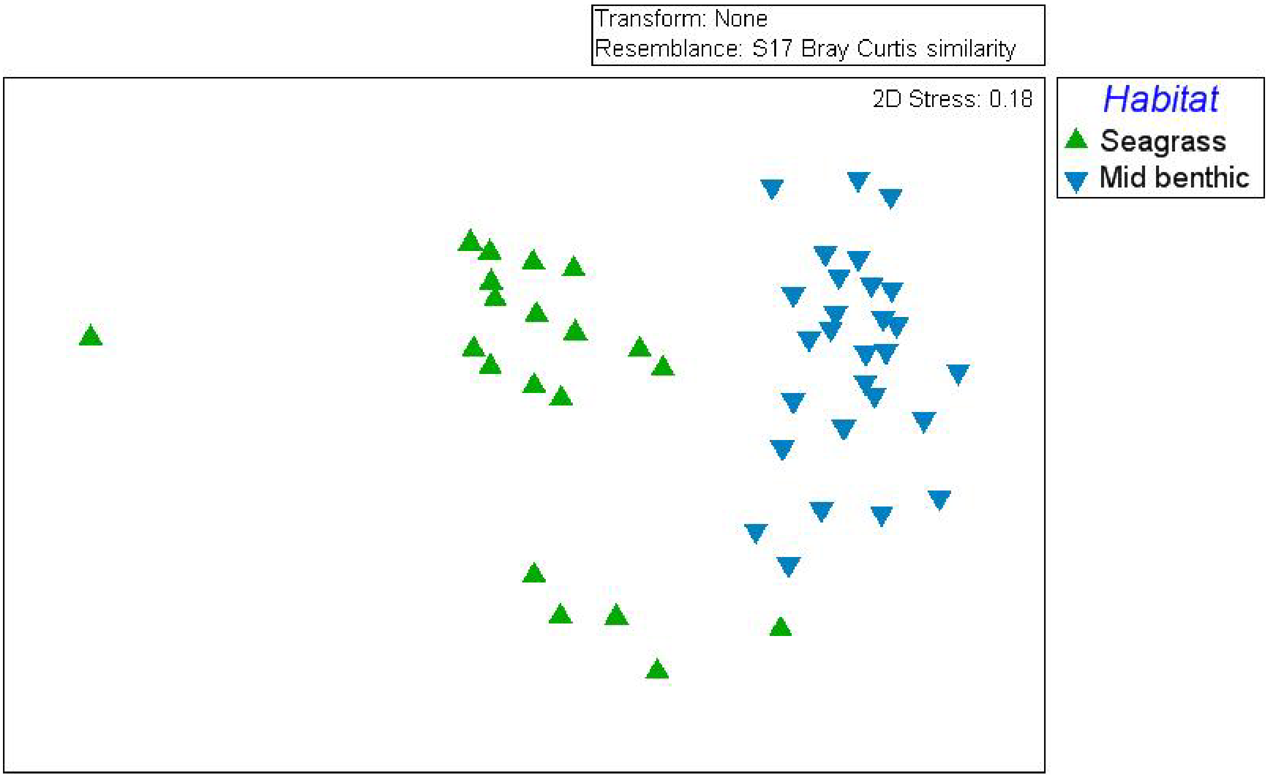
Figure 27: Number of Taxa per Site.



Site codes: D = Distance, N = North, S = South

The above two graphs indicate that there are apparent differences between the macro-infaunal assemblages found in the seagrass habitat as opposed to the mid benthic sandy sediment. For the purpose of identifying the most appropriate approach to the analyses, the apparent difference between the two habitats was explored further using an MDS ordination plot. As seen in Figure 28, the MDS plot indicated that the assemblages recorded from the seagrass and mid benthic habitats were different, and as such, were subsequently analysed separately.

Figure 28: MDS ordination plot of seagrass and mid benthic infauna samples

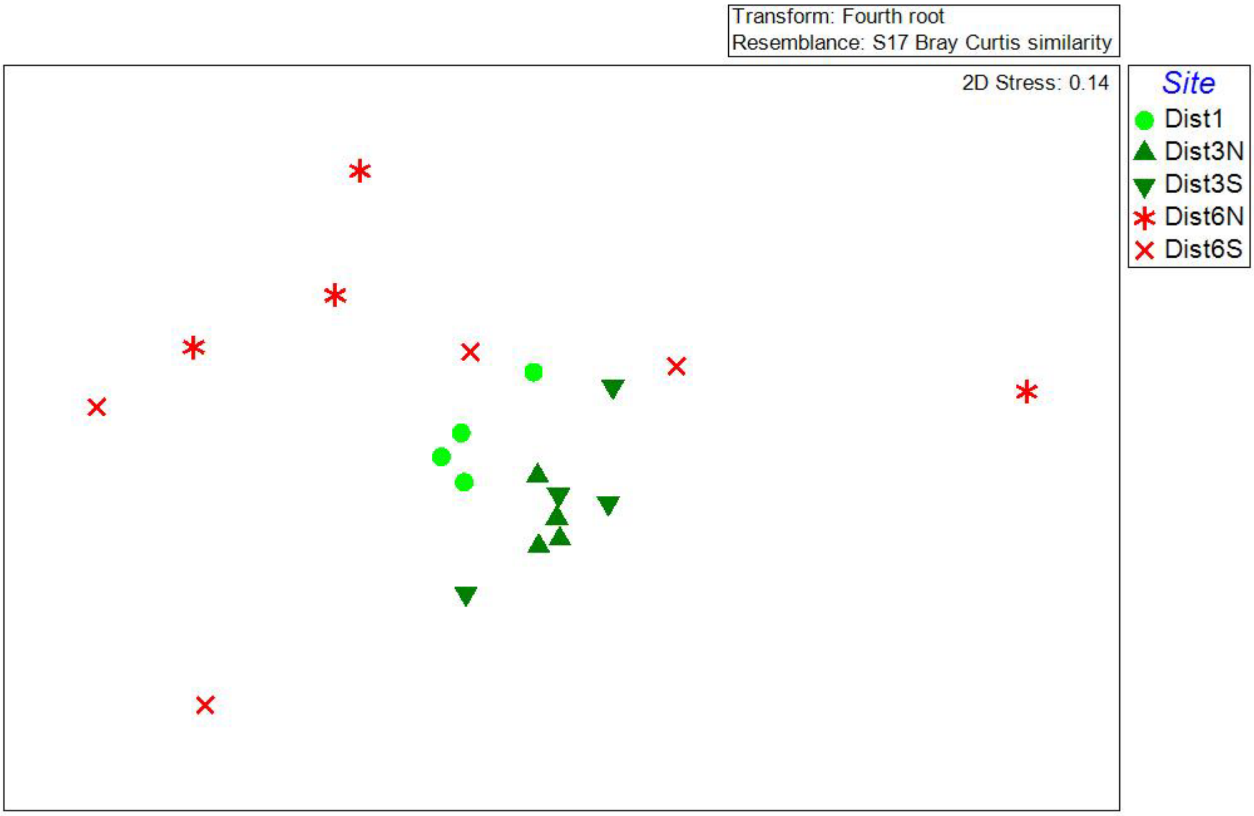


Additional MDS plots were created for both seagrass and mid benthic assemblages in order to investigate whether the assemblages found at each of the sites were similar. The MDS below (Figure 29) indicates that the there was relatively low variability between replicates within some seagrass sites (Distance 1, Distance 3 North and Distance 3 South) and that the assemblages at these sites were also similar to each other. The assemblage recorded at Distance 6 South was less similar to these sites and there was a higher degree of variability between replicates. Distance 6 North was the least similar to the other sites, and it too had a higher degree of within site variability.

The MDS plot below indicates that the samples collected within the Potential Impact Zone (Distance 1, Distance 3 North and Distance 3 South) are different from those collected at the control locations.

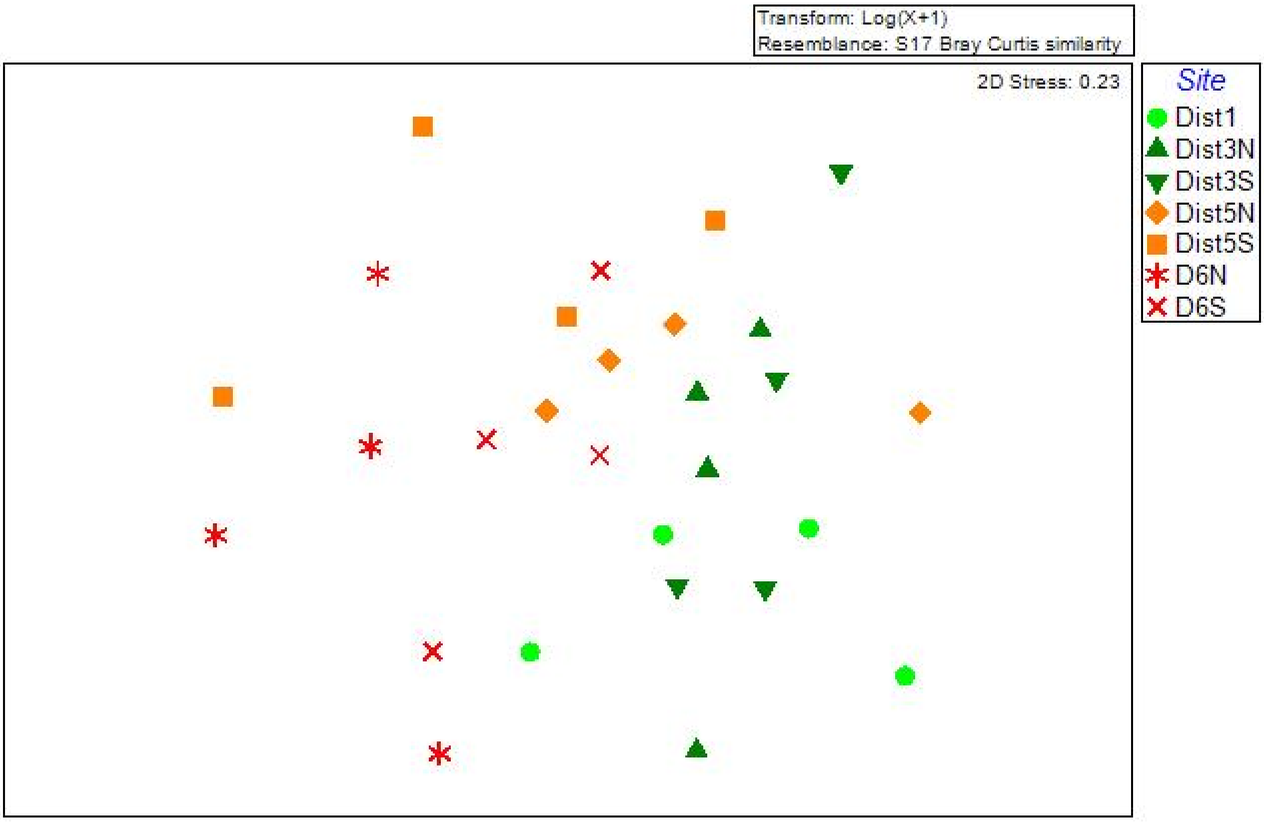
The apparent differences between the Potential Impact versus control locations was supported by the results of the PERMANOVA test which indicated that there was a significant difference between these factors (P = 0.009). This result is likely due to the high variability observed between the Potential Impact sites and the control locations for the number of individuals per site (Figure 26) and the number of taxa per site (Figure 27). The PERMANOVA test also indicated that there was not a significant difference between sites within each location (P = 0.102).

Figure 29: nMDS ordination plot comparing similarity of infaunal assemblages found in seagrass meadows (nearshore) for Control versus Potential Impact locations



Mid benthic infaunal assemblages were similarly explored through MDS and PERMANOVA. Figure 30 below explores differences between the Potential Impact and control locations, as well as sites within these locations.

Figure 30: nMDS ordination plot compariing similarity between infaunal assemblages within the mid benthic sandy substrate for Control versus Potential Impact locations



The MDS plot above indicates that there is a difference between the assemblages recorded within the Potential Impact Zone (samples which mostly fall to the right of the plot) compared with those recorded at the control locations (left of the plot). There is an apparent similarity between the Distance 3 North samples and those collected from Distance 5 North. It is noted that the stress value is high (0.23) which may indicate that there are limitations to accurately interpreting this plot.

The PERMANOVA test supported the apparent difference between the Potential Impact Zone (Distance 1, Distance 3 North and Distance 3 South) and the control locations (Distance 5 North and South and Distance 6 North and South) with the results indicated a statistically-significant difference ($P = 0.014$). There was not a significant difference ($P = 0.115$) between sites within the locations.

13.4 Other Findings

13.4.1 Presence of the marine pest *Musculista senhousia*

The Asian mussel, *Musculista senhousia,* has been found in a number of macro-infaunal samples at the Site. *M. senhousia* is a member of the Mytilidae family and is native to the Pacific Ocean. It is an invasive species in California, the Mediterranean, Australia, and New Zealand (National Introduced Marine Pest Information System (NIMPIS) 2009). Common names for this species include the Asian date mussel, the Japanese mussel, Senhouse's mussel, the green mussel and the green bag mussel.

The majority of individuals were found in samples collected in seagrass beds in the vicinity of the proposed jetty. Thirteen individuals were recorded at Distance 1 (with between one and five individuals per replicate sample), 16 individuals at Distance 3 North (between one and 11 individuals per replicate sample) and seven individuals at Distance 3 South (two samples with three and four individuals, respectively). Distance 6 North and South had one individual reported at each location. There were no individuals recorded in the sandy sediment samples taken from the mid benthic zone.

In previous samples collected by Golder (2009), a species of the Mytilidae family was found which resembles *M. senhousia*. The identity of this species was unconfirmed at the time due to the small size of the individuals; however, given the positive identification of the specimens collected as part of the current survey, it is considered possible that the unidentified Mytilidae may have been *M. senhousia.* The number of individuals reported in samples collected during the previous survey was one, five and six. These low numbers may suggest a slight increase in the number of individuals present at the Site; however additional monitoring would be required to establish any trends in abundance.

13.4.1.1 Ecology and distribution of M. senhousia

M. senhousia is a successful invader species due to high fecundity, rapid growth, a short life span and good dispersal ability. It can reach adult size in only 9 months; however, its life span is typically no longer than two years (NIMPIS 2009). It settles in aggregations and is therefore able to reach high densities.

M. senhousia was first discovered in Australia in 1983 in the Swan River, Western Australia. It has since been discovered in other Western Australian locations as well as Tasmania, and locations around Melbourne, Victoria (NIMPIS 2009).

In South Australia, the mussel was first found on a trawler in 1988 in Port Adelaide, Gulf St Vincent, but was not considered established until the 2001 Port of Adelaide survey. During this survey, the mussel was detected at several sites within Port Adelaide (Wiltshire *et al.* 2010). Subsequent surveys indicated that the population had declined and in the 2007-08 Port Adelaide survey, no specimens were located (Wiltshire *et al.* 2010). Golder was unable to find any records that indicated that *M. senhousia* has previously been reported in Spencer Gulf. Subsequent discussions with Biosecurity SA have confirmed that the presence of *M. senhousia* at the Site is an extension of the pest's known distribution in South Australia.

13.4.1.2 Implications of the presence of M. senhousia

The presence of *M. senhousia* has shown to alter benthic habitats due to the byssal mats formed by the mussel (Crooks 1998). This can restrict growth of seagrasses where seagrass is already patchy (Allen and Williams 2003), but can also increase the species richness and density of the macro-infauna (Crooks 1998). Some of the taxa that appear able to exploit the new habitat provided by *M. senhousia* include tanaids, gastropods, amphipods, insect larvae, and polychaetes. Mussel survival and growth has been found to decline with increasing seagrass shoot density and patch size (Allen and Williams 2003).

Sedimentary properties may also be altered (Crooks 1998). This is caused by the mussels binding sediments and organic matter, trapping faeces and pseudofaeces, and passive deposition of low-density material, creating more organic material (finer sediments). The mussel prefers to settle in groups on soft substrata, but is capable of fouling wharf pilings and man-made structures (NIMPIS 2009).

The implications of these potential habitat and sediment alterations on the ecology of the area are likely to be low considering the low density of specimens found. However, more favourable conditions for the mussel may be created during construction of the jetty if the seagrass habitat is disturbed. This is supported by the National Control Plan for *M. senhousia* (Aquanel 2008) that reports that there are links between human-mediated disturbance and invasion success for *M. senhousia.* Disturbance to seagrass meadows is important to consider as research has shown that patchy or fragmented seagrass beds are vulnerable to invasion by *M. senhousia*, while dense seagrass inhibits invasion (Aqunel 2008).

The addition of man-made structures may also provide new potential habitat for mussel growth as *M. senhousia* is known to form high densities on artificial structures (Aquanel 2008).

13.4.1.3 Vectors for transport

It is thought that the main vectors for the spread of *M. senhousia* to and around Australia are ballast water and ship hull biofouling (Cohen 2005). Management options for these vectors are outlined in Sections 16.2 and 16.3.

13.4.1.4 Recommended Approach to Ongoing Management of M.senhousia

Populations of *M. senhousia* should be monitored as part of ongoing surveys undertaken at the Site. The presence of the species in the area has been lodged with Biosecurity SA and as part of their investigations a site visit will be undertaken to establish its distribution in the region.

Specific measures to eradicate this pest at the Site are not feasible due to the Site being situated on an open stretch of coastline. Therefore, management of *M senhousia* should aim to minimise the risk of this species spreading to other locations. This may occur if the larvae become established in ballast water or mussels become attached to ship hulls during the port construction. It is recommended that *M. senhousia* be managed using the marine pest management plan in Section 16.4.

13.4.2 Rare and/or threatened species and communities

The leucosiid crab, *Cryptocnemus vincentianus* has been identified as occurring at the Site. One specimen was found in the seagrass habitat at the Distance 1 sampling location. The identity of the specimen was confirmed by taxonomic experts at the Museum of Victoria.

The occurrence of this specimen is notable as it is the only species in the genus *Cryptocnemus* (of the five which occur in Australian waters) that is known to occur in southern Australia waters, and its documented presence in Australia is based on a single specimen found in 1927 (Poore 2004). This specimen was recorded from dredged material off Semaphore (Davie 2002) in Gulf St. Vincent. In addition to the Gulf St. Vincent specimen, this species has been reported from subtidal rocky reef samples collected in Western Australia (Keesing in Murphy *et al*. 2006).

13.5 Potential for Impacts on Macro-infauna

Impacts on macro-infaunal assemblages, should they occur, are most likely to be associated with habitat loss (namely seagrass from construction and ongoing shading from the proposed jetty) or from minor localised disturbance of sediments from scour holes (which are predicted to form around individual piles). Some changes to macro-infauna populations may also occur as a result of sedimentation.

These potential impacts are discussed further below.

13.5.1 Construction phase

Impacts on benthic macro-infauna assemblages will occur in the areas directly beneath where piles are installed. These areas constitute a small area and the extent of disturbance to macro-infauna populations is considered to be negligible.

Localised increases in the level of suspended particulates and sedimentation from pile driving and drilling activities also has the potential to create localised impacts, however mitigation measures will be employed during construction activities to minimise the potential for these impacts to occur (refer to Section 13.5.3).

13.5.2 Operational phase

It is anticipated that seagrass loss will be localised to the area in the immediate vicinity of the proposed jetty. As such, it is considered likely that impacts on infaunal assemblages in this habitat will also be restricted to this area. Where seagrass loss occurs, it is predicted that the species composition of macro-infauna assemblages will change to reflect assemblages that are more typically found in sandy substrates in the area.

As discussed above, the crab *C. vincentianus* has been found in one sample at the Site. This crab is considered to be a naturally-rare species, and, as virtually nothing is known about this species (including its distribution, habitat requirements or biology), it is difficult to ascertain what the potential for impacts on this species may be. The three reported specimens of *C. vincentianus* have been found in two (potentially three) different habitats (seagrass and subtidal reef, while the sample from the dredged material may have been from seagrass or sediment). Given the diversity of the habitats, it is unclear whether this species utilises seagrass and reef habitats at different stages of its life cycle or whether it opportunistically exploits different habitats dependent on local environmental conditions. In the absence of more detailed information about the species, some inference can be made about the potential for impacts based on what is known about other species of decapod crustaceans.

Pittman and McAlpine (2001) report that many marine species have evolved a multi-phase life cycle, with each phase of life being characterised by changes in morphology, physiology and behaviour (Thorson 1950; Balon 1984; Hines 1986; Fuiman 1997 as cited in Pittman and McAlpine 2001). For species of crabs, the life cycle follows a typical pattern whereby the adult female crab lays eggs, and the emergent larvae enter the water column as zooplankton. Once developed, they settle out of the water column onto the sea floor as juvenile crabs. Bottom-dwelling species such as crabs utilise the larval stage of their life cycle as a means of facilitating dispersion of the species (Ritz *et al.* 2003). Given that, the distribution of the species in the region will be largely determined by larval dispersal, it is considered unlikely that there will a detrimental impact to the species as a result of the predicted localised loss of habitat under the proposed jetty.

Changes to sediment characteristics under the proposed jetty are considered likely to be localised to the areas surrounding the piles. In addition to this, it was previously reported (ASR 2011) that sediment is predicted to begin to build up immediately inshore of the facility, although it is considered likely that seabed level changes will alter by less than 0.3 to 0.5 m per year. The potential for impacts to occur on macro-infauna communities from sediment accretion is considered likely to be low given the existing naturally dynamic environment at the Site, and due to the opportunistic nature of many benthic infauna (Levinton 1982). Numerous studies (for examples refer to McCauley *et al.* 1977 and Wilbera *et al.* 2008) report that relatively quick recovery of macro-infaunal assemblages is typically found after sediment disturbance occurs. However, it is noted that impacts on macro-infauna (if they occur) are likely to reflect the following:

- The extent of changes to substrate characteristics
- The extent of seagrass loss
- The actual (versus predicted) rate of accretion, and
- The ability of local species to recolonise newly-accreted substrates.

In previous reports (Golder 2009 and 2011), disturbance from propeller wash effects was also identified as a potential source of impacts. More recent information suggests that this is unlikely to be a source of impact as operational measures will be in place to minimise disturbance of the sediments in the vicinity of the proposed jetty. These operational measures will ensure that cargo vessels are not under their own power within at least 1.5 km of the proposed jetty, with tugboats being the only vessels permitted to operate in the area.

Long-term changes to macro-infaunal assemblages may also occur due to shipping-related increases in sediment contaminant levels, however the risk of these potential impacts occurring are also considered low due to the sandy substrate and the wave energy of the coastline.

The abundance of the marine pest *M. senhousia* at the Site may increase as a result of disturbance to seagrass meadows. Research has shown that patchy or fragmented seagrass beds are vulnerable to invasion by *M. senhousia*, while dense seagrass inhibits invasion (Aquanel 2008). The addition of man-made structures may also provide new potential habitat for mussel growth as *M. senhousia* is known to form high densities on artificial structures (Aquanel 2008).

13.5.3 Mitigation measures

As discussed in previous sections, operational measures (such as end-over-end construction, pile fabric filtering, enclosed conveyors, and vessel speed management) will be implemented to minimise the potential for impacts on the marine environment. These measures will assist with minimising increased suspended particulates and turbidity, which will in turn reduce impacts of benthic macro-infauna assemblages.

13.6 Conclusions

Specific information about the macro-infaunal assemblages in the Lower Eyre Pensinsula was not found during the literature search undertaken for this component of work. However, the taxa reported as present in the macro-infaunal samples are broadly consistent with taxa typically found in subtidal seagrass and sandy substrates, with the exception of the crab *C. vincentianus* and the marine pest *M. senhousia.*

Impacts on macro-infaunal assemblages, should they occur, are most likely to be associated with habitat loss (namely seagrass from construction and ongoing shading from the proposed jetty) or from minor localised disturbance of sediments from scour holes (which are predicted to form around individual piles). Some changes to macro-infauna populations may also occur as a result of sedimentation. Operational mitigation measures will be employed during construction activities and during the ongoing operation of the Port to minimise the potential for these impacts to occur.

As there is no information currently available regarding the biology or ecology of *C. vincentianus*, ongoing monitoring at the Site and at control locations may provide a valuable opportunity to gather information about the species. The Museum of Victoria has expressed their interest in obtaining data regarding this species in order to better document its distribution and abundance in the region.

The presence of the marine pest *M. senhousia* at Port Spencer is an extension of its known distribution in South Australia. Biosecurity SA will assess the potential risks associated with this species and will provide advice as to the ongoing management of the species at the Site.

14.0 ARTIFICIAL SUBSTRATES

The development of Port Spencer will result in the creation of artificial substrates at the Site.

In marine systems, man-made structures such as seawalls, jetties and artificial reefs can provide habitat for a diverse set of marine biota. Although artificial structures can be detrimental to local marine ecosystems when first introduced, they can eventually become havens for marine life, resulting in increased abundance and diversity in the region. However, while studies show that artificial habitats generally support the same species as found on natural reefs, the assemblages between natural and artificial habitats usually differ (Clynick et al, 2008).

Artificial structures are also areas where fish tend to aggregate. Because of this, such structures are often assumed to be beneficial to fish populations. However, research investigating whether these habitats sustain viable populations of fish (or whether they just provide structures to which fish are drawn) suggests that artificial reefs act predominately as aggregating devices only and therefore could have detrimental effects on fish stocks by promoting targeted fishing (PIRSA, 2009).

The subtidal infrastructure associated with jetties typically includes pylons and pontoons and at times, additional infrastructure such as pipelines. These structures are common to estuarine and coastal areas throughout the world because they facilitate large-scale commercial and recreational boating (Holloway and Connell 2002). Studies have shown that these structures also represent novel habitats for subtidal epibiota because the diversities and abundances of organisms develop differently between these habitats and rocky reef (Connell 2001a).

The physical presence of hard structures in the area will provide attachment sites for sessile organisms such as sponges, sea squirts and macroalgae. Organisms colonising this new habitat will be likely be recruited from local communities, but there is also the potential for colonisation by non-indigenous marine organisms (e.g.*Carcinus maenas, Musculista senhousia, Sabella spallanzanii*) given the expected degree of marine vessel traffic to and from the area.

15.0 OPPORTUNISTIC MARINE MAMMAL SIGHTINGS

During the field surveys, several marine mammals were sighted at, or in the vicinity of, the Site. A targeted marine mammal survey was not undertaken as part of the current survey, however opportunistic sightings were recorded. These sightings included the following:

- A pod of Common dolphins (*Delphinus delphis*) – approximately 10 individuals
- A pod of Bottlenose dolphins (*Tursiops aduncus*) - approximately 20 individuals, and
- One Southern Right whale (*Eubalaena australis*).

16.0 ASSESSMENT OF POTENTIAL IMPACTS FROM MARINE PESTS

Non-indigenous marine species are marine animals or plants that are not native to Australia but have arrived in the country via pathways such as shipping and other marine-based activities. The establishment and spread of these species can result in pest populations that have the potential to significantly impact marine ecosystems, environments and industries. Australia has over 250 non-indigenous marine species, some of which are aggressive pests. The non-indigenous marine species found in parts of South Australia currently include toxic dinoflagellates, ascidians, bryozoans, hydroids, crustaceans, molluscs, polychaete worms and aquatic weeds (NIMPIS 2009).

Ports are typically the first points of entry for non-indigenous marine species, particularly ports with high volumes of international shipping traffic. The transfer of marine species between domestic ports is now also a recognised problem as pest populations can be spread further than their initial entry location. Mechanisms for this transfer include domestic shipping as well as recreational and coastal development activities.

Possible means for the introduction of non-indigenous marine species at Port Spencer include organisms present in ballast water or as hull biofouling being translocated via construction equipment (i.e., dredges and barges) during the port development and with shipping traffic during the operation of the Port. The creation of jetty structures provides opportunity at the Site of potential translocation for colonisation by marine pests on the newly-formed artificial substrates or in disturbed marine habitats. The presence of a marine pest, *Musculista senhousia* (Asian date mussel) at the Site also requires consideration in biosecurity management to reduce the possibility of transferring this pest species to other locations via vessels leaving Port Spencer.

In Australia there is legislation and guidelines in place to reduce the risk of transferring non-indigenous marine species from vessels to port structures (see discussion below). However in addition to these, it is also prudent for ports to incorporate marine biosecurity management procedures into environmental plans to reduce the risks associated with marine pests at the port. Such procedures can include regular monitoring for marine pest species on underwater structures.

This section provides an overview of the authorities responsible for marine biosecurity management in Australia and the requirements for which ships entering Port Spencer should adhere to as a first measure to reducing biosecurity risk. Further suggestions for the management of marine biosecurity risks at the Port Spencer are based on practices carried out in other Australian ports.

16.1 Marine Biosecurity Authority

The ‘National System for the Prevention and Management of Marine Pest Incursions’ (the ‘National System’) has been implemented in Australia to help protect the marine environment and industries from the effects of marine pests (www.marinepests.gov.au/national_system). The National System has three main aims:

- To prevent new marine pests arriving in Australia
- To respond when a new pest does arrive, and
- To minimise the spread and impact of pests already established in Australia.

The Australian Department of Agriculture, Fisheries and Forestry (DAFF) provides national leadership in the development and implementation of the National System and is the lead agency in implementing Australian government responsibilities under the ‘Intergovernmental Agreement on a National System for the Prevention and Management of Marine Pest Incursions’ (Marine IGA). In South Australia, Biosecurity SA is involved in a number of national committees that aims to improve collaboration and the coordination of the management of aquatic pests across Australia. This includes involvement with the National System.

The Australian Quarantine and Inspection Service (AQIS) provides quarantine inspection services for the arrival of international passengers, cargo, mail, animals and plants and their products into Australia, including monitoring of compliance of international shipping at each first port of call in Australia. AQIS is the lead agency for the management of ballast water ensuring that foreign ballast-water management complies with Australian requirements.

16.2 Ballast Water Management

Australia has ballast water management requirements in place to minimise the risk of translocation of harmful aquatic species in international ships' ballast water – the 'Australian Ballast Water Management Requirements - Version 5'. These arrangements are in line with the International Maritime Organization's (IMO) 'International Convention for the Control and Management of Ships' Ballast Water and Sediment', which Australia has signed subject to ratification. The management requirements have legislative backing and are enforced under the Quarantine Act 1908. Therefore, all arriving international vessels are required to comply with the Australian ballast water management requirements as managed by AQIS.

Ballast water discharge into the Port environment may occur if vessels are arriving ballasted and are loading at the Port. Several management options exist for minimising the biosecurity risk associated with ballast water from international vessels such as the following:

- Non-discharge of 'high-risk' ballast water in Australian waters
- Tank-to-tank transfers, and
- Full ballast water exchange at sea.

It is understood that the latter option will be required to be undertaken by any vessels wishing to berth at Port Spencer.

Such measures could also be applied as a voluntary option for domestic vessels that are considered to present a biosecurity risk via interstate shipping. The release of marine pests with ballast water discharges is most likely if ballast water was taken up in areas known to contain such species (e.g., Hobart & Port Phillip Bay) or if mid-ocean exchanges had not been successfully completed.

It is further recommended that the ballast water management practices employed by vessels entering Australia are considered as best practice for ships travelling from Port Spencer to other international and domestic ports. In this way, good stewardship of the marine environment is encouraged to prevent transfer of marine pests already present at Port Spencer to other locations. This approach could be carried out in combination with any relevant legislation and best practice requirements for the destination port.

The marine biosecurity risk associated with ballast water discharge at Port Spencer could be determined by assessing the main users of the port and their need to discharge ballast water. This risk would also depend on whether the ballast water is seawater, brackish water or fresh water, as well as the vessel design and its previous ports of call. AQIS deems all salt water from ports and coastal waters outside Australia's territorial sea to be a 'high-risk' and capable of introducing exotic marine pests into Australia. Further assessment of the biosecurity risk associated with ballast water could be made when the likely type and frequency of shipping traffic has been confirmed for Port Spencer.

16.3 Biofouling on Vessels

The risk of marine pests being introduced to or spread from Port Spencer through transfer from biofouling can be reduced by incorporating practices that minimise the build up of biofouling into routine vessel maintenance programs. A series of 'National Biofouling Management Guidelines' have been developed for a range of vessel types through the National System and published by DAFF. These guidelines have been developed in conjunction with the Australian shipping industry and provide practical information on managing biofouling on hulls and in niche areas on vessels including commercial vessels and non-trade vessels such as barges and dredges. The guidelines are an important reference for port operators and maintenance contract managers for the following:

- Managing biofouling when operating in Australian waters.
- Preparing a vessel prior to arrival in Australia or departure from a site known to harbour marine pests, to ensure it is free of marine pests on entry or before leaving an infected port.
- Developing maintenance contracts that will meet best practice in biofouling management and ensure optimal performance, and
- Supervising maintenance contractors.

As a brief overview to the guidelines, some of the recommended management practices for vessels that are most relevant to activities at Port Spencer include, but are not limited to, the following:

- Using an antifouling coating that is appropriate for the vessels' operating profile, i.e., to suit the planned docking cycles, vessels speed and activity, and projected lay-up periods.
- Vary the position of docking blocks and supports at each docking to ensure that the areas under the blocks are recoated by antifoulant at least every alternate docking.
- Inspect niche areas between dockings and remove biofouling ensuring that debris is captured and disposed of at licensed onshore facilities. Niche areas requiring close inspection include sea chests, bow and stern thrusters, bilge keels, stabiliser apertures, rudder hinges, cathodic protection anodes, echo sounders, propellers and shafts. Note that there are restrictions on in-water cleaning in Australia (see further detail below).
- Regularly use steam blow-out pipes (where fitted) to minimise biofouling growth in sea chests.
- Regularly operate and monitor marine growth prevention systems fitted to internal seawater systems to ensure effective biofouling control is maintained, and
- Closely monitor any seawater system operating whilst in port as it will be particularly vulnerable to biofouling and treat to remove any accumulated biofouling.

Further details on biofouling management guidelines are available at www.marinepests.gov.au.

To minimise the risk of further exotic organisms establishing in Australian waters, the Australian and New Zealand Environment and Conservation Council (ANZECC) in consultation with AQIS established the 'ANZECC Code of Practice for In-water Hull Cleaning and Maintenance 1997' which applies in Australian waters to all commercial vessels. Some of the most relevant code of practice procedures to be considered at Port Spencer are presented below:

- No part of a vessel's hull treated with antifoulant is to be cleaned in Australian waters without the written permission of the Harbour Master, local government or state environmental protection agency (administering authority).

- In-water hull cleaning is prohibited, except under extraordinary circumstances and permission will not normally be granted.
- The cleaning of sea chests, sea suction grids and other hull apertures may be permitted provided that any debris removed is not allowed to pass into the water column or fall to the sea bed and subject to any other conditions attached to the permit. An application seeking permission to carry out this work must be lodged with the administering authority.
- Biological materials (marine biota) removed from antifouled hulls, should be disposed of as solid waste in accordance with local requirements e.g., to landfill, and
- The polishing of ship's propellers may be permitted subject to any conditions attached to the permit.

These guidelines should be applied to vessels arriving at Port Spencer.

These practices should also be considered for vessels that depart from the Port Spencer facility after berthing at this location for an extended period of time. That is, vessels that have accumulated biofouling after berthing at Port Spencer should avoid removal of biofouling into the water column at a new port site as this increases the risk of spreading marine pests (specifically the Asian date mussel) from Port Spencer to further afield. Ideally, vessels departing Port Spencer will be clear of biofouling prior to departure.

16.4 Marine Biosecurity Management in the Port

Marine biosecurity management is now becoming regular practice for ports to ensure the control of pest plant and animal species at ports and for emergency response to marine pest incursions. This can include regular surveillance and monitoring for marine pest populations on port structures and in underwater environs around the port, in addition to management of ballast water and biofouling on vessels.

In summary, key practices for marine biosecurity management for Port Spencer development could include the following:

- Facilitate compliance by visiting vessels with AQIS requirements to prevent and control introduced marine pest species, particular with regard to ballast water management.
- Facilitate compliance by visiting vessels with biofouling management guidelines.
- Facilitate compliance by departing vessels with ballast water and biofouling best practice guidelines to reduce the risk of transferring marine pest species from Port Spencer, particularly the Asian date mussel.
- Undertake biofouling 'housekeeping' actions, including regular cleaning of navigational aids, mooring buoys and jetty piles to reduce biofouling build-up and the risk of spreading marine pests from the Port Spencer site.
- Undertake periodic monitoring of port marine structures and undersea environs to help identify introduced marine species prior to the establishment and spread of pest populations.
- Reporting all potential pest incursions (i.e., to the 'FISHWATCH' hotline on 1800 065 522), and
- Support marine pest surveys undertaken by state or national authorities under the National System and use results in the review of marine flora and fauna management measures.

17.0 ASSESSMENT OF POTENTIAL IMPACTS FROM ACOUSTIC POLLUTION

Many forms of underwater noise may affect marine animals. These can include jet skiing, motor boating, seismic testing, and underwater construction activities (Baker 2004). The impacts of human-induced noise on marine biota depend upon the type of noise, its frequency and duration, and impacts vary widely depending upon the type of marine animal (Baker 2004).

Golder Associates (2009) previously discussed the potential impacts of acoustic noise in the marine environment from construction activities at the Port Spencer facility. This earlier report detailed different piling techniques, potential implications for marine mammals at the Site, and recommendations for mitigation measures.

The current assessment is based on a more detailed understanding of the proposed construction methodology (including pile installation). Using this information, Golder has completed underwater noise modelling for the three main project activities that have the potential to result in effects on sensitive receptors.

The following assessment of potential impacts includes the following:

- Consideration of the results from the underwater noise modeling
- A summary of the potential adverse effects of proposed construction activities and vessel movements on sensitive marine fauna in Spencer Gulf
- The provision of mitigation measures for minimising these potential adverse effects.

17.1 Background

The use of sound for communication and detection in the marine environment is important for foraging, habitat use and survival of marine animals. Marine organisms that are most sensitive to noise impacts are those which occupy the water column and that have well developed auditory structures. This typically includes marine mammals and some species of fish.

There are a number of potential effects that may arise as a result of elevated background noise levels. These can include: limiting the detection by the mammals of natural sounds; disturbing their normal behaviour resulting in possible displacement from areas, and causing temporary or permanent reductions in hearing sensitivity (Baker 2004). These potential effects depend to a degree on the type of marine mammal involved. The potential area or zone of influence of a man-made sound is also influenced strongly by the levels and types of ambient noise (Richardson *et al.*, 1995)

Increases in underwater noise are expected to occur at the Site as a result of the construction and operation of the Port. These increases are considered to have the potential to result in physical and/or behavioural effects on sensitive receptors such as marine fish and marine mammals. The three main sources of project-generated noise considered within this assessment are as follows:

- pile driving (impact/vibration)
- pile drilling, and
- vessel traffic and activity.

Sound sources can be categorised generally as pulsed (pile driving) or continuous (drilling). Sounds from moving sources (ships) are considered to be transient relative to the receivers.

As discussed above, Golder completed underwater noise modelling for the three main project activities that have the potential to result in effects on sensitive receptors. A descriptive analysis of each Project noise source, as well as Project-specific noise modelling, is provided in Appendix C.

Offshore seismic surveys and underwater blasting are not expected to be required for the construction of the jetty. As such, these activities were not considered as part of this assessment.

17.2 Noise Impact Criteria

There are presently no underwater noise impact criteria established under Australian legislation. The National Marine Fisheries Service (NMFS) in the United States established noise impact criteria that are based on noise levels reported in the literature which are known to potentially result in physical or behavioral effects in fish, cetaceans and pinnipeds (NMFS 1998; Southall *et al.* 2007; Stadler and Woodbury 2009). These noise impact criteria are expressed in root mean square (RMS) sound pressure levels (SPLs)[16] as adapted for impulsive sound sources. In the absence of regional impact criteria for underwater sound, the following NMFS criteria (NMFS 1998) have been adopted for assessing impacts to fish and marine mammals in the Spencer Gulf region:

- The underwater noise pressure threshold (RMS) for potential injury to cetaceans is 180 dB re 1 u uPa (Southall *et al.* 2007)
- The underwater noise pressure threshold (RMS) for potential injury to pinnipeds is 190 dB re 1 uPa (Southall *et al.* 2007)
- The underwater noise pressure threshold (RMS) for behavioral disturbance to cetaceans and pinnipeds is 160 dB rel 1 uPa for pulsed sounds (Southall *et al.* 2007) and 140 dB re 1 uPa for continuous sounds (Richardson *et al.* 1995)
- The underwater noise cumulative sound pressure threshold (sound exposure levels (SEL)) for potential injury to fish weighing ≥2 g is 187 dB re 1 uPa (Stadler and Woodbury, 2009)
- The underwater noise cumulative sound pressure threshold (SEL) for potential injury to fish weighing <2 g is 183 dB re 1 uPa (Stadler and Woodbury, 2009)
- The underwater noise peak sound pressure threshold (RMS) for potential injury to fish is 206 dB re 1 uPa (Stadler and Woodbury 2009)
- The underwater noise pressure threshold (RMS) for behavioral disturbance to fish is 150 dB re 1 uPa (Stadler and Woodbury 2009)
- All sound pressure levels are referenced to 1 micro Pascal (uPa) at 1 m.

Based on the outcome of the underwater noise modelling (refer to Appendix C), the predicted noise effects were compared to values known to cause behavioral disturbance or injury to marine mammals and marine fish. The assessment is based on those species previously identified (refer to Golder 2009 and Golder 2011) as being potentially present in the vicinity of the Site, together with a review of the available literature. The potential impacts on sensitive receptors from increased noise are discussed qualitatively below.

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[16] The standard sound measurement for determining potential effects on marine organisms is root mean square (RMS) pressure, although peak pressure is often used to determine threshold values.

17.3 Fish

17.3.1 Background Literature

Sound sensitivity in fish

Sensitivity to sound differs among fish species based on their anatomical form. There is considerable anatomical and physiological variation amongst fish with respect to hearing structures, suggesting that various species may detect and process sound in different ways (Popper and Fay 1993). Physical variability in a fish species' hearing anatomy generally determines its overall hearing sensitivity (Popper *et al.* 2003; Yan *et al.* 2000). Fish can be divided into two broad categories: hearing "generalists" ("non-specialists") and hearing "specialists"[17] (Popper *et al.* 2003; Ladich and Popper 2004).

Hearing specialists have specialised auditory structures (prootic bullas) connected to well-developed pressure sensitive organs (swim bladders) (Popper and Fay 1993). These morphological adaptations enhance a species' hearing bandwidth and sensitivity (i.e., lowering their hearing threshold). Hearing specialists tend to detect sound pressure with greater sensitivity and in a wider bandwidth than generalists, and are typically more sensitive to high-amplitude noise introduced to the marine environment (e.g., impact pile driving). The main factor affecting this is the close proximity and/or connection of the swim bladder to the inner ear (otophysic connection). The density of the gas within the swim bladder is much lower than that of seawater and a fish's body. As a result, the gas in the swim bladder can be easily compressed by sound pressure waves. The swim bladder changes in volume cyclically in reaction to passing sound waves. If the movements of the swim bladder wall are transmitted to the ear, this results in the stimulation of the sensory cells of the ear.

Examples of hearing specialists include catfish, herring and relatives, and many other taxonomically-diverse species. Quite often, hearing specialists can detect signals up to 3,000 – 4,000 Hz, with thresholds that are 20 dB or more lower than generalists (Hastings and Popper 2005). There are no fish species identified in the Project area in Spencer Gulf that are known hearing specialists. While it is likely that there may be hearing specialists in this region, this cannot be determined without additional experimental studies on hearing capabilities conducted for those species of interest.

Fish species without any specialisations to the auditory system have relatively poor auditory sensitivity and are referred to as hearing generalists (Popper *et al.* 2003). This includes fish species lacking a swim bladder (e.g. elasmobranchs such as sharks and rays), those that have a small or reduced swim bladder (most bottom-dwelling species such as flatfish), or those that have a swim bladder that is not in close proximity, or mechanically connected to the ears (e.g., toadfish) (Popper *et al.* 2003). The majority of fish species fall into this category and generally do not hear frequencies much above about 800 Hz, with peak sensitivities around 300 to 500 Hz (Ladich and Popper 2004). The sound pressure detection threshold can be as high as 120 dB re 1 µPa at the most sensitive frequency (Nedwell *et al.* 2004). Fish without swim bladders are only sensitive to the particle motion component of the sound field. The majority of fish species identified in Spencer Gulf belong to the hearing generalist group.

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[17] The grouping of fish into hearing generalists and specialists may serve as a general guideline for determining the hearing sensitivity of a fish species but does not replace audiograms, which describe the hearing sensitivity of a species more accurately. Audiograms have only been measured for a very small number of species and many fish species have not yet been classified as hearing generalists or specialists.

Effects of pile driving on fish

The extent of potential noise impacts on fish is not comprehensively understood. It is known, however, that intense impulsive signals such as those produced from pile drivers, can cause fish kills, and signals of a smaller magnitude can cause behavioural changes (Nedwell *et al.* 2004 as cited in McCauley and Kent 2008). Fish audition may be temporarily or permanently damaged by high-intensity sounds. However, the extent of damage will depend on the auditory threshold of the receiving species and this will vary from species to species (Popper and Fay 1973, 1993 as cited in McCauley and Kent 2008).

Pile-driving noise during construction is of potential concern for marine fish due to the high sound pressure levels transmitted through the water column. These compressive shock waves (overpressure) are characterised by a rapid rise to a high peak pressure followed by a rapid decay to below ambient hydrostatic pressure (Wright and Hopky 1998). These shock waves can result in physical damage and sometimes direct mortality to nearby fish (Caltrans 2001). In finfish, the swim bladder is the primary site of damage although the kidney, liver and spleen may also be ruptured. Studies have shown that fish eggs and larvae also may be killed or damaged from overpressure (Popper and Hastings 2009). There is evidence that smaller fish appear to be more vulnerable to overpressure impacts than larger fish and fish near the surface are more vulnerable than deep fish (Baxter *et al.* 1982; Keevin and Hempen 1997).

Experiments were conducted by Nedwell and Turnpenny (2003) with Brown trout (*Salmo trutta*), where wild fish were captured, caged, and then exposed to impact pile-driving (hammering) noise at a distance of 400 m from the source. Results demonstrated that no physiological damage occurred at received exposure levels of 194 dB re 1 uPa.

Ruggerone *et al.* (2008) examined the effects of pile-driving exposure on caged yearling Coho salmon (*Oncorynchus kisutch*). Fish were exposed to cumulative sound exposure levels (SEL) of approximately 207 dB re 1 uPa^2-s during a 4-h period. Fish were sampled at 10 and 19 days post-exposure with zero mortality observed. An examination of the external and internal anatomy showed no differences between exposed and control fish.

Studies conducted by Weinwold and Weaver (1972) demonstrated no auditory damage in salmon (*Oncorynchus kisutch*) exposed to estimated received exposure levels (SEL) of 214 to 216 dB re 1 uPa. However, another study (Falk and Lawrence 1973) demonstrated auditory damage in fish exposed to received SELs of 230 dB re 1 uPa.

Several studies have been conducted assessing noise effects on the survival of fish eggs and larvae in a marine environment. Kostyvchenko (1973) exposed fish eggs (*Engraulis encrasicholus* and *Mullus surmuletus*) to a calibrated noise source at variable distances. Received SPLs were 236 dB re 1 uPa at 0.5 m, 230 dB re 1 uPa at 1 m, and 210 dB re 1 uPa at 10 m, assuming a noise concentric dispersion. Egg mortality was demonstrated to be 0% for both species at 10 m, and 7.8% and 0% at 1 m, for each species, respectively. In the same experiment, mortality rates as a function of noise exposure were also evaluated for fish egg samples comprised of multiple commercial species, including anchovy (*Engraulis encrasicholus*), striped mullet (*Mugil cephalus*), turbot (*Scophthalmus maeoticaus*) and fine flounder (*Solea lascaris*). Egg mortality (averaged across all species) occurred in 16.9% of the eggs at 0.5 m from the source and in 2.1% of the eggs at 10 m from the source for the same received SPL.

17.3.2 Impact assessment and mitigation

Table 2 and Table 3 present fish species which are either potentially present in the Spencer Gulf region (Table 2) or, more specifically, those which were recorded at the Site during the current survey (Table 3). These tables present a classification of the potential sensitivity of these species to underwater noise/overpressure. Sensitivity to noise was categorised as either low, moderate, or high; based on physical and anatomical characteristics of a specific fish species, known hearing sensitivity (if available), and conditioned based on the following factors:

- Hearing specialists[18] considered as high sensitivity
- Hearing generalists with fully developed swim bladders considered as moderate sensitivity with the exception of the following:
  - those with overall small body size (< 30 cm) = high sensitivity
  - those likely to be located in the direct path of underwater noise or overpressure (neritic pelagic zone specialists - occupying nearshore/upper water column) = high sensitivity;
- Hearing generalists with modified/reduced swim bladders considered as low sensitivity (e.g. flatfish), with the exception of the following:
  - those with overall small body size (< 30 cm) = moderate sensitivity
  - those likely to be located in the direct path of underwater noise or overpressure (neritic pelagic zone specialists - occupying nearshore/upper water column) = moderate sensitivity
- Hearing generalists without swim bladders considered as low sensitivity (e.g. sharks and rays).

Table 2: Underwater Noise Sensitivity of Fish Species Potentially Present in Spencer Gulf

Scientific Name	Common Name	Swim Bladder	Body Size (cm)	Habitat Type	Hearing Category	Sensitivity to Under-water Noise
Pagrus auratus	Snapper	Yes	<40	Reef-associated; ocean-wide; depth range 0 - 200 m	Generalist	Moderate
Hyporhamphus melanochir	Garfish	Yes	<60	Pelagic-neritic; depth range 0-20 m	Generalist	Moderate
Sillaginodes punctatus	King George whiting	Yes	<80	Demersal; common depth range 2-18 m	Generalist	Moderate
Arripis georgianus	Australian herring	Yes	<50	Pelagic-neritic	Generalist	Moderate

[18] Fish with the prootic bulla generally have higher sensitivity than those with a swimbladder, and those with a swimbladder (moderate sensitivity) usually have greater sensitivity than non-specialists with no swimbladder (lower sensitivity), as suggested by Nedwell et al. (2004).

Scientific Name	Common Name	Swim Bladder	Body Size (cm)	Habitat Type	Hearing Category	Sensitivity to Under-water Noise
Sillago schomburgkii	Yellow-fin whiting	Yes	<60	Demersal; common depth range 0-2 m	Generalist	Moderate
Arripis truttacea	Western Australian salmon	Yes	<80	Benthopelagic; depth range 0-80 m	Generalist	Moderate
Sphyraena novaehollandiae	Snook	Yes	<120	Pelagic-neritic	Generalist	Moderate
Aldrichetta forsteri	Yellow-eye mullet	Yes	<30	Demersal; catadromous common depth range 0-10 m	Generalist	High*
Monacanthidae (family)	Leather-jacket	Yes	28-40	Reef-associated; demersal; depth range 1-70 m	Generalist	High*
Terapontidae (family)	Striped perch	Yes	20-40	Benthopelagic; demersal	Generalist	High*
Rajiformes (order)	Rays and skates	No	V*	Variable	Generalist	Low
Scaridae (family)	Parrotfish	Yes	38-175	Reef-associated; depth range 5-65 m	Generalist	Moderate
Carangidae (family)	Trevally	Yes	V*	Variable	Generalist	Moderate
Nemadactylus valenciennesi	Blue morwong	Yes	~ 90	Demersal; depth range 40–240 m	Generalist	Low
Platycephalidae (family)	Flathead	Yes	V*	Variable	Generalist	Low to Moderate
Heterodontus portusjacksoni	Port Jackson shark	No	120-140	Demersal; depth range 0-275 m	Generalist	Low
Carcharhinus brachyurus	Bronze whaler shark	No	~245	Reef-associated	Generalist	Low
Isurus oxyrinchus	Mako shark	No	~270	Pelagic-oceanic; common depth range 100-150 m	Generalist	Low

Scientific Name	Common Name	Swim Bladder	Body Size (cm)	Habitat Type	Hearing Category	Sensitivity to Under-water Noise
Sphyrna sp.	Hammer-head shark	No	~360	Pelagic-oceanic	Generalist	Low
Galeorhinus galeus	School shark	No	~160	Benthopelagic; common depth range 2 - 470 m	Generalist	Low
Alopias sp.	Thresher shark	No	~450	Pelagic-oceanic; common depth range 0-200 m	Generalist	Low
Furgalues macki	Whiskery shark	No	~160	Demersal; common depth range 0-220 m	Generalist	Low
Mustelus antarcticus	Gummy shark	No	~ 175	Demersal; common depth range 0-80 m	Generalist	Low
Carcharodon carcharias	Great white shark	No	~ 600	Pelagic-oceanic; common depth range 0-250 m	Generalist	Low
Dasyatis brevicaudata	Smooth stingray	No	~ 125	Demersal; common depth range 0-476 m	Generalist	Low
Trygonorrhina sp.	Fiddler ray	No	~ 125	Demersal; common depth range 0-180 m	Generalist	Low
Myliobatis australis	Eagle ray	No	~ 120	Reefs; common depth range 0-85 m	Generalist	Low
Seriola lalandi	Yellowtail kingfish	Yes	~ 80	Aquaculture species	Generalist	Low
Sciaenidae (family)	Mulloway	Yes	~ 100	Aquaculture species	Generalist	Low
Upeneichthys lineatus	Red Mullet	Yes	~ 30	Demersal; common depth range 5-100 m	Generalist	Moderate

* denotes variable with body size

Table 3: Underwater Noise Sensitivity of Fish and Cuttlefish Species Recorded at the Site

Scientific Name	Common Name	Swim Bladder	Body Size (cm)	Habitat Type	Hearing Category	Sensitivity to Under-water Noise
Cheilodactylus nigripes	Magpie perch/ Magpie morwong	Yes	≤40	Shallow rocky reefs to 25 m	Generalist	Moderate
Chelmonops curiosus	Western talma	Yes	≤ 26	Coastal reefs to 60 m	Generalist	High
Dactylophora nigricans	Dusky Morwong	Yes	≤120	Shallow seagrass beds, edges of rocky reefs to 20 m	Generalist	Moderate
Girella zebra	Zebrafish	Yes	≤50	Estuaries, rocky reefs, algal sand flats in shallow coastal waters to 20 m	Generalist	High
Meuschenia galii	Blue-lined Leatherjacket	Yes	≤35	Coastal reefs	Generalist	High
Meuschenia hippocrepis	Horseshoe Leatherjacket	Yes	≤60	Near-shore coastal reefs	Generalist	High
Notolabrus parilus	Brown-spotted Wrasse	Yes	≤32	Shallow, algae-covered rocky reefs to 20 m	Generalist	High
Notolabrus tetricus	Blue-throat Wrasse	Yes	≤42	Shallow grass, algal beds, reefs to 20 m	Generalist	High
Parma victoriae	Scalyfin / damsel fish	Yes	≤20	Shallow reefs to 30 m	Generalist	High
Pempheris multiradiata	Bigscale Bullseye	Yes	≤28	Rocky reefs <30 m, but can be found to 70 m	Generalist	High
Pictilabrus laticlavius	Senator Wrasse	Yes	≤25	Coastal reefs, algal beds	Generalist	High
Scorpis aequipinnis	Sea Sweep	Yes	≤60	Near rocky reefs in shallow coastal waters to 25 m	Generalist	Moderate
Sepia apama	Giant cuttlefish	No	≤100	Reef, seagrass up to 50 m depth	Generalist	Low
Tilodon sexfasciatus	Moonlighter	Yes	≤30	Rocky reefs especially along drop-offs, to 30 m	Generalist	Moderate
Gobiid sp.	Goby	Yes (redu-ced)	1.5-50	Shallow coastal waters but range from intertidal zone to 800 m	Generalist	Moderate
Neoodax balteatus	Little Weed Whiting	Yes	≤16	Seagrass beds and rocky reefs, to 20 m depth	Generalist	High

Scientific Name	Common Name	Swim Bladder	Body Size (cm)	Habitat Type	Hearing Category	Sensitivity to Under-water Noise
Siphonognathus beddomei	Pencil Weed Whiting	Yes	≤14	Coastal waters around rocky outcrops with dense brown macroalgae, often at 20 m	Generalist	High
Haletta semifasciata	Blue weed whiting	Yes	20-30	Demersal; 1-7 m	Generalist	High
Omegaphora armilla	Ringed Toadfish	Yes	≤25	Coastal waters to 146 m	Generalist	High
Aracana aurita	Shaw's Cowfish	Yes	≤20	Coastal rocky reefs, grassy embayments at 10-160 m	Generalist	High
Notolabrus parilus	Brown spotted wrasse	Yes	≤ 49	Reef-associated to 20 m depth	Generalist	Moderate

Based on the literature and noise modelling predictions, impact pile driving has the potential to result in physical injury to marine fish within close range of the source. The predicted SPL for impact pile driving based on a single pile strike is 190 dB re 1 uPa (RMS @ 20 m). Based on multiple pile strikes (as is expected for this activity), the cumulative sound exposure level (SEL) is predicted to exceed the injury threshold for fish (187 dB re 1 uPa) in the immediate area of impact pile driving works (up to 469 m from the source).

Underwater noise generated from vibration pile driving, drilling, and vessel traffic is not anticipated to exceed the injury threshold for fish during any phase of the Project.

Predicted underwater noise from impact pile driving, vibration pile driving, and drilling may exceed the potential behavioral threshold of fish (150 dB re 1 uPa) for distances from the source up to 4,642 m, 215 m, and 5 m, respectively. Predicted vessel noise may exceed the potential behavioral threshold of fish (150 dB re 1 uPa) for a distance up to 30 m from the source (vessel).

Based on a review of the literature and noise impact modelling (Appendix C), it is expected that underwater noise generated by construction activities will not exceed levels known to cause irreversible damage or death to fish (adults and eggs), with the exception of during impact pile-driving activities when cumulative SEL could exceed the threshold for injury to fish at distances < 469 m from the source. Within this zone of potential injury, impact pile driving could cause physical impacts to fish species with moderate to high noise sensitivity (Table 2 and Table 3).

Consequently, the recommended mitigation for impact pile driving includes adopting a construction procedure known as a “soft start” which consists of gradually increasing the impact energy delivered to the hammer during pile installation. This method may stimulate an “avoidance” behavior for fish species in the area which will minimise the risk of physical damage to nearby fish with high and medium noise sensitivity. No effects at the population level are anticipated. Concerning possible effects on fish eggs and larvae, it is considered likely that effects will be limited to the immediate vicinity of the source (<5 m). Given the relatively small volume of water affected, no measurable effects are expected and no effects at the population level are anticipated. In addition, construction of the Port will begin onshore and will advance seaward, allowing for an extended period of response time by acoustically sensitive fish in the area (by means of avoidance or habituation).

17.4 Marine Mammals

17.4.1 Background literature

Marine mammals are acoustically diverse, with wide variations in ear anatomy, frequency range and amplitude sensitivity. The general trend is that larger species tend to have lower frequency ranges than smaller species (Pidock *et al.*, 2003 as cited in Baker 2004).

The efficiency of underwater sound propagation allows marine mammals to use underwater sounds as a primary method of communication with one another. Toothed whales use echolocation sounds to detect the presence and location of objects, other whales of the same species, and prey (Richardson *et al.* 1995).

There is considerable variation among marine mammals in both hearing range and sensitivity. Toothed whales (such as dolphins) commonly have good hearing between 200 and 100,000 Hz; whereas several baleen whales (i.e., humpback whales), fur seals and sea lions have good hearing in the lower frequency range. The upper functional range for most baleen whales has been predicted to extend to 20 or 30 kHz (Richardson *et al.* 1995).

Little knowledge exists on the habituation of marine mammals to anthropogenic noises. Direct lethal effects attributable to acoustic emissions are not represented in available literature, although military sonar trials have been implicated in mass stranding events. Richardson *et al.* (1995) postulated that "it is doubtful that many marine mammals would remain for long in areas where received levels of continuous underwater noise are >140 dB at frequencies to which the animals are most sensitive."

Impulsive pile driving (hammering) is considerably louder than vibrational pile driving or underwater drilling, with levels as high as 131 to 135 dB re 1 uPa measured 1 km from a hammer used for pipe installation (Richardson *et al.* 1995). Blackwell *et al.* (2003) measured sounds generated by impact-driving conductor and insulator pipes for oil and gas wells. Individual pile-driving pulses generated a mean underwater broadband level of 151 dB re 1 uPa. These pipes were similar in size and material to the proposed piles for the Port Spencer facility.

The threshold peak impulse sound pressure for direct physical trauma in marine mammals is generally considered to be > 200 dB (Gordon *et al.* 2003). This being the case, marine mammals would not be expected to experience permanent hearing impairment from sound pressures generated by pile-driving activity, even when very close to the source. Effects on behavior are considered more likely to occur. In addition to masking of communication and echolocation signals, pile driver noise could interfere with environmental sounds that animals listen to, for example the sound of surf or prey species. In addition, underwater noise could startle or displace animals. Wursig *et al.* (2000) recorded the impact of pile driving into the seabed, in 6 to 8 m depths of water, on humpbacked dolphin behavior. No overt behavioral changes were observed in response to the pile-driving activities; however, the animals' speed of travel increased and some dolphins remained within the vicinity while others temporarily abandoned the area. Dolphin numbers returned close to normal once pile driving had ceased.

In regards to shipping, the noise generated from this activity generally dominates ambient noise at frequencies from 20 to 300 Hz; above 300 Hz, shipping sounds may or may not be significant depending on the level of wind-dependant ambient noise, and above 500 to 50,000 Hz, wind, wave and precipitation noise dominate (Richardson *et al.* 2005). Frequencies used by marine mammals may overlap with frequencies produced by cargo ships and carriers which range from 10 to 1,000 Hz (Richardson *et al.* 1995). Lower frequency (10 to 100 Hz) emissions have been shown to influence large baleen whale behavior, including humpback whales (Frankel and Clark 2002).

Much remains uncertain regarding the potential effects of vessel noise on marine mammals; however, 'noise masking' and avoidance are primary effects to consider. Increases in noise levels within the same frequency band as sounds associated with communication, foraging, predator avoidance, and navigation can mask these signals, diminishing the distances over which marine mammals can detect them. The effects that such detection-range reduction may have on individual reproduction or survival, and the actions marine mammals may undertake to avoid masking, are highly variable.

Research has demonstrated that vessel noise affects both the movement and acoustic behavior of marine mammals (Richardson *et al.* 1995). While other cues, e.g., vision or pressure waves, may be available to animals during extremely close approaches, it is likely that most responses are acoustically mediated.

Acoustic responses to vessel noise include animals changing the composition of call types, the rates and duration of call production, and the actual acoustic structure of the calls. With regard to locomotory behavior, demonstrable responses to both the opportunistic observations (i.e., transiting vessels) and experimental approaches have been reported for some species. Responses include changes in respiration rates, diving, swim speed, and these changes have, in some cases, been correlated with numbers of vessels and their proximity, speed and direction changes. Responses have been shown to vary by gender and individual.

Many odontocetes (toothed whales) show considerable tolerance of vessel traffic. Dolphins of many species often tolerate or even approach vessels, but at times members of the same species show avoidance. Reactions to boats often appear related to the dolphin’s activity: resting dolphins tend to avoid boats, foraging dolphins ignore them, and socialising dolphins may approach (Richardson *et al.* 1995). Toothed whales sometimes show no avoidance reaction to vessels or even approach them. However, avoidance can occur and may cause temporary displacement, but no clear evidence is available that toothed whales have abandoned significant parts of their range because of vessel traffic (Richardson *et al.* 2005).

Reactions of humpbacks to vessels vary considerably. Some humpbacks show little or no reaction when vessels are well within the hearing zone of influence. When baleen whales such as humpbacks receive low-level sounds from distant or stationary vessels, the sounds often seem to be ignored. Some whales approach the sources of these sounds. When vessels approach whales slowly and non-aggressively, whales often exhibit slow and inconspicuous avoidance maneuvers. In response to strong or rapidly changing vessel noise, baleen whales often interrupt their normal behavior and swim rapidly away. Avoidance is especially strong when a boat heads directly toward the whale (summarised from Richardson *et al.* 2005). Feeding humpbacks have been shown to be displaced temporarily by vessels. Although vessels caused short-term changes in behavior including avoidance, some specific humpbacks remained for weeks in areas often used by vessels, and returned to the area in later years (Baker *et al.* 1988; Baker *et al.* 1992).

Sea lions in the water tolerate close and frequent approaches by vessels, and sometimes congregate around fishing vessels. Sea lions hauled out on land are more responsive (Peterson and Bartholomew 1967) but rarely react until a boat approaches within 100 to 200 m (Bowles and Stewart 1980). In general, evidence about reactions of seals to vessels is lacking. The limited data, plus the responses of seals to other noise from human activities, suggest that pinnipeds often show considerable tolerance of vessels.

17.4.2 Impact assessment and mitigation

Based on noise modelling predictions, impact pile driving could result in physical injury to marine mammals within close range of the source. The predicted sound pressure level (SPL) for impact pile driving is 190 dB re 1 uPa (RMS @ 20 m) based on a single pile strike. This SPL is predicted to exceed the injury threshold for pinnipeds (190 dB re 1 uPa) and cetaceans (180 dB re 1 uPa) at distances of up to 93 m and 431 m from the source, respectively.

Underwater noise from vibration pile driving, drilling, and vessel traffic is not anticipated to exceed the injury threshold for pinnipeds or cetaceans during any phase of the Project.

Predicted underwater noise from impact pile driving and vibration pile driving may exceed the behavioral threshold for marine mammals (160 dB re 1 uPa – impulsive) for distances from the source up to 928 m and 46 m, respectively. Predicted underwater noise from underwater drilling may exceed the behavioral threshold for marine mammals (140 dB re 1 uPa – continuous) for distances from the source up to 25 m. Predicted vessel noise may exceed the behavioral threshold for marine mammals (140 dB re 1 uPa - continuous) for a distance up to 115 m from the source (vessel).

Many of the marine mammal species identified as potentially occurring in the Spencer Gulf region (Golder 2011) are protected under Australian legislation. Southern Right whales are protected under state and federal legislation and are known to be transient in this region during their calving season (between May and November). During this period, Southern Right whales would be more susceptible to impacts from pile driving activities. Effects could range from changes to their distribution, migration, or behavioral patterns. However, noise impacts will not be continuous and will be of short duration.

In summary, it is considered unlikely that underwater noise generated by construction and operational activities will not exceed levels known to cause injury to marine mammals, with the exception of during impact pile driving activities when cumulative SEL could exceed the threshold for injury to marine mammals at very close distances from the source.

In order to minimise impacts from pile driving activities, the principles of ‘best management practice’ (BMP) and ‘best available technology economically achievable’ (BATEA) should be applied. BMP is the adoption of particular operational procedures that minimise vibration impacts while retaining productive efficiency. BATEA includes equipment, plant and machinery which incorporate the most advanced and affordable technology to minimise vibration output. Where BMP fails to achieve the required vibration reduction by itself, the BATEA approach should be considered.

The following measures will assist with reducing potential impacts to marine mammals:

- When impact pile driving, a “ramp up” or “soft start” technique should be employed. Where equipment allows, power shall be built up slowly from a low-energy start to give adequate time for marine mammals to leave the vicinity before exposure to the maximum sound pressure level. There should be a soft start every time pile driving is resumed, even if no marine mammals have been observed in the area.
- Marine mammal monitoring shall be implemented during impact pile driving activities undertaken during the Southern Right whale calving season (between May and November). A 500 m safety perimeter shall be visually monitored around the pile being driven as this represents the maximum distance from the source for which potential injury is possible based on acoustic modelling results. If a marine mammal is present within the safety perimeter prior to the start of impact pile driving, the activity shall be delayed until such time that the marine mammal has cleared outside the safety perimeter. If a marine mammal enters the safety perimeter during active impact pile driving, these activities shall be suspended until such time as the marine mammal departs outside the safety perimeter. Activities shall not resume until the Environmental Monitor (EM) visually confirms that the marine mammal is outside the safety perimeter, or if a minimum of 15 minutes has elapsed since the marine mammal was last sighted within the safety perimeter. If a marine mammal is known or suspected to be present in the area but outside the safety perimeter, pile driving can proceed provided that the “soft start” procedure is employed so as to allow sufficient time for the marine mammals to achieve a safe distance from the source.
- In addition, construction of the marine structures will begin onshore and will advance seaward, allowing for an extended period of response time by acoustically sensitive marine mammals in the area (by means of avoidance or habituation), and
- Use of noise insulation and hammer cushions to reduce noise generated.

No mitigation measures are recommended for vibrational pile driving, pile drilling, and vessel traffic, as noise generated during these activities is not anticipated to reach levels that would result in injury to marine mammals.

The implementation of mitigation measures will assist with reducing potential impacts to marine mammals. Based on the information provided above, it is predicted that marine mammals may either habituate to the noise generated from these activities, or they may leave the area temporarily to avoid behavioral disturbance. All species are predicted to return once the activity has been completed. No effects at the population level are anticipated.

Notwithstanding this, underwater noise monitoring should be considered during initial pile-driving activities to verify that the noise signals being generated do not overly exceed the modelling predictions used in this risk assessment.

18.0 ASSESSMENT OF POTENTIAL IMPACTS FROM LIGHT POLLUTION

Marine fauna are influenced by light in various ways exhibiting both and positive and/or negative phototactic responses (Depledge et al. 2010; McConnell et al. 2010; Marchesan et al. 2005). The response to light can be species- as well as life-stage specific. Light is used for feeding, breeding and predator avoidance and therefore marine fauna behaviour may be impacted in various ways by the introduction of artificial light (Longcore and Rich 2004). Responses to artificial light may include changes in behaviour, predator-prey dynamics, schooling, spatial distribution, migration, reproduction and changes in population dynamics (McConnell et al. 2010; Longcore and Rich 2004).

A common reaction of fish to artificial light is to school and move towards or away from the light source (Marchesan et al. 2005). This reaction may facilitate feeding (Ryer and Olla 1999) as well as the avoidance of predators. The attraction towards the light source has been shown to vary among fish species and can be related to phylogenetic and ecological factors and also differ according to light characteristics in particular, intensity and wavelength (Marchesan et al. 2005).

Marine invertebrates, such as zooplankton, exhibit diel migrations where they move up and down within the water column over a 24-hour period. Presumably this behaviour allows the zooplankton to forage in the dark conditions and thus avoid predators (Longcore and Rich 2004). Artificial lighting has been shown to decrease the diel migrations in zooplankton, both in the range of vertical movement as well as the abundance of individuals migrating (Moore et al. 2000). Studies have shown naturally high predation of zooplankton by fish on nights of full moon. The zooplankton migrated to the surface after sunset; however, due to the full moon, were subjected to a high predatory intensity because of the increased illumination (Longcore and Rich 2004). Increased illumination due to human activities is likely to mimic this response favouring the predator and consequently changing the predator-prey interactions (Longcore and Rich, 2004).

Some benthic fauna have planktonic larval stages that are photopositive allowing them to avoid benthic predators. Artificial lights may potentially affect the normal response to light and influence breeding patterns, as well as attract predators (McConnell et al. 2010).

There is little research on the impacts of artificial light on mammals. Longcore and Rich (2004) mention the increased predation by seals on salmon in the presence of artificial lighting. In regards to cetaceans, it is considered unlikely that there would be a significant impact due to localised artificial lighting associated with the Port as cetaceans predominantly utilise acoustic (rather than visual) senses to survey their environment.

As the area likely to be influenced by artificial lighting will be localised around the jetty area, the potential for impacts on marine environment from this source are considered to be low.

19.0 SEDIMENT CHEMISTRY AND PARTICLE SIZE ANALYSIS

Characterisation of sediments as part of baseline assessments forms a component of the overall Site characterisation. Data collected before a potential impact has occurred can provide valuable information about background concentrations of chemicals that can occur at naturally high levels in a region. Over time, these background levels may provide useful site-specific screening criteria which can be used after Port operations have commenced.

19.1 Sampling Methods

Surface sediment sampling was performed by divers between 12 and 15 July 2011 at 12 locations. The sites sampled were the same as those adopted for the broader ecological assessment gradient sample design and included the collection of samples from seagrass habitat (approximately 11 m BSL) and the mid benthic habitat (approximately 20 m BSL).

Sampling was undertaken at the following locations:

- One impact location (the Potential Impact Zone), which included three separate sites (one central site (Distance 1) and one of each site to the north and south of the central site (Distance 3 North and Distance 3 South).
- Two control locations each at a distance of approximately 3.5km from the central impact location, consisting of one location to the north and south (Distance 6 North and Distance 6 South), and
- Two reference (additional ‘near field’ control) locations. One at Lipson Island (due to the high conservation value of the region as a National Estate Conservation Park) and one approximately 1.5 km north (Distance 5 South and Distance 5 North respectively). At these locations, sampling was restricted to the mid benthic zone due to unfavourable weather conditions).

These sampling locations are detailed in Figure 6, Appendix A.

Sediment samples were collected directly into pre-labelled laboratory supplied glass jars and consisted of the surface sediment to a depth of 5 cm. Once on the surface, samples were stored in a chilled, insulated storage container, containing cooler bricks, until completion of the day’s field survey. The samples were then transported to a NATA-accredited laboratory, together with the appropriate chain of custody (COC) forms. For quality assurance/quality control purposes a triplicate sample, containing a primary (D1MB2) and secondary (D1MB3) duplicate sample was collected at the Distance 1 site from within the mid benthic habitat.

For the particle size distribution tests, samples were collected into a 10 cm diameter by 15 cm high polycarbonate corer. Once on the surface, samples were transferred to sample bag and labelled with a unique site code. All samples were collected from within a 1 m by 1 m area within the sampling location.

19.2 Physical Sediment Characteristics

19.2.1 Particle size distribution analysis

Samples were sent to the Golder Associates Pty Ltd NATA-accredited laboratory in Adelaide for analysis of particle size distribution. These samples were air dried and sieved through 0.075 mm sieves to determine the grain size distribution. Graphs are attached in Appendix D. When enough fine material could be retained, hydrometer testing was conducted according to standard AS1289 3.6.3 to determine particle size of fines <0.075 mm. The hydrometer results of four mid benthic samples (Distance 3 and Distance 6 North and South) are presented in Table 5.

Particle size distribution is a physical property of the sediment and is important for quantifying and managing potential sedimentation and erosion processes. Sediments were characterised as follows:

- Gravel: >2mm
- Sand: 2 mm – 63 µm, and
- Fines: silt <63 µm and clay <2 µm.

As the majority of the sampled sediments were sand, a further classification of fine, medium and coarse sand was used. For this report the limit between fine and medium sand is set at 200 µm (PIANC, 1984):

- Coarse sand: 500 µm – 2 mm
- Medium sand: 200 – 500 µm, and
- Fine sand: 63 – 200 µm.

The analysis indicates that the sediment textures are mainly fine to medium sand, with small amounts of gravel and fines, containing silt/mud and only minor amounts of clay when tested. The nearshore samples contained organic material (likely dead and decaying seagrass) and slightly higher proportions of gravel. This is considered likely because of their proximity to the rocky shoreline. Table 4 and Table 5 illustrate that particle sizes of the mid benthic samples were generally finer than the nearshore (seagrass) locations, again because of the locations proximity to the shoreline and high velocity (wave energy) environments.

Table 4: Nearshore (seagrass) sediment particle size distribution

	Moisture content (%)	D50 (µm)	% clay (<2 µm)	% fines (<75 µm)	% sand (75 µm – 2 mm)	% gravel (>2 mm)	Description
Distance 1	19	240	NA	8	89.5	2.5	Medium sand, organics present
Distance 3 North	20	340	NA	5	95	0	Medium sand, organics present
Distance 3 South	20	390	NA	5	87	8	Medium sand, organics present
Distance 6 North	22	230	NA	5	86	9	Medium sand, organics present
Distance 6 South	26	500	NA	6	92	2	Medium sand, organics present

Notes: NA = not analysed. D50 = the median diameter; 50% of the particles is larger, 50% is smaller.

Table 5: Mid benthic sediment particle size distribution.

	Moisture content (%)	D50 (µm)	% clay (<2 µm)	% fines (<75 µm)	% sand (75 µm – 2 mm)	% gravel (>2 mm)	Description
Distance 1	30	130	NA	7	93	0	Fine sand
Distance 3 North	29	180	3	11	87	2	Fine sand
Distance 3 South	28	150	2	12	88	0	Fine sand
Distance 6 North	28	280	3	10	87	3	Medium sand
Distance 6 South	29	220	3	11	87	2	Medium sand

Notes: NA = not analysed. D50 = the median diameter; 50% of the particles is larger, 50% is smaller. % fines include % clay.

The findings of the sediment particle-size distribution analyses are considered similar to the previous surveys of October 2008 and July 2010 based on the laboratory results. A graph of the grain size distribution of the nearshore and mid benthic sediment samples are presented in Figure 31 and Figure 32. The results of the particle size distribution analyses of all sediment samples are similar.

The grain size may influence the type of benthic organisms living in the sediment and may be correlated with the presence of contaminants. In general, higher amounts of silt and clay in sediment can suggest a greater chance of contaminants being present, because of the contaminants' affinity to bind to the finer particulates.

Figure 31: Sediment grain size distributions of nearshore samples

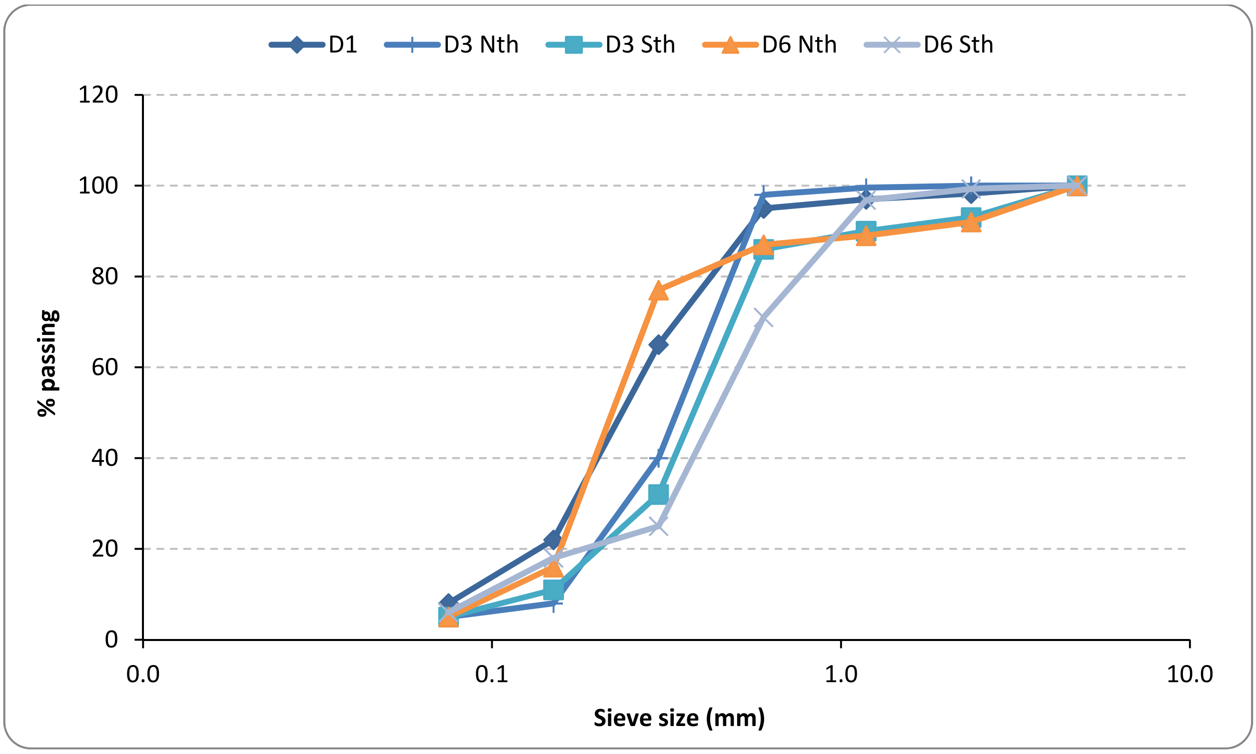
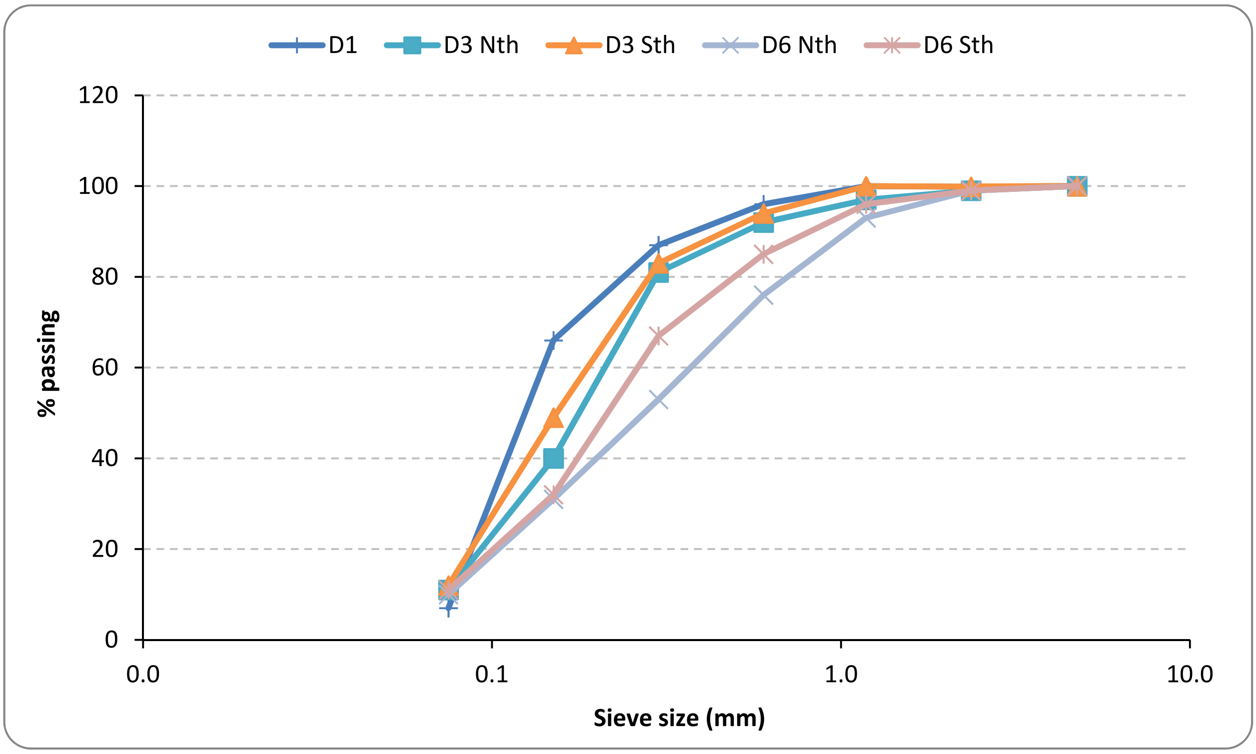


Figure 32: Sediment grain size distributions of mid benthic samples



19.2.2 Total organic carbon

Organic matter in sediments is widely distributed in aquatic environments. The quality of organic matter in sediments is key to the bioavailability of organic-type contaminants. Naturally-occurring organic carbon forms are derived from the decomposition of plants and animals. The determination of total organic carbon is an essential part of organic compound characterisation, since its presence or absence can markedly influence how chemicals will react in the soil or sediment (USEPA, 2002).

Table 6 and Table 7 below illustrate the baseline total organic carbon content in samples collected at the Site.

Table 6: Total organic content (TOC) for nearshore samples

	TOC (%)
Distance 1	0.04
Distance 3 North	0.09
Distance 3 South	0.75
Distance 6 North	0.28
Distance 6 South	0.33

Table 7: Total organic content (TOC) for mid benthic samples

	TOC (%)
Distance 1, sample 1	0.31
Distance 1, sample 2	0.29
Distance 3 North	0.29
Distance 3 South	0.28
Distance 5 North	0.17
Distance 5 South	0.41
Distance 6 North	0.34
Distance 6 South	0.36

19.3 Sediment Chemistry

The chemical analyses were performed by ALS Laboratory Group. The following parameters have been analysed:

- Metals and metalloids - aluminium (Al), iron (Fe) and manganese (Mn), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni) and zinc (Zn)
- Total Petroleum Hydrocarbons (TPH)
- Tributyltin (TBT)
- Polycyclic Aromatic Hydrocarbons (PAH), and
- Monocyclic Aromatic Hydrocarbons (MAH)

One triplicate sample (secondary duplicate sample from Distance 1, mid benthic, replicate 3) was sent to MGT Labmark for inter-laboratory quality assurance purposes.

19.3.1 Screening criteria

The sediment chemistry results have been compared to the Australian and New Zealand Environment and Conservation Council and Agriculture and Resource Management Council of Australia and New Zealand guidelines (ANZECC & ARMCANZ, 2000). Where a more conservative value has been provided in the National Assessment Guidelines for Dredging (NAGD) (Commonwealth of Australia, 2009) Interim Sediment Quality Guidelines (Low trigger values (ISQG-Low)), this value has been used. Where this is the case, the value has been identified as such in the presentation of data.

19.3.2 Metals and metalloids

The reported concentrations of the following metals and metalloids in nearshore and mid benthic sample locations have been compared to the interim sediment quality guideline (ISQG) of ANZECC & ARMCANZ (2000) and NAGD (Commonwealth of Australia 2009). These sediment quality guidelines and screening levels provide benchmarks to better understand the potential for adverse effects to occur to sediment-dwelling animals from chemicals present in the sediment and provide an estimate below which toxicity is unlikely to occur. The sediment quality guidelines and screening levels and the measured metal/metalloid concentrations are presented in Table 8 and Table 9. These screening levels are extracted from NAGD, 2009 Table 2 and from ANZECC & ARMCANZ, 2000, Table 3.5.1.

Table 8: Screening levels and metal/metalloid concentrations at nearshore sediment samples (in mg/kg).

Analytical parameter	ANZECC ISQG-Low	Distance 1	Distance 3 North	Distance 3 South	Distance 6 North	Distance 6 South
Arsenic	20	<1.00	<1.00	<1.00	<1.00	<1.00
Cadmium	1.5	<0.1	<0.1	<0.1	<0.1	<0.1
Chromium	80	1.2	1.7	1.8	3.5	2.1
Copper	65	<1.0	<1.0	<1.0	1.1	<1.0
Lead	50	<1.0	<1.0	<1.0	<1.0	<1.0
Mercury	0.15	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	21	<1.0	<1.0	<1.0	1.5	<1.0
Zinc	200	1	1.1	<1.0	2.8	<1.0
Aluminium	-	260	410	450	1050	500
Iron	-	300	460	470	1770	540
Manganese	-	<10	<10	<10	17	<10

Table 9: Screening levels and metal/metalloid concentrations at mid benthic sediment samples (in mg/kg).

Analytical parameter	ANZ-ECC ISQG-Low	Distance 1, samplee 1	Distance 1, sample 2	Distance 3 North	Distance 3 South	Distance 5 North	Distance 5 South	Distance 6 North	Distance 6 South
Arsenic	20	1.05	1.88	2.53	1.66	< 1.00	2.19	3.39	2.8
Cadmium	1.5	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1	< 0.1
Chromium	80	5.9	6.7	7	5.3	3.3	5.4	5.8	6.2
Copper	65	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Lead	50	< 1.0	< 1.0	1.1	< 1.0	< 1.0	1	1.1	< 1.0
Mercury	0.15	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
Nickel	21	9	< 1.0	1	< 1.0	< 1.0	< 1.0	< 1.0	< 1.0
Zinc	200	1.6	1.7	1.7	1.1	1.2	1.1	1.1	1.3
Aluminium	-	850	1660	1140	850	680	870	840	930
Iron	-	1330	1830	1990	1320	860	1720	2310	1710
Manganese	-	12	15	13	< 10	< 10	< 10	< 10	13

Aluminium, iron and manganese are abundant in the earth's crust and in marine sediments. No ISQG-Low screening values are available for these elements in ANZECC & ARMCANZ (2000) or NADG (2009).

There were no reported exceedences of the ISQG-Low screening values (where screening values are available). Comparison between the 2008, 2010 and 2011 sediment assessments show consistent results with almost all metals reported below detection limit. Slightly higher concentrations were reported at the mid benthic locations compared to the nearshore locations.

A summary of the laboratory results and a table presenting the results against the screening criteria (is attached in Appendix D (Table 1).

19.3.3 Organic chemicals

Table 10 and Table 11 present the concentrations of the analysed organic chemicals in nearshore and mid benthic sediment samples.

Table 10: Screening levels and organic chemical concentrations in nearshore sediment sample

Analytical parameter	ANZECC ISQG-Low	Distance 1	Distance 3 North	Distance 3 South	Distance 6 North	Distance 6 South
Total polycyclic aromatic hydrocarbons (PAHs) (mg/kg)	4	< 0.020	< 0.020	< 0.005	< 0.014	< 0.012
Total petroleum hydrocarbons (TPHs) (mg/kg)	Not defined (550 in NADG 2009)	55	40	< 15	36	21
Tributyltin (µg/kg)	5 µg Sn/kg	< 2.5	< 2.5	< 0.7	< 1.8	< 1.5
Monocyclic Aromatic Hydrocarbons (MAH)	NA	-	<1	<1	<1	<1

Table 11: Screening levels and organic chemical concentrations in mid benthic sediment samples

Analytical parameter	ANZ-ECC ISQG-Low	Distance 1, sample 1	Dist ance 1, sample 2	Distance 3 North	Distance 3 South	Distance 5 North	Distance 5 South	Distance 6 North	Distance 6 South
Total polycyclic aromatic hydrocar bons (PAHs) (mg/kg)	4	< 0.013	< 0.014	< 0.014	< 0.014	< 0.020	< 0.010	< 0.012	< 0.011
Total petroleu m hydrocar bons (TPHs) (mg/kg)	Not defined (550 in NADG 2009)	35	38	81	61	105	70	69	93
Tributyltin (µg/kg)	5 µg Sn/kg	< 1.6	-	< 1.7	< 1.8	-	-	< 1.5	< 1.4

Results of the organics were standardised to 1% total organic carbon (TOC) over the range 0.2 to 10 %. When TOC values were below 0.2 % (Distance 1 and Distance 3 North in nearshore/seagrass habitat; Distance 5 North in mid benthic habitat) a factor of 0.2 was applied for normalisation. Tributyltin, individual polycyclic aromatic hydrocarbons (PAH) and total PAHs were below limit of reporting (LOR) for all samples. Individual TPH fractions C6 – C9, C10 – C14, C6 – C10 were all below the LOR of 3 mg/kg.

There are few screening values for individual polycyclic aromatic hydrocarbons. Where ANZECC & ARMCANZ (2000) provide screening values for individual PAH, these have not been exceeded. The NAGD (2009) trigger value for Total PAHs was not exceeded.

The sediment was analysed for monocyclic aromatic hydrocarbons (MAHs). These were reported below the LOR in all samples. A summary of the results of organic chemicals reported in the sediment is attached in Table 1, Appendix D.

19.4 Quality Assurance/Quality Control

Quality assurance/quality control (QA/QC) measures were undertaken as part of the sediment analyses and include a review of the field data quality. The review of field data quality includes the evaluation of primary samples, primary duplicate and secondary duplicate samples.

The quality assurance and quality control (QA/QC) results that meet the acceptance criteria include all relative percentage differences (RPDs) less than 50% and duplicates <30% for metals and organics.

Three sediment samples were assessed for QA/QC purposes, comprising a primary sediment sample (Distance 1 mid benthic sample 1), a primary duplicate (Distance 1 mid benthic sample 2) and secondary duplicate sample (Distance 1 mid benthic sample 3). Samples Distance 1 mid benthic sample 1 and Distance 1 mid benthic sample 2were analysed within required laboratory holding times for extraction and analysis. Sample Distance 1 mid benthic sample 3 breached the holding time for mercury, moisture content and organics and so these analytes were excluded from the QA/QC comparisons.

During chemical analysis, ALS analysed sample Distance 1 mid benthic sample 2 as the primary duplicate for sample Distance 1 mid benthic sample 1. Table 12 shows the results as reported by ALS. Variation is expressed as the relative percentage difference.

Table 12: Summary of primary duplicate QA/QC analysis by ALS

	Distance 1 Mid benthic sample 1	Distance 1 Mid benthic sample 2	Difference (RPD%)
Moisture content (%)	29.7	36.2	6.5 (18.0)
Aluminium (mg/kg)	850	1660	810 (48.8)
Arsenic (mg/kg)	1.05	1.88	0.83 (44.1)
Cadmium (mg/kg)	< 0.1	< 0.1	-
Chromium (mg/kg)	5.9	6.7	0.8 (11.9)
Copper (mg/kg)	< 1	< 1	-
Iron (mg/kg)	1330	1830	500 (27.3)
Lead (mg/kg)	< 1	<1	-
Manganese (mg/kg)	12	15	3 (20)
Mercury (mg/kg)	< 0.01	< 0.01	-
Nickel (mg/kg)	9	< 1	> 8 (>88.9)
Zinc (mg/kg)	1.6	1.7	0.1 (5.9)
Total organic carbon (%)	0.31	0.29	0.02 (6.4)
Tributyltin (mg/kg)	<0.0005	-	-
Total PAH (mg/kg)	<0.004	<0.004	-
TPH (mg/kg)	20.5	11	9.5 (46.3)

Table 12 above indicates that inter-sample variability ranged from 0 to 49%, with the exception of nickel. Nickel results indicated variability of 89%, with one of the two values reported below limit. Aluminum, arsenic and total petroleum hydrocarbon concentrations reported the highest variability after nickel. Measured aluminium concentrations (see tables 3 and 4) show that aluminium is not homogeneous."

Mid benthic sediment sample Distance 1 (sample 3) was analysed by the secondary laboratory mgt-LabMark as a secondary duplicate sample. Inter-laboratory results are presented in Table 13.

Table 13: Secondary duplicate analysis

	Mgt-LabMark (Distance 1 mid benthic replicate 3)	**ALS (Distance 1 mid benthic replicate 2)**	**Difference (RPD%)**
Moisture content (%)	21	36.2	15.2 (42.0)
TOC (%)	< 0.5	0.29	> 0.21 (> 42)
Aluminium (mg/kg)	490	1660	1170 (70.5)
Iron (mg/kg)	750	1830	1080 (59.0)
Manganese (mg/kg)	8.4	15	6.6 (44.0)
Arsenic (mg/kg)	< 1	1.88	-
Cadmium (mg/kg)	< 0.1	<0.1	-
Chromium (mg/kg)	4.1	6.7	2.6 (38.8)
Copper (mg/kg)	< 2	<1	-
Lead (mg/kg)	< 2	<1	-
Nickel (mg/kg)	< 1	<1	-
Zinc (mg/kg)	< 5	1.7	-

While the sample was collected on 8 July, Mgt-LabMark analysed Distance 1 mid benthic sample 3 on 26 August. ALS analysed the corresponding samples Distance 1 mid benthic sample 1 and Distance 1 mid benthic sample 2 on 20 July. The delay with the analyses was due to a laboratory error, and this delay resulted in an exceedence of the holding time for some analytes, namely the ultratrace PAH, TPH, MAH and mercury.

The reported values for Distance 1 mid benthic sample 3 were in general lower than the values of corresponding samples Distance 1 mid benthic sample 2 and Distance 1 mid benthic sample 1. It is considered likely that the different results on the corresponding samples (which were within holding times) shown in Table 11 are attributable to lack of homogeneity in background contaminant concentrations in sediments.

19.5 Potential for Impacts on Sediment Quality

Changes to sediment quality are likely to be associated with changes in the physical characteristics of the sediment (from altered hydrodynamic conditions around the jetty). Longer-term changes may also result from increases in level of contaminants associated with shipping activities. These potential impacts are discussed in more detail in Section 11.7 and 12.5.

These changes, if they occur, may result in localised changes to infaunal assemblages. Discussion regarding the potential for impacts on macro-infauna assemblages is presented in Section 13.5.

19.6 Conclusion

No sediment contamination was detected from the analyses performed with all analytes reported below the relevant screening criteria.

The information obtained during this survey will provide useful information regarding the background (pre-construction) conditions of the physical and chemical properties of the sediment.

20.0 PHYSICAL PARAMETERS - WATER QUALITY

Water quality samples were collected on 15 August 2011 to document the water quality conditions at Port Spencer and at locations further afield. These data provide information about baseline conditions at the proposed Port Spencer facility. The results have been compared to South Australian Environmental Protection Policy, 2003 Water Quality Guidelines (EPP, 2003) and the Australian and New-Zealand Environment and Conservation Council (ANZECC, 2000) water quality guidelines for South-central Australia, Level of Protection (95% species) (ANZECC, 2000).

20.1 Sampling Methods

The sampling method implemented was consistent with the South Australia Environment Protection Authority (SA EPA) Regulatory Monitoring and Testing: Water and Wastewater Sampling Guidelines (EPA, 2007). At each site, surface samples (up to 1 m BSL) were collected from above both the seagrass (nearshore) and the mid benthic sandy habitats. The sample locations (refer to Figure 6, Appendix A) were as follows:

- One impact location (the Potential Impact Zone), which included three separate sites (one central site (Distance 1) and one of each site to the north and south of the central site (Distance 3 North and Distance 3 South).
- Two control locations each at a distance of approximately 3.5km from the central impact location, consisting of one location to the north and south (Distance 6 North and Distance 6 South), and
- Two reference (additional ‘near field’ control) locations. One at Lipson Island (due to the high conservation value of the region as a National Estate Conservation Park) and one approximately 1.5 km north (Distance 5 South and Distance 5 North, respectively).

One water sample was collected at each location, as well as an additional two samples from the Distance 1 (nearshore) location for quality assurance purposes. The parameters measured were as follows:

- total iron
- chlorophyll-a
- nitrite and nitrate, and
- total phosphorus.

For each sample, laboratory-supplied sample bottles were used. Each sample bottle was pre-labelled with the date, a unique site code and a unique sample reference number. Each sample was collected up to 1 m below the water surface, using a mighty gripper apparatus. This sampling device assisted with the samples being collected away from the vessel engine to avoid contamination.

All samples were collected directly into the pre-labelled containers, except for samples that required filtering (nitrate/nitrite). The nitrate/nitrite samples were collected into clean sampling containers and filtered using the vacuum filtration method (Stericup Filter Units with Millipore 0.22 µm membrane) on board the research vessel. Field filtration was undertaken on these samples to maximise the sample’s integrity during transport from the sampling site to the laboratory. Nutrients such as nitrate and nitrite can have a short retention period in a sample and filtering can extend this significantly (EPA, 2007).

Once collected, labelled samples were stored in chilled, insulated containers and upon return from the field, sent directly to NATA-accredited laboratories (ALS Melbourne and ALS Sydney). Chain of Custody (COC) forms were used to keep track of samples from the field, to the laboratory and then for receipt of the data. All samples were collected on 15 August 2011 and transferred using overnight delivery to the laboratories in order to meet holding times. Samples were transported in chilled, insulated containers to maintain a temperature of 4°C to reduce degradation rates.

For Quality Assurance/Quality Control (QA/QC) purposes, the primary duplicate sample D1 NS2 was analysed at the ALS laboratories, while the secondary duplicate sample D1 NS3 was sent to Mgt-Labmark.

In addition to the water chemistry samples, a hand-held multi-parameter meter (Aquaread™ water quality meter) was used to measure the following:

- dissolved oxygen
- water temperature
- pH
- electrical conductivity/salinity, and
- turbidity.

Many physical properties are best determined in-situ by field measurements. In-situ measurements for the parameters listed above are considered more reliable (EPA, 2007). Water temperature, electrical conductivity, dissolved oxygen, redox, turbidity and salinity were measured on Site by the Aquaread water-quality meter, at up to 1 m below surface at all locations. Three replicate readings were collected per location. The Aquaread water-quality meter was calibrated prior to use and the calibration certificate was provided by the manufacturer.

Additional turbidity readings were recorded by using a secchi disk. The secchi disk is a circular disk with a black and white pattern, lowered by a chain, used to measure water transparency. By recording the length of the released chain until the pattern is no longer visible, the visibility in the water column in metres is measured. The higher the secchi disk depth, the clearer the water. The weather was sunny with little to no wind on the day of sampling, which provided optimal conditions for secchi disk readings.

20.2 Screening Criteria

The water quality measurements were assessed against the Australian and New Zealand Guidelines for Fresh and Marine Waters (ANZECC & ARMCANZ 2000) and the South Australian *Environment Protection (Water Quality) Policy* (EPA 2003). These guidelines provide water quality trigger values, that, if exceeded, indicate possible impacts, and may trigger further investigations.

Where South Australian water quality guidelines were available, the trigger values of EPP (2003) were followed. In instances where they were not available, ANZECC & ARMCANZ (2000) guidelines were used. Table 3.4.1 from ANZECC & ARMCANZ (2000) defines trigger values for marine waters. For Port Spencer, a 95% level of protection (slightly to moderately disturbed ecosystem) was used for comparison between laboratory results and trigger values.

20.3 Results and Discussion

The results of the chemical analyses and in-situ readings are presented in Appendix E.

20.3.1 Total iron

Samples were collected in 60 mL plastic containers as required to avoid contamination during sampling. All total iron results were below the reporting limit (LOR) of 0.50 mg/L.

Total iron is absent from the ANZECC & ARMCANZ (2000) and EPP (2003) Guidelines.

20.3.2 Chlorophyll-a

Chlorophyll-a is a specific form of chlorophyll used by most photosynthetic organisms to absorb energy from light and release chemical energy. Chlorophyll-a is the most common of the six photosynthetic pigments and is found in all plants, including phytoplanktonic algae. Each pigment absorbs light more efficiently in a different part of the spectrum. Chlorophyll-a absorbs well at a wavelength of about 400-450 nm (violet-blue) and at 650-700 nm (orange-red).

Concentrations of chlorophyll-a in estuarine, coastal or marine waters are used as an indicator of photosynthetic plankton biomass and the increased amounts of nutrients incorporated into this biomass. Chlorophyll-a concentration is the most commonly used parameter for monitoring phytoplankton biomass and nutrient status, as an index of water quality, with low levels suggesting good condition. However, high levels may be naturally occurring and therefore may not necessarily be indicative of poor conditions. Rather, it is the long-term persistence of high levels above that which is considered to be ‘natural’ background levels which may create a problem.

Poor water quality associated with high chlorophyll concentrations needs to be distinguished from the natural variation observed with the seasons and with hydrodynamic features. Observed increases in the concentrations of chlorophyll may be related to increased nutrient concentrations, decreased flow and/or decreased turbidity (increased light penetration) (Estuarine, Coastal and Marine Habitat Integrity, 2008).

Samples were collected in 1 L plastic bottles. For analysis of chlorophyll-a, the pigments were extracted into aqueous acetone. The optical density of the extract before and after acidification at both 664 nm and 665 nm was determined spectrometrically.

ANZECC and ARMCANZ (2000) nominate a trigger value of 1 µg/L chlorophyll-a. The results of the water quality sampling programme indicated that some exceedences of the ANZECC & ARMCANZ (2000) guideline occurred. The locations and exceedences are listed below.

- Nearshore locations south of the jetty:
  - Distances 3 South (6 µg/L); Distance 5 South (6 µg/L); Distance 6 South (4 µg/L)
- Mid benthic areas north of the proposed jetty:
  - Distances 3 North (2 µg/L); Distance 5 North (3 µg/L); Distance 6 North (2 µg/L).
- Distance 1, nearshore QA/QC primary duplicate (4 µg/L).

The remaining concentrations were below the LOR of 1µg/L.

20.3.3 Ultratrace nutrients: nitrites and nitrates

Oxidised nitrogen includes nitrite (NO_2) and nitrate (NO_3). Compounds of nitrogen are essential in low concentrations for all biota, though excessive amounts mean direct-effect stressors which could cause problems. High concentrations of nutrients, such as nitrogen, can result in excessive growth of aquatic plants like phytoplankton, cyanobacteria, macrophytes, seagrasses, and filamentous and attached algae (ANZECC & ARMCANZ 2000).

Nitrate and nitrite were filtered on site, collected in 60 ml containers and analysed at ALS Sydney. Nitrite is determined by direct colourimetry by Flow Injection Analysis (FIA). Nitrate is reduced to nitrite and nitrite is determined separately by direct colourimetry. The result for Nitrate is calculated as the difference between the two results. Combined oxidised Nitrogen (NO_2+NO_3) is determined by Cadmium Reduction and direct colourimetry by FIA.

Guidelines for nitrates and nitrites are absent in the South Australian EPP (2003) for marine waters. ANZECC and ARMCANZ (2000) indicate a trigger value for oxides of nitrogen (NOx) of 0.050 mg/L.

Nitrite results for all sites were below LOR of 0.002 mg/L. Nitrate values vary between 0.016 and 0.034 mg/L. The guideline value of 0.05 mg/L was not exceeded.

20.3.4 Total phosphorus

Phosphorus is a naturally-occurring element and is found in ocean sediments. Total phosphorus (TP) is the sum of organic and inorganic forms of phosphorus. Although TP is likely to be an overestimate of the biologically-available phosphorus in a water sample, biochemical processes, remineralisation of organic phosphorus and conversions between the various forms, mean that measures of TP give a reasonable indication of the amount of phosphorus ultimately available.

Nutrients such as phosphorus and nitrogen are essential at low concentrations for the effective functioning of marine life but excessive concentrations can lead to direct-effect stressors. Increased concentrations of phosphorus may provide increased opportunity for algae growth. Anthropogenic sources of phosphorus are soil erosion, stormwater runoff, sewage and agricultural discharges.

ANZECC & ARMCANZ (2000) defines a trigger value for total phosphorus of 0.1 mg/L. The South Australian EPP (2003) lists a total phosphorus trigger value of 0.5 mg/L. The reported values for TP ranged from 0.09 to 0.34 mg/L. With the exception of samples collected from the nearshore Distance 5 South and mid benthic Distance 6 South locations, all sites exceeded the ANZECC & ARMCANZ (2000) trigger value. There were no exceedences of the EPP (2003) trigger value of 0.5 mg/L.

20.3.5 Dissolved oxygen and water temperature

Dissolved oxygen (DO) is a measure of the amount of oxygen in the water and is presented in mg/L, or as a saturation percentage. DO in marine water usually ranges from 6 to 14 mg/L, with higher values indicating greater oxygen availability and better water quality. DO is a direct indicator of the amount of available oxygen for marine fauna and flora. ANZECC & ARMCANZ (2000) contains no trigger values for DO for south central Australian marine waters. For south-east Australian marine waters, the lower limit is 90% and the upper limit trigger value is 110%. EPP (2003) defines a limit of >6 mg/L dissolved oxygen.

The mid benthic locations had slightly higher DO than the nearshore locations and there was a slight gradual increase from Distance 1 towards Distance 6 distances. The DO variability at nearshore locations ranged from 9.52 to 10.16 mg/L, while at the mid benthic locations DO varied from 10.07 to 9.7 mg/L. All DO values are above the limit of 6 mg/L, which indicates high oxygen concentrations.

The Aquaread meter contains an optical DO sensor and readings are automatically corrected in the meter for temperature, salinity and atmospheric pressure. Measurements ranged from 9.5 to 10.16 mg/L.

20.3.6 pH

Table 3.3.8 from ANZECC & ARMCANZ (2000) outlines a default trigger values for pH in south-central Australia, with a lower limit of 8.0 and an upper limit of 8.5. Water Quality EPP (2003) does not include a pH value for marine waters.

The pH level was measured in the laboratory and by the Aquaread water-quality meter via a temperature-corrected, combined gel-filled pH redox electrode. A small difference between laboratory results from samples and meter readings were noted. The meter shows slightly greater variability in pH than the laboratory results.

There is no obvious difference between nearshore and mid benthic locations. The pH of the water ranged from 7.90 to 8.26 for the in-situ measurements, and 7.83 to 8.15 for the laboratory results.

20.3.7 Electrical conductivity/salinity

Conductivity is measured as electrical conductivity (EC) in micro Siemens per centimetre-squared ($\mu S/cm^2$) in situ and at the laboratory at 25 °C. EC values from the water samples vary for all locations from 54.8 to 55.3 $\mu S/cm^2$ analysed by ALS Sydney and from 57.1 to 63.4 $\mu S/cm^2$ at ALS Melbourne. Salinity was measured in-situ at an average of 35.9 ± 2.5 ppt for all sites.

20.3.8 Turbidity

ANZECC & ARMCANZ (2000) defines default trigger values for turbidity of estuarine and marine waters of south central Australia. Values are, however, highly site-specific. The lower limit is 0.5 NTU (Nephelometric turbidity) and the higher limit is 10 NTU, where the latter is mostly applicable for estuarine and inshore coastal environments due to wind-induced resuspension or inputs from the catchment. Lower values are normally found in offshore waters (ANZECC & ARMCANZ, 2000). South Australian EPP (2003) also defines a turbidity trigger value of 10 NTU.

Nephelometric turbidity (in NTU) was measured in situ using the Aquaread meter. All readings were reported below the detection limit (i.e. <1 NTU).

Water transparency through the water column was also measured with a secchi disk. The sea bottom was visible from the research vessel at all of the nearshore sites with water depths of 8 to 10 m. The secchi disc reached the seagrass before the limit of visibility was reached. At the mid benthic sites with more than 12 m of water depth, 11 m was consistently measured. Secchi disk readings were 8 to 11 m at all sites, which indicates good visibility and clear water at the time of sampling.

20.4 QA/QC

Quality assurance/ quality control (QA/QC) measures are undertaken as part of the water quality analysis and include a comparison between in-situ readings, inter-sample laboratory results and inter-laboratory variation.

20.4.1 Inter-sample variability

As an inter-measurement check, three replica measurements were taken in situ with the Aquaread water quality meter at each location. All 42 readings per parameter showed the same result per location, except of one dissolved oxygen reading being 10.15 mg/L compared to two 10.16 mg/l readings.

As an inter-sample variability check, a primary duplicate sample (Distance 1 nearshore sample 2) was collected at the Distance 1 location. D1 NS1 and D1 NS2 were analysed by the ALS laboratories. The results are presented in Table 14.

Table 14: Summary of primary duplicate analysis by ALS of Distance 1 Nearshore sample

	Distance 1 Nearshore sample 1	Distance 1 Nearshore Sample 2	Difference (RPD %)
Chlorophyll-a (µg/l)	<1	4	-
Electrical conductivity (µS/cm) ALS Melbourne	60300	63400	3100 (4.9)
Electrical conductivity (µS/cm) ALS Sydney	55200	55200	0 (0)
Nitrate (mg/l)	0.021	0.018	0.003 (14.3)
Nitrite (mg/l)	< 0.002	< 0.002	-
pH (-) ALS Melbourne	8.06	8.08	0.02 (0.2)
pH (-) ALS Sydney	7.83	7.90	0.07 (0.9)
Total phosphorus (mg/l)	0.34	0.26	0.08 (23.5)
Total iron (mg/l)	< 0.50	< 0.50	-

Inter-sample differences are low, with a variability ranging from 0 to 23.5 %.

20.4.2 Inter-laboratory variability

Parameters pH and electrical conductivity were both measured from the water samples by two different laboratories; ALS Melbourne and ALS Sydney and are illustrated in Table 15 and Table 16.

Table 15: Inter-laboratory variability in pH measurement (pH unit) of nearshore and mid benthic water samples.

	ALS Melbourne	ALS Sydney	Difference (RPD %)	Aquaread water quality meter
Nearshore water quality samples				
Distance 1 sample 1	8.06	7.83	0.23 (2.8)	7.90
Distance 1 sample 2	8.08	7.90	0.18 (2.2)	-
Distance 3 North	8.09	8.04	0.05 (0.6)	8.16
Distance 3 South	8.11	8.06	0.05 (0.6)	8.00
Distance 5 North	8.12	8.07	0.05 (0.6)	8.07
Distance 5 South	8.12	8.08	0.04 (0.5)	8.25
Distance 6 North	8.10	8.15	0.05 (0.6)	7.98
Distance 6 South	8.12	8.08	0.04 (0.5)	8.26
Mid benthic water quality samples				
Distance 1	8.09	8.07	0.02 (0.2)	8.10
Distance 3 North	8.08	8.07	0.01 (0.1)	8.26
Distance 3 South	8.12	7.88	0.24 (3.0)	8.00
Distance 5 North	8.12	8.04	0.08 (1.0)	8.24
Distance 5 South	8.13	8.06	0.07 (0.9)	7.98
Distance 6 North	8.12	8.07	0.05 (0.6)	8.11
Distance 6 South	8.11	7.99	0.12 (1.5)	8.11

Additional information regarding Table 15 includes:

- For completeness, the in situ readings of the water quality meter are added to Table 15. Every Aquaread value represents three readings per location. All three pH and EC readings were the same per location.
- The difference between the two laboratories is low; the relative percentage difference reaches from 0.1 to 3.0 %. The in situ readings are similar to both laboratory results, and
- Secondary duplicate sample Distance 1 Nearshore sample 3 was analysed by secondary laboratory Mgt-Labmark. pH value is 8.2, which is slightly higher than all D1 NS readings; 8.06, 7.83, 8.08, 7.90, 7.90.

Table 16: Inter-laboratory variability of electrical conductivity (µS/cm) of nearshore and mid benthic samples.

	ALS Melbourne	ALS Sydney	Difference (RPD %)
Nearshore water quality samples			
Distance 1	60300	55200	5100 (8.5)
Distance 1 (D1 NS2)	63400	55200	8200 (12.9)
Distance 3 (D3 Nth NS)	63000	55100	7900 (12.5)
Distance 3 (D3 Sth NS)	60800	55200	5600 (9.2)
Distance 5 (D5 Nth NS)	60600	55300	5300 (8.7)
Distance 5 (D5 Sth NS)	61200	55200	6000 (9.8)
Distance 6 (D6 Nth NS)	62000	54800	7200 (11.6)
Distance 6 (D6 Sth NS)	60800	55200	5600 (9.2)
Mid benthic water quality samples			
Distance 1 (D1 MB)	60400	55100	5300 (8.8)
Distance 3 (D3 Nth MB)	61100	55100	6000 (9.8)
Distance 3 (D3 Sth MB)	63000	55300	7700 (12.2)
Distance 5 (D5 Nth MB)	60200	55000	5200 (8.6)
Distance 5 (D5 Sth MB)	57100	55100	2000 (3.5)
Distance 6 (D6 Nth MB)	61800	55000	6800 (11.0)
Distance 6 (D6 Sth MB)	60600	55300	5300 (8.7)

Additional information regarding Table 16 includes:

- EC values measured by ALS Melbourne are consistently about 10% higher than the ALS Sydney measurements. Distance 5 South mid benthic is an exception with a 3.5% difference, and
- Secondary duplicate sample Distance 1 nearshore sample 3 was analysed by secondary laboratory Mgt-Labmark. EC at location D1 is 56000, which is close to the ALS Sydney measurement of 55200.

All parameters were analysed by secondary laboratory Mgt-Labmark for nearshore location Distance 1. Distance 1 nearshore sample 3 is considered the secondary duplicate sample for samples Distance 1 nearshore sample 1 and Distance 1 nearshore sample 2.

Table 17 presents the results as inter-laboratory differences between Mgt-Labmark and ALS, either Melbourne, Sydney or both.

Table 17: Inter-laboratory variability of all parameters on nearshore water sample at Distance 1.

	Mgt-Labmark: Distance 1 Nearshsore Sample 3	ALS: Distance 1 Nearshsore Sample 1 and Distance 1 Nearshsore Sample 2	Difference (RPD %)
Chlorophyll-a (µg/l)	<5	< 1 , 4	-
Electrical conductivity (µS/cm)	56000	60300, 63400, 55200, 55200	2525 (4.3)*
Nitrate (mg/l)	<0.02	0.021, 0.018	-
Nitrite (mg/l)	<0.02	< 0.002, <0.002	-
pH (-)	8.2	8.06, 8.08, 7.83, 7.90	0.2 (2.5)*
Phosphorus (mg/l)	<0.05	0.34, 0.26	-
Total iron (mg/l)	<0.05	<0.50, <0.50	-

Note: * - Where a difference is calculated, the average of the four ALS results is used.

Additional information regarding Table 17 includes:

- If there are two values shown in the column of ALS, Distance 1 nearshore sample 1 and Distance 1 nearshore sample 2 were analysed. Four values mean both ALS Melbourne and Sydney, also for Distance 1 nearshore sample 1 and Distance 1 nearshore sample 2, and
- Most values are reported below LOR at Mgt-Labmark, hence a difference was not calculated.

20.5 Potential for Impacts on Water Quality

Water quality can be impacted through increased nutrients, chemicals or suspended particulates. These can have subsequent flow-on effects such as altered biological responses (for example, increased phytoplankton or epiphyte growth, loss of algal or seagrass species, and/or acute or chronic toxicity to plants and animals).

Spills from vessels are considered one of the major sources of water pollution from shipping. Such spills are typically relatively small in volume (OECD 1997); however, they typically also occur more frequently than other types of spills in a port environment (OECD 1997). The potential for impacts to occur from cargo spills (iron ore and grain) at the Site has been addressed in section 21.0.

Increases in turbidity may result from shipping or pile driving activities (suspended sediment) or from loss of export material (suspended particulates). Increased turbidity can negatively impact on the marine environment through either a direct reduction of water clarity (which reduces the level of light reaching plants), or through smothering of plants and sessile invertebrates and the sediment settles out of the water column (Edgar 2001).

The potential impacts to habitats from increased suspended sediment and/or particulates has been discussed in Sections 10.6, 11.7, 12.5 and 13.5.

20.5.1 Mitigation measures

As discussed in previous sections, measures to reduce impacts on water quality will include the use of fabric filtering around piles to reduce the potential for increased turbidity during pile driving activities; as well as management practices during the operation of the port. These measures will require that vessels are not under their own power within 1.5 km of the jetty to minimise the potential for increased suspended sediment, and the use of enclosed conveyors to minimise the loss of export material.

20.6 Conclusions

Baseline water-quality data were collected in August 2011. The water quality measurements were assessed against the Australian and New Zealand Guidelines for Fresh and Marine Waters (ANZECC & ARMCANZ 2000) and the South Australian *Environment Protection (Water Quality) Policy* (EPA 2003). These guidelines provide water quality trigger values, that, if exceeded, indicate possible impacts, and may trigger further investigations.

The parameters measured were as follows:

- total iron
- chlorophyll-a
- nitrite and nitrate
- total phosphorus
- dissolved oxygen
- water temperature
- pH
- electrical conductivity/salinity, and
- turbidity.

All values were within an acceptable limit when compared to trigger value guidelines (where they were available) with the exception of chlorophyll-a concentrations at several sites. ANZECC and ARMCANZ (2000) nominate a trigger value of 1 µg/l chlorophyll-a. The results of the water quality sampling program indicated that some exceedences of the ANZECC & ARMCANZ (2000) guideline occurred for chlorophyll-a (range between 2 µg/l and 6 µg/l).

21.0 ASSESSMENT OF POTENTIAL IMPACTS FROM INCIDENTAL ORE OR GRAIN SPILLAGE

Iron is abundant in the Earth's crust but is uncommon in seawater because of its poor solubility (Phippen *et al.*, 2008). Dissolved concentrations of iron in the deep ocean are in the order 33.5 x 10^{-9} mg/L, and have been measured in surface Antarctic waters in the order of 12.8 x 10-9 mg/L to 55.8 x 10^{-9} mg/L (cited by Phippen *et al.*, 2008). Armstrong (1957, citing Lewis and Goldberg, 1954) reports concentrations of iron in marine waters up to 3 mg/L with the majority of concentrations in the range of 10 to 100 µg/L – (the geographical region, depth of water samples or proximity to land mass is not provided). Iron concentrations (particulate and dissolved) are greater closer to the shore and decrease towards the open ocean (Mallavarapu *et al.*, 2008)).

Breitbarth *et al.* (2010) note that concentrations of iron in coastal waters are several orders of magnitude higher than the open ocean, except in high-nutrient low-chlorophyll (HNLC) waters. These waters exist where nutrients such as nitrogen and phosphorus are high but iron levels are low. The Southern Ocean is considered a HNLC environment (Breitbarth *et al.*, 2010). Spencer Gulf is not considered to be a HNLC region, but a low nutrient environment (*pers. comm.* Simon Bryars and Peter Fairweather, 2011; SA EPA, 2010).

Iron is most commonly present in water in the ferrous (Fe^{2+}) and the ferric (Fe^{3+}) valencies. In surface waters, iron is generally present in the ferric state. In reducing waters, the ferrous form can persist (ANZECC & ARMCANZ, 2000). Ferrous iron is largely considered to be a limited and poorly bioavailable source of iron as a consequence of its short residence time in oxygenated water (Brietbarth *et al.*, 2010). However, there is recent evidence that ferrous iron is retained in oxygenated water by organic ligands (Breitbarth *et al.*, 2010).

Hematite and magnetite (the iron (oxide) ore that will predominate in the ore handled at the proposed Port) are particularly stable and insoluble forms of iron. Iron oxides in well oxygenated high pH (e.g. pH 8) waters (such as seawater) are highly stable and therefore poorly soluble (Mallavarapu *et al.*, 2008). A number of factors increase the availability of iron in coastal waters. Breitbarth *et al.* (2010) consider these factors to be primarily: photochemical processes; organic complexation; cycling of iron between particulates, colloids and the truly dissolved fraction. Mallavarapu *et al.* (2008) and Phippen *et al.* (2008) note the main factors that affect the solubility of iron in high pH waters to be the following:

- concentration of dissolved and total organic matter
- dissolved oxygen
- mineralogy of the iron
- humic and organic acids
- chloride concentration
- ionic substitution
- particle-size and surface area
- particulate deposition rate
- pH, and
- ultra-violet radiation.

As reported by Mallavarapu *et al.* (2008), there is limited evidence in the literature to suggest that low molecular weight organic acids released by phytoplankton, terrestrial plants and bacteria may increase the dissolution of iron minerals, in the presence of sunlight and low pH. Furthermore, Mallavarapu *et al.* (2008)

consider that iron may be increasingly soluble in coastal water relative to offshore waters, due to increased availability soluble organic carbon and phytoplankton. This is supported in the recent review by Breitbarth *et al*, (2010) who note that iron bioavailability is influenced by the chemical speciation of iron, redox, biological cycling and an organism's uptake strategy. One strategy by microorganisms is to release organic matter that reacts with iron thereby increasing its bioavailablity.

Mallavarapu *et al.* (2008) conducted solubility tests using hematite and saltwater and found that the larger iron ore particles (0.5 – 2 mm fraction) from hematite were insoluble. The 0.1 – 0.5 mm size particles on the other hand were slightly soluble. Modelling of an assumed release of 75 kg hematite ore dust into a 50,000 m^3 volume of seawater at Port Spencer would equate to an increase in soluble iron of 1.5 ng/L.

In the absence of scientific study on the effects of ultraviolet radiation on hematite availability, Mallavarapu *et al.* (2008) consider that, although ultraviolet radiation can increase soluble iron (depending on chemical form of iron, and other environmental factors such as pH, redox), hematite is unlikely to be photoreduced.

The rate at which dust particles settle out of the water column and settle on the benthos will depend on the particle size. Fine particles are likely to remain in suspension for longer, with greater potential for transport further afield, and greater potential for dissolution (should suitable environmental conditions prevail), than larger particles. Furthermore, the ionic-substitution (i.e. where other elements have substituted for iron) in hematite and magnetite can affect the solubility. Aluminium is the element most commonly associated with hematite and magneitite. Aluminium substitution typically results in increased stability and therefore reduced potential for dissolution in seawater (Malllavarapu *et al.*, 2008).

21.1 Water Quality and Sediment Guidelines

21.1.1 Iron

Iron can be measured directly in water. Trace element analyses in water are performed using Inductively Coupled Plasma - Mass Spectrometry (ICP -MS) techniques. The current analytical practical quantitation limit (PQL) for iron is 2 µg/L in marine water (NSW EPA 2000 cited in ANZECC & ARMCANZ, 2000).

There are no water quality guidelines for iron in marine waters in Australia and New Zealand (ANZZECC & ARMCANZ, 2000), Canada (CCME, 2011) or the United States (USEPA, 2011). This is due to a lack of marine ecotoxicological studies from which to develop them. A low-reliability trigger value is provided in ANZECC & ARMCANZ (2000), which has been derived from a freshwater guideline used in Canada. This value is 300 µg/L; however, its applicability to marine waters in Australia is questionable. Additional site-specific data collected over time will better serve the purpose of establishing background concentrations, against which potential changes can be assessed.

Phippen et al., (2008) state that "*due to the relatively high mean pH of marine waters (approximately pH 8.2), very little iron would remain in solution, and it is not anticipated that iron toxicity would therefore be a concern.*"

Similarly, there are no applicable sediment quality guidelines (marine or freshwater) in Australia and New Zealand, Canada or the United States.

The high energy marine environment prevailing at the Site makes it unlikely that significant accumulation of hematite or magnetite dust releases (should they happen) in sediment will occur. Furthermore, the low solubility and toxicity of iron relative to other metals suggests the potential for adverse effects associated with iron ore releases at Port Spencer are low.

21.1.2 Physical parameters

The energy of the coastal environment is a major factor in determining the impacts of suspended solids and organic matter inputs. A high energy environment will significantly disperse organic particulates and bring in waters with increased dissolved oxygen levels. A moderate energy marine environment, such as at Port Spencer, may be expected to flush out releases of particulates and organic matter, and introduce oxygen into surface waters from wave action. These prevailing conditions would help to mitigate adverse effects of releases of iron ore dust and grain to the marine environment surrounding the jetty (should they occur). However, the extent of impacts would be largely determined by the quantity of iron ore or grain released and the frequency of spillage. The extent of iron ore or grain release during loading activities will be minimised at the Site through the use of enclosed conveyors.

The physical parameters suspended solids, turbidity, organic matter, dissolved oxygen and chlorophyll-a are discussed in the following paragraphs.

Suspended solids

An increase in suspended particulates (such as might occur from releases of iron ore or grain) can result in a reduction in light penetration and smothering of benthic species (ANZECC & ARMCANZ, 2000). Suspended particles also affect aquatic life by clogging the feeding apparatus of filter-feeders, altering the physical habitat by filling the interstices of the substrate and affecting decomposition rates and availability of detrital material. Changes in detritus will affect the availability of food for many macroinvertebrates and subsequently biodiversity.

The South Australia Environment Protection (Water Quality) Policy 2003 (SA EPA, 2003) provides a water criterion of 10 mg/L for suspended sediment in marine waters.

Turbidity

Low turbidity values are normally found in offshore marine waters with higher values found in inshore coastal waters.

The South Australian water policy provides a criterion of 10 NTU which is consistent with the range provided by ANZECC & ARMCANZ (2000) of 0.5–10 NTU for South-Central Australia. The SA EPA (2003) policy water quality criteria should be used in preference to ANZECC & ARMCANZ (2000) trigger values.

Organic matter and dissolved oxygen

An increase in fine organic matter (associated with grain releases) may result in decreased dissolved oxygen (ANZECC & ARMCANZ, 2000) as a consequence of increased decomposition by microorganisms. Aerobic heterotrophic[19] microorganisms decompose organic matter and use dissolved oxygen in the process. Low dissolved oxygen concentrations can result in adverse effects on many aquatic organisms which need adequate oxygen for normal functioning and survival. The extent of the reductions in dissolved oxygen concentrations depend upon the biodegradable organic matter loading, microbial activity, the amount of respiration occurring, and the energy of the coastal environment. At reduced dissolved oxygen concentrations many toxic compounds become increasingly toxic (ANZECC & ARMCANZ, 2000). However there is limited information available on the oxygen concentration tolerance range of Australian marine species.

The South Australia Environment Protection (Water Quality) Policy 2003 (SA EPA, 2003) provides a water quality criterion of >6 mg/L for dissolved oxygen in marine waters.

19 A heterotrophic organism is one that cannot manufacture its own food. Instead it obtains its food and energy by taking in organic substances, usually plant or animal matter.

Chlorophyll-a

Iron is an essential element required for photosynthesis, respiration, nitrogen fixation and nitrate reduction (Breitbarth *et al.*, 2010) and is needed by plants to produce chlorophyll. Soluble iron in marine waters is thus needed for plant growth and is a limiting factor to primary production (and therefore photosynthesis) (Breitbarth *et al.*, 2010).

Concentrations of chlorophyll-a in estuarine, coastal or marine waters are used as an indicator of photosynthetic plankton biomass and the increased amounts of nutrients incorporated into this biomass. Chlorophyll-a concentration is the most commonly used parameter for monitoring phytoplankton biomass and nutrient status, as an index of water quality, with low levels suggesting good condition.

A trigger value of 1 µg/L for chlorophyll-a is recommended by ANZECC & ARMCANZ (2000) for marine waters in South Central Australia. The South Australian water policy does not provide a criterion for chlorophyll-a.

21.2 Potential Effects of Accidental Iron Releases

The iron ore handled at the proposed port facility will predominantly consist of the iron oxides hematite (Fe_2O_3) and magnetite (Fe_3O_4). These are very poorly soluble forms of iron.

Management controls will be in place to limit dust releases to the atmosphere and marine environment. However, consideration should also be given to accidental spills and releases that could impact on the environment. Increases in suspended particulates could reduce light penetration and cause smothering of benthic organisms.

The rate at which dust particles settle out of the water column and settle on the benthos will depend on the particle size. Fine particles are likely to remain in suspension for longer, with greater potential for transport further afield, and greater potential for dissolution (should suitable environmental conditions prevail), than larger particles.

Work conducted by researchers at the University of South Australia for Centrex (Mallavarapu *et al.* 2008), into the solubility of iron ore in seawater support the view that these forms or iron will be poorly soluble in seawater and unlikely to result in increased primary production (or increased phytoplankton growth). Solubility calculations conducted by Mallavarapu *et al.* (2008) on an accidental release of iron ore (for the purpose of the study, a spill quantity of 75kg was nominated) could result in an increase in soluble iron by 1.5 ng/L. Considering the dissolved concentrations of iron in seawaters presented earlier and reported by Phippen *et al.*, (2008) - 12.8 x 10-9 mg/L to 55.8 x 10-9 mg/L in surface Antarctic waters and Armstrong (1957) – 10 to 100 µg/L, this increase in soluble iron is of trace proportions.

This estimate of increased solubility is considered to be a conservative figure as the calculations also assumes discharge into a finite volume of water (50,000 m^3), little dispersion, and little sedimentation.

After consideration of the prevailing moderate energy environment at the Site, the solubility of iron in the marine environment, and assuming iron ore releases are the order of 75 kg as discussed in Mallavarapu *et al.* (2008), the impacts to the marine environment are not expected to be significant.

21.3 Potential Effects of Accidental Grain Releases

Should accidental grain releases occur, it is the introduction of fine organic matter into the marine environment which could potentially have a greater impact on the marine environment rather than the grain itself. An increase in fine organic matter may result in the following:

- decreased dissolved oxygen as a consequence of increased decomposition by microorganisms
- increased suspended particulates that reduce light penetration and can cause smothering of benthic species, and
- increased growth of aquatic plants due to increased nutrient inputs. Nuisance growth of aquatic plants can result in algal blooms and associated toxic effects. In addition, when the plants die, there is a reduction in dissolved oxygen concentrations as the plants are decomposed.

Calculations on releases of grain into the marine environment at Port Spencer have not been performed however, if they occur, they are considered likely to be similar in nature to those at other nearby loading facilities (for example, Wallaroo, Port Pirie and Port Linciln). Similarly, calculation on the quantity of fine organic matter in a specified quantity of grain has not been estimated. However, it is considered unlikely that an accidental spill of grain at the proposed Port Spencer facility will result in an unacceptable environmental impact given that accidental releases will be readily minimised and mitigated.Conclusion

Hematite and magnetite (the iron (oxide) ores that will predominate in the ore handled at the Port) are particularly stable and insoluble forms of iron. Iron oxides in well-oxygenated high pH (e.g. pH 8) waters (such as seawater) are highly stable and therefore poorly soluble. The potential for loss of export product during loading activities will be minimised through the use of an enclosed conveyor system. There is the potential for an accidental releases of iron ore or grain to occur at the Site; however, it is considered unlikely that an accidental spill would result in an unacceptable environmental impact given that any accidental releases will be readily minimised and mitigated.

22.0 ASSESSMENT OF POTENTIAL IMPACTS FROM ACCIDENTAL RELEASES OF HYDROCARBONS

Petroleum entering the marine environment through spills or long-term (chronic) releases is eventually broken down, removed from the environment by natural processes or diluted to levels below concentrations of concern (NRC 2003). The composition of each product will influence how it will behave in the marine environment and determine its likely effects on biota and habitats (NRC 2003), while the rate of weathering (and abiotic degradation) is dependent on temperature, wave action and sunlight (ANZECC & ARMCANZ 2000). However, until hydrocarbon degradation occurs, released petroleum products can pose a threat to the environment (NRC 2003). The nature and extent of this threat can vary depending on parameters such as the size of the release, composition of the petroleum, the location of the release and sensitivity of the organisms exposed.

The potential for accidental releases of hydrocarbons to occur from operational shipping activities associated with Port Spencer is considered low, as loading and unloading of petroleum products will not occur at the Port.

There is also the potential for accidental releases to occur more widely beyond the Port, through shipping accidents. However, the shipping industry is regulated by government to ensure that safety and environmental protection is considered. Commonwealth legislation (such as the Navigation Act 1912) provides the basis for regulating matters such as (amongst other things) ship safety and protection of the marine environment. Given the well regulated nature of the industry, and considering the infrequent nature of significant shipping incidents, the potential for impacts to occur on marine life from oil spills associated with shipping accidents is considered low.

Notwithstanding this, it is recommended to implement an oil spill management plan within the Site environmental management plan. This shall include mobilising on-site spill response measures, when required, as well as emergency response measures, should a larger spill occur that requires the use of booms and dispersants.

23.0 RECOMMENDED APPROACH TO ONGOING MONITORING

In order to further understanding of the ecological conditions at the Site, and, in turn, support an assessment of potential impacts from the development of the Port, Golder proposes to implement a survey design that will monitor the biological communities that are considered most at risk at the Site.

In the longer term, quantitative data collected during this stage of works will provide a database which can be utilised as part of future assessments.

23.1 Survey Design

Assessments of changes to biological communities are widely accepted as the best means of measuring overall environmental impact (Downes et al. 2002; AAD 2009). However, in order to assess changes, an understanding of the nature of the potential impact is needed. For example, consideration of where and when the potential effect will likely occur (i.e. definition of the spatial and temporal extent), what organisms will likely be affected (fish, plants, etc.), and what exposures are likely to be experienced (type, magnitude and duration) are important to the survey design (Smith 2002).

Further to these key considerations, the design of the survey must be sensitive enough to be able to detect a change. It is widely accepted (for example, Roberts et al. 2010; Downes et al. 2002; Underwood 1991, 1992, 1993, 1994; Green 1979 amongst others) that a robust (and therefore defensible) study should include following sampling:

- Before and After the event
- at multiple Control locations, and at least one Impact location (together referred to as a MBACI[20] design), and
- with sufficient replication of sampling effort to ensure a sufficiently powerful test.

As described in Terlizzi et al. (2005) and Downes et al. (2002), the MBACI (multiple Before/After-Control/Impact) approach, in particular, has been proposed in order to support the confident identification of changes associated with human-induced impacts as opposed to those caused by natural variability (Osenberg and Schmitt 1996 as cited in Terlizzi et al. 2005). Since the first formulation of BACI experimental designs (Green 1979 as cited in Terlizzi et al. 2005), various improvements have been developed to deal with cases of spatial and temporal confounding (Bernstein & Zalinski 1983, Stewart-Oaten et al. 1986, Eberhardt and Thomas 1991 as cited in Terlizzi et al. 2005). The development of Beyond-BACI (Underwood 1991) and MBACI designs, in particular, has led to significant advances in the reliable detection of impacts associated with human activities. Such designs use multiple control locations and multiple times of sampling, and an impact, if it exists, can be detected as a statistical interaction in the difference between the impacted and control locations from before to after the disturbance.

23.2 Intertidal Rocky Shores

Golder does not consider that ongoing monitoring of the intertidal rocky shores will be required for the Stage 1 Development Application.

23.3 Intertidal Sandy Beaches

Golder does not consider that ongoing monitoring of the intertidal sandy habitats at the Site will be required for the Stage 1 Development Application.

[20] BACI pertains to Before/After/Control/Impact, while MBACI is an advanced version of BACI and refers to Multiple Control and multiple Before/After sampling which has been shown to be more reliable for the assessment of impacts.

23.4 Subtidal Rocky Reefs

Golder recommends that additional quantitative surveys be implemented prior to the start of construction works and that that these surveys should be undertaken during the summer and winter seasons. This will provide a baseline of 'before' data to support ongoing environmental monitoring of potential impacts.

During future surveys, it will be necessary to collect data from the Potential Impact Zone (as was done for the current survey) and from control locations. Golder propose that Distance 6 North and South be retained as the control locations; however, these locations should be ground-truthed during a preliminary site visit to ensure that conditions at these locations are similar to those in the Potential Impact Zone. The Reef Life Survey methods are considered appropriate for future surveys; however, some modifications to the number (and possibly length) of transects sampled may be necessary to ensure sufficient replication within sites.

23.5 Seagrass Meadows

Golder proposes that additional quantitative surveys of the seagrass meadows be undertaken in the period prior to construction (before) and post-construction (after) in the Potential Impact Zone as well as at two control locations in order to document change which may occur to the cover of seagrass meadows. Golder propose that these surveys should be undertaken in summer and winter. This will provide a baseline of 'before' data to support the ongoing construction and operation monitoring assessment.

The differences recorded by the video sled in regards to the seagrass species present at the different locations have implications for ongoing monitoring at the Site. Subsequent surveys should involve a preliminary site visit to ground truth conditions so that new control locations can be chosen that better represent the conditions within the Potential Impact Zone.

Once established, quantitatively documenting the conditions at the control locations compared to the Potential Impact Zone is a key element to the survey design. Without these 'before' data, pre-existing differences between locations may be perceived as impacts attributable to the construction of the proposed jetty.

Golder further recommends that a combination of techniques be used to monitor seagrass meadows in both shallow (approximately 8 – 9 m BSL) and deep (approximately 11 – 12 m BSL) water. These include the following:

- Percentage cover of seagrass cover to document the existing extent of patchiness and percentage cover of sand from naturally-occurring fragmentation of seagrasses, and
- Counts of epifaunal invertebrate and cryptic fish assemblages.

Some modifications to the number of replicate transects may need to be implemented to ensure sufficient replication is achieved within sites.

23.6 Subtidal Sandy Substrates

As part of the current survey, benthic macro-infaunal samples were collected from the mid benthic sandy habitat (see Section 13.0). No species of conservation significance were identified as part of these surveys. As such, Golder does not consider that further sampling of the benthic macro-infaunal assesmblages in sandy sediments is required prior to construction. Further discussion about macro-infaunal surveys has been provided below (Section 23.7).

23.7 Macro-infauna

Macro-infaunal assemblages are widely used in the monitoring of effects of marine impacts as the organisms are mostly sessile and integrate the effects over time (Gray, Clarke, Warwick, & Hobbs, 1990 as cited in Currie and Isaacs 2005).

Ongoing monitoring of *M. senhousia* at the Port Spencer site should be included as part of future surveys.

In addition to the marine pest monitoring, Golder proposes that benthic macro-infaunal samples continue to be collected from seagrass habitats from sites within the Potential Impact Zone and from two control locations. In regard to the control locations, Distance 6 North and South are considered the most appropriate as they are sufficiently far from the proposed jetty to be well outside the area of potential impact.

Ongoing monitoring will also provide valuable information about the distribution and abundance of the leucosiid crab *C. vincentianus,* which until now, has not been documented. Any information about this species will assist with demonstrating its distribution in the broader context of the region.

23.8 Sediment

Golder recommends that sediment sampling be undertaken as part of monitoring once Port operation begins. Further pre-construction monitoring is not considered necessary. Together with the results of the before construction surveys, ongoing monitoring will provide information regarding the physical and chemical properties of the sediment over time.

Sampling should be undertaken at sites within the Potential Impact Zone and at the Distance 6 north and south two control locations. Such information will assist with understanding changes in sediment quality which may be associated with port operations.

23.9 Water Quality

Golder recommends that water quality sampling be undertaken on a monthly basis for 12 months in order to obtain a more comprehensive baseline of data.

Sampling should be undertaken at multiple sites within the Potential Impact Zone and at two control locations.

Water samples should be collected and analysed for the following parameters:

- Total Nitrogen (TN)
- Total Kjeldahl Nitrogen (TKN)
- Ammonium (NH4-N)
- Nitrite (NO2-N)
- Nitrate (N03-N)
- Total Phosphorus (TP)
- Orthophosphate (FRP)
- Chlorophyll a, b, c (trichromatic)
- Dissolved Metals
- Total Fe

Physico-chemical profiling should also be undertaken using a multi-parameter water quality meter (YSI or equivalent).

The proposed monitoring will provide a more thorough understanding about the existing marine environment. This includes documenting background concentrations of the potential contaminants, which may be introduced from future incidental spillage during ship loading operations, as well as an understanding of the factors which influence eutrophication (algal growth), including total nitrogen and temperature, should an algal bloom occur during operational activities.

24.0 SUMMARY OF FINDINGS

The findings of these surveys indicate that the habitats at the Site are naturally spatially variable and representative of those founds in the region. No threatened species were identified as occurring at the Site; however, a naturally-rare leucosiid crab (*Cryptocnemus vincentianus)* and a marine pest (*Musculista senhousia*) were identified as occurring in the seagrass habitat.

The information obtained during the current study has been used to further document the baseline conditions at the Site and to develop a more comprehensive understanding of the potential for impacts to occur from the construction and operation of the proposed jetty.

25.0 LIMITATIONS OF THIS REPORT

Your attention is drawn to the document - “Limitations” (LEG04, RL1), which is included in Appendix F of this report. The statements presented in this document are intended to advise you of what your realistic expectations of this report should be. The document is not intended to reduce the level of responsibility accepted by Golder Associates, but rather to ensure that all parties who may rely on this report are aware of the responsibilities each assumes in so doing.

We would be pleased to answer any questions the reader may have regarding these ‘Limitations’.

26.0 REFERENCES

26.1 General References

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Report Signature Page

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APPENDIX A

Figures

PORT SPENCER

CENTREX METALS LTD

SITE SETTING

LEGEND

- Township
- Approximate Site Boundary

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Aerial image sourced from Bing Maps, date sourced 15.12.2011.

Site data sourced from Parsons Brinckerhoff

Aerial image sourced from DEH, South Australian Government

0 5 10 20 30 40 50 Kilometers

SCALE (at A3) **1:1,000,000**

DATUM GDA 94, PROJECTION MGA Zone 53

PROJECT:	**107661001**
DATE:	**7 OCT 2011**
DRAWN:	**KB**
CHECKED:	**EL**

FIGURE 1

Golder Associates

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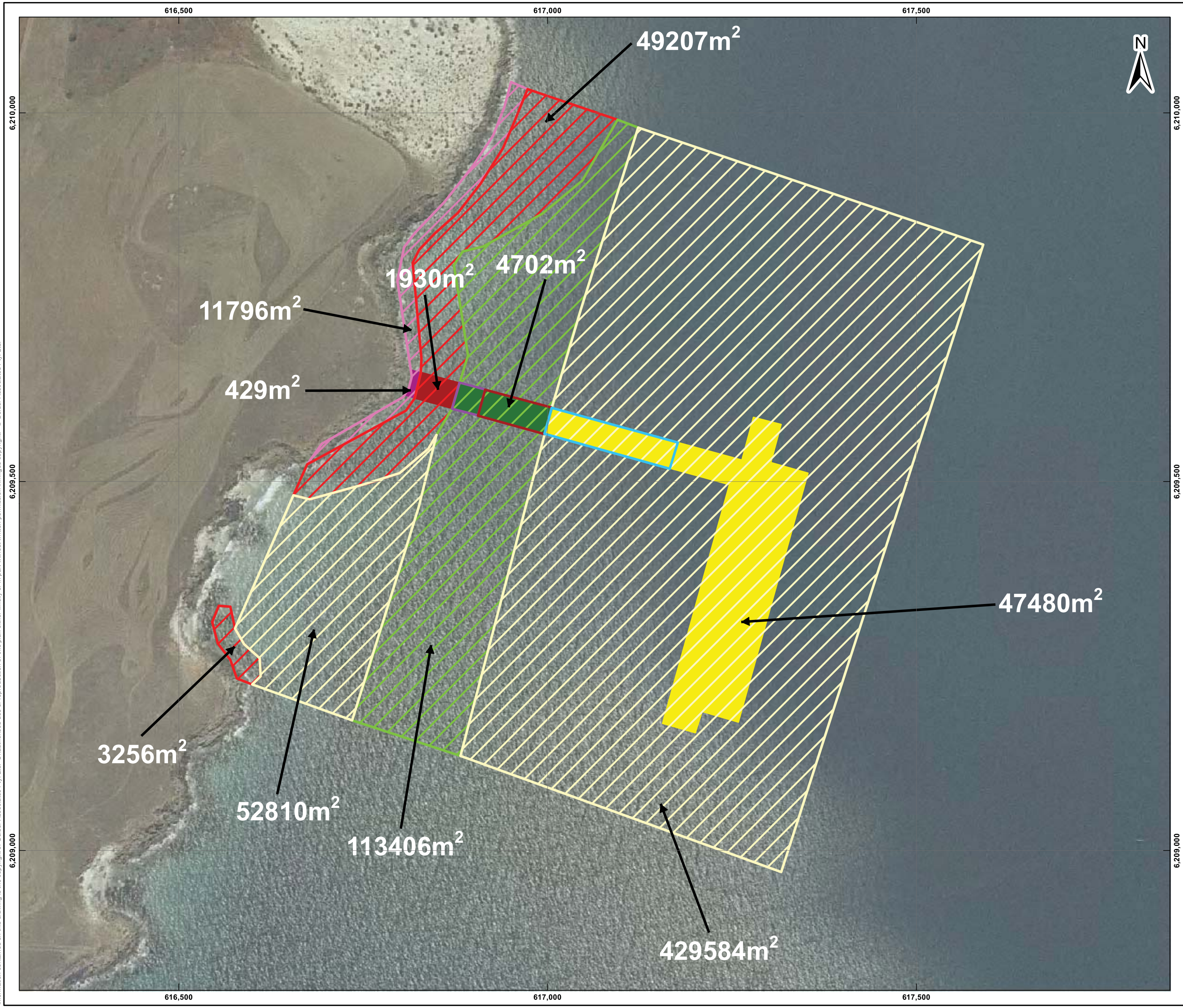

PORT SPENCER

CENTREX METALS LTD

HABITAT CALCULATION

LEGEND

- Seagrass (Amphibolis antarctica, Posidonia sinuosa and P. angustifolia)
- Seagrass (Posidonia sinuosa and P. angustifolia)
- Sand (sparse cover of Heterozostera nigricaulis and Halophila australis)

Jetty width plus 5 m buffer either side

- Intertidal Rocky Reef
- Subtidal Rocky Reef
- Seagrass
- Sandy Substrate

Jetty width plus 25 m buffer on either side

- Intertidal Rocky Reef
- Subtidal Rocky Reef
- Seagrass
- Sandy Substrate

0 25 50 100 150 200 Meters

SCALE (at A3) 1:5,000

DATUM GDA 94, PROJECTION MGA Zone 53

PROJECT: 107661001
DATE: 08 FEB 2012
DRAWN: KB
CHECKED: EL

FIGURE 2

Golder Associates

PORT SPENCER

CENTREX METALS LTD

GENERAL DISTANCE LOCATIONS

LEGEND

Distance Location

NOTES

Potential Impact Zone includes Distance 1, Distance 2 North and South and Distance 3 North and South.

Distance 4 North and South were not sampled and have been removed from the gradient design.

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Site data sourced from Parsons Brinckerhoff.

0 0.25 0.5 1 1.5 2 Kilometers

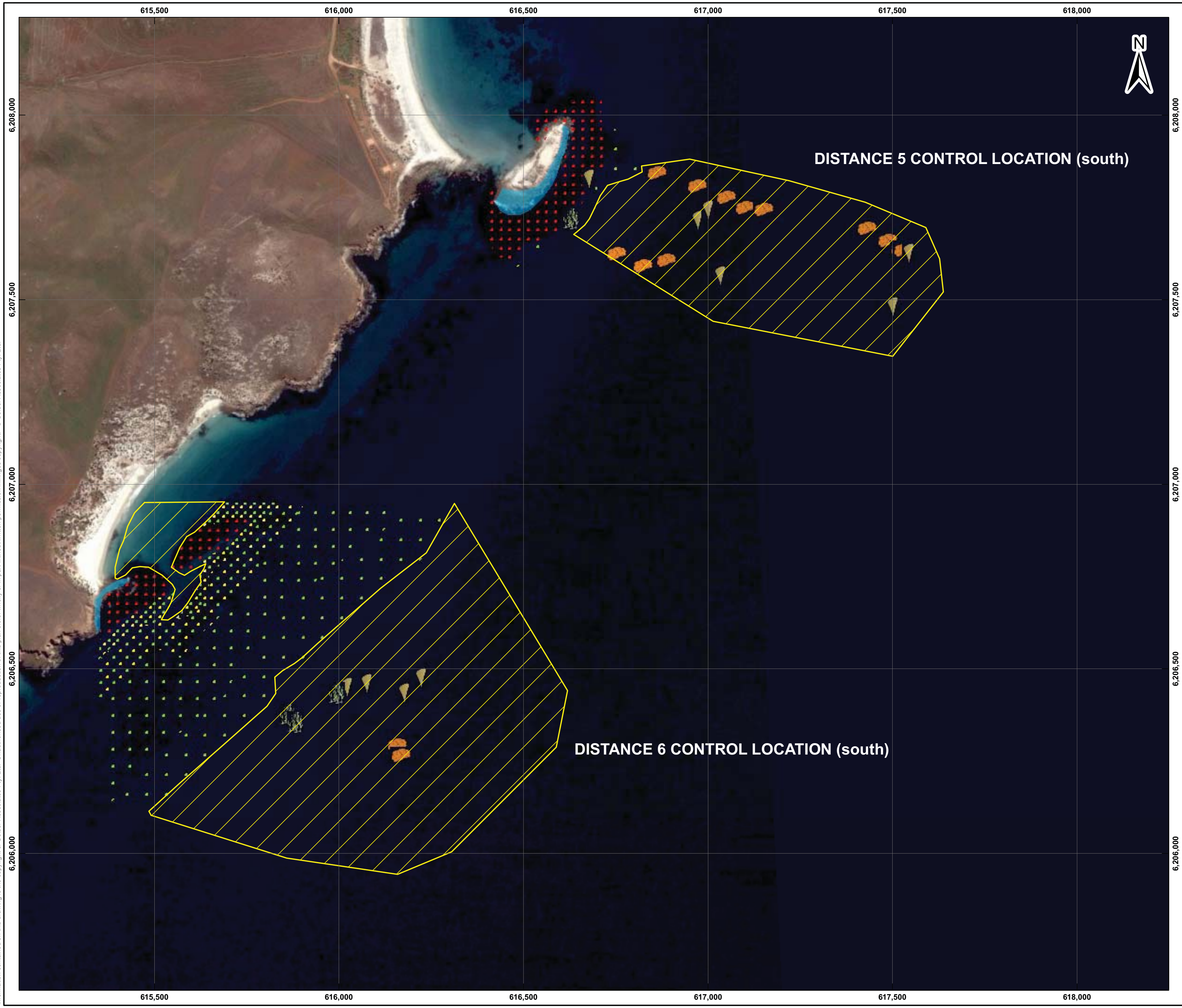
SCALE (at A3) 1:50,000

DATUM GDA 94, PROJECTION MGA Zone 53

PROJECT: **107661001**
DATE: **07 OCT 2011**
DRAWN: **KB**
CHECKED: **EL**

FIGURE 3

Golder Associates



PORT SPENCER

CENTREX METALS LTD

DISTANCE 6 AND 5 FAR-FIELD ZONE (SOUTH) HABITAT PLAN

LEGEND

- Reef / Macroalgae
- Posidonia sinuosa / angustifolia
- Amphibolis antartica
- Sand
- Heterozostera nigricaulis
- Razor clam
- Sponge
- Intertidal Rocky Shore

Habitat Density key

- Dense Coverage
- Medium to Dense Coverage
- Medium Coverage
- Sparse Coverage

Aerial image sourced Bing Maps, date sourced 26.11.2011.

0 50 100 200 300 400 500 metres

SCALE (at A1) **1:10,000**

DATUM GDA 94, PROJECTION MGA Zone 53

PROJECT: **107661001**
DATE: **18 NOV 2011**
DRAWN: **KB**
CHECKED: **EL**

FIGURE 4a

Golder Associates

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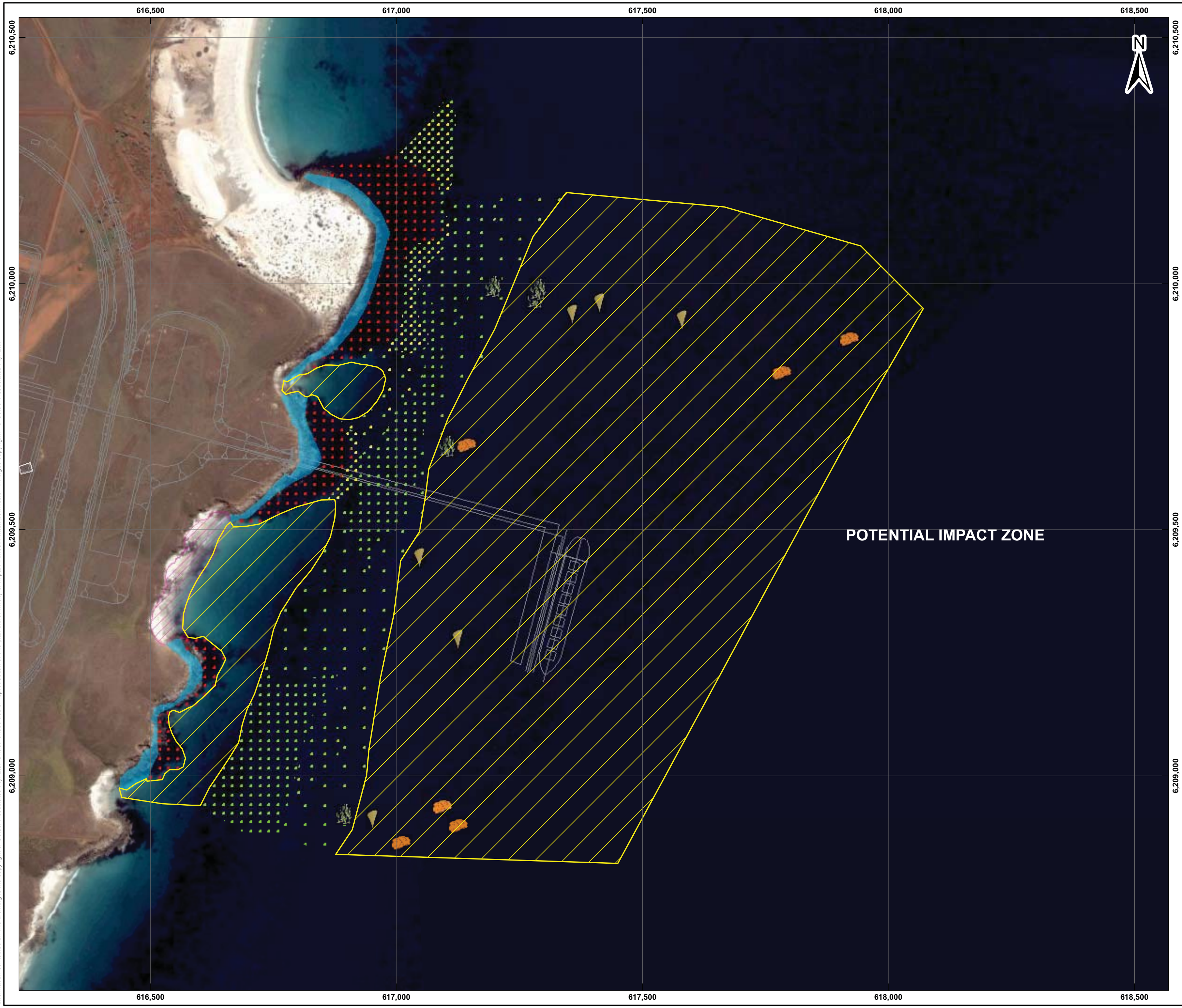

PORT SPENCER

CENTREX METALS LTD

DISTANCE 1 , 2 AND 3 NEAR FIELD (POTENTIAL IMPACT) ZONE HABITAT PLAN

LEGEND

- Reef / Macroalgae
- Posidonia sinuosa / angustifolia
- Amphibolis antartica
- Sand
- Heterozostera nigricaulis
- Razor clam
- Sponge
- Intertidal Rocky Shore
- Intertidal Sandy Beach / Bays

Habitat Density key

- Dense Coverage
- Medium to Dense Coverage
- Medium Coverage
- Sparse Coverage

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Aerial image sourced Bing Maps, date sourced 26.11.2011.

Site data sourced from Parsons Brinckerhoff, Drawing No: 2172612A-CIV-0003 Rev C, Drawn By: JMc, Drawing Date: 15.08.2011.

0 50 100 200 300 400 metres

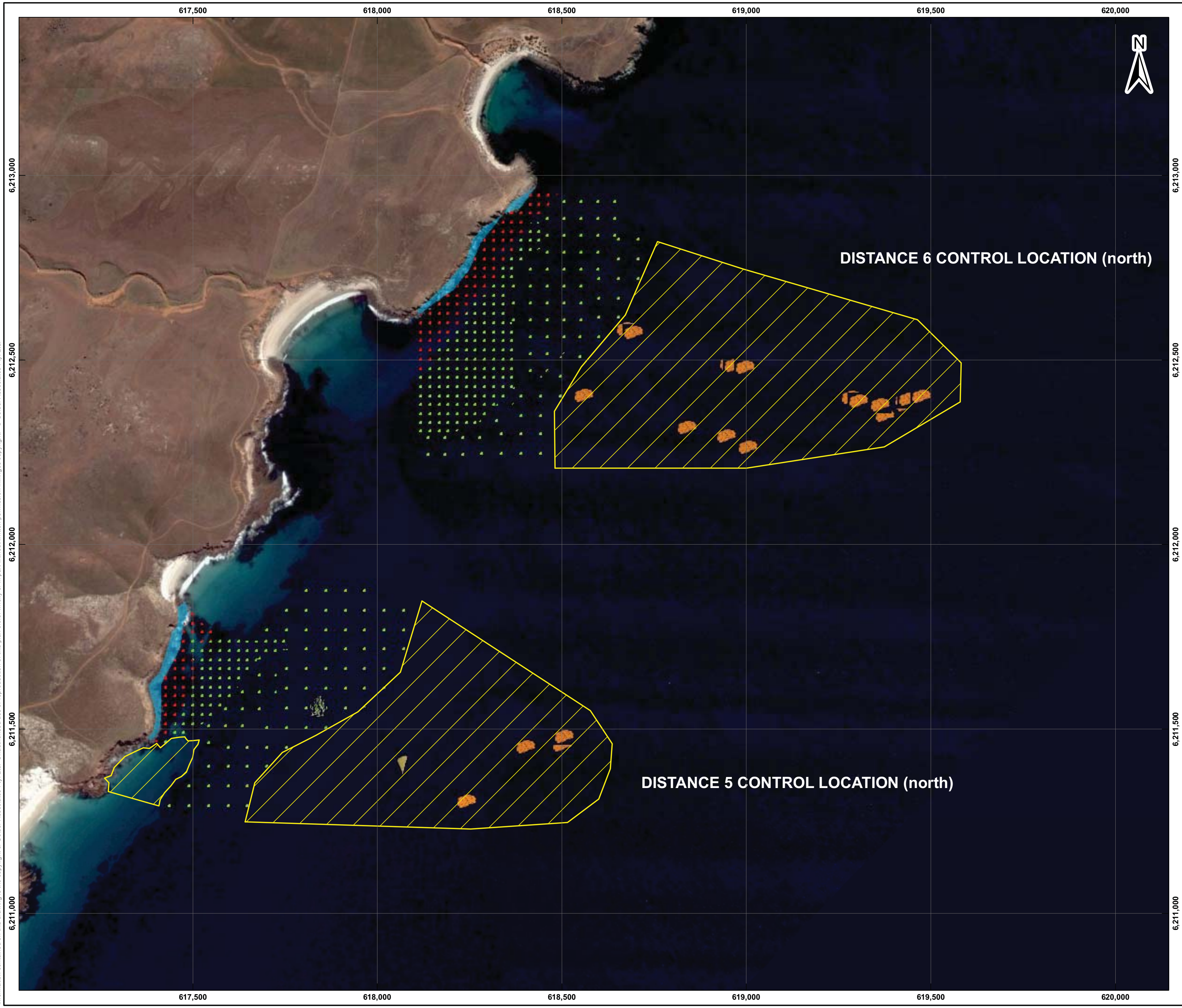
SCALE (at A1) **1:7,500**

DATUM GDA 94, PROJECTION MGA Zone 53

PROJECT: **107661001**
DATE: **18 NOV 2011**
DRAWN: **KB**
CHECKED: **EL**

FIGURE 4b

Golder Associates



PORT SPENCER

CENTREX METALS LTD

DISTANCE 6 AND 5 FAR FIELD ZONE (NORTH) HABITAT PLAN

LEGEND

- Reef / Macroalgae
- Posidonia sinuosa / angustifolia
- Amphibolis antartica
- Sand
- Heterozostera nigricaulis
- Razor clam
- Sponge
- Intertidal Rocky Shore

Habitat Density key

- Dense Coverage
- Medium to Dense Coverage
- Medium Coverage
- Sparse Coverage

Aerial image sourced Bing Maps, date sourced 26.11.2011.

0 50 100 200 300 400 500 metres

SCALE (at A1) 1:10,000

DATUM GDA 94, PROJECTION MGA Zone 53

PROJECT: 107661001
DATE: 18 NOV 2011
DRAWN: KB
CHECKED: EL

FIGURE 4c

Golder Associates

PORT SPENCER

CENTREX METALS LTD

INTERTIDAL SAMPLING LOCATIONS

LEGEND

● Intertidal Sampling Location

NOTES

Distance 4 North and South were not sampled and have been removed from the gradient design.

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Site data sourced from Parsons Brinckerhoff.

0 125 250 500 750 1,000 Metres

SCALE (at A3) 1:22,500

DATUM GDA 94, PROJECTION MGA Zone 53

PROJECT:	107661001
DATE:	07 OCT 2011
DRAWN:	KB
CHECKED:	EL

FIGURE 5

Golder Associates

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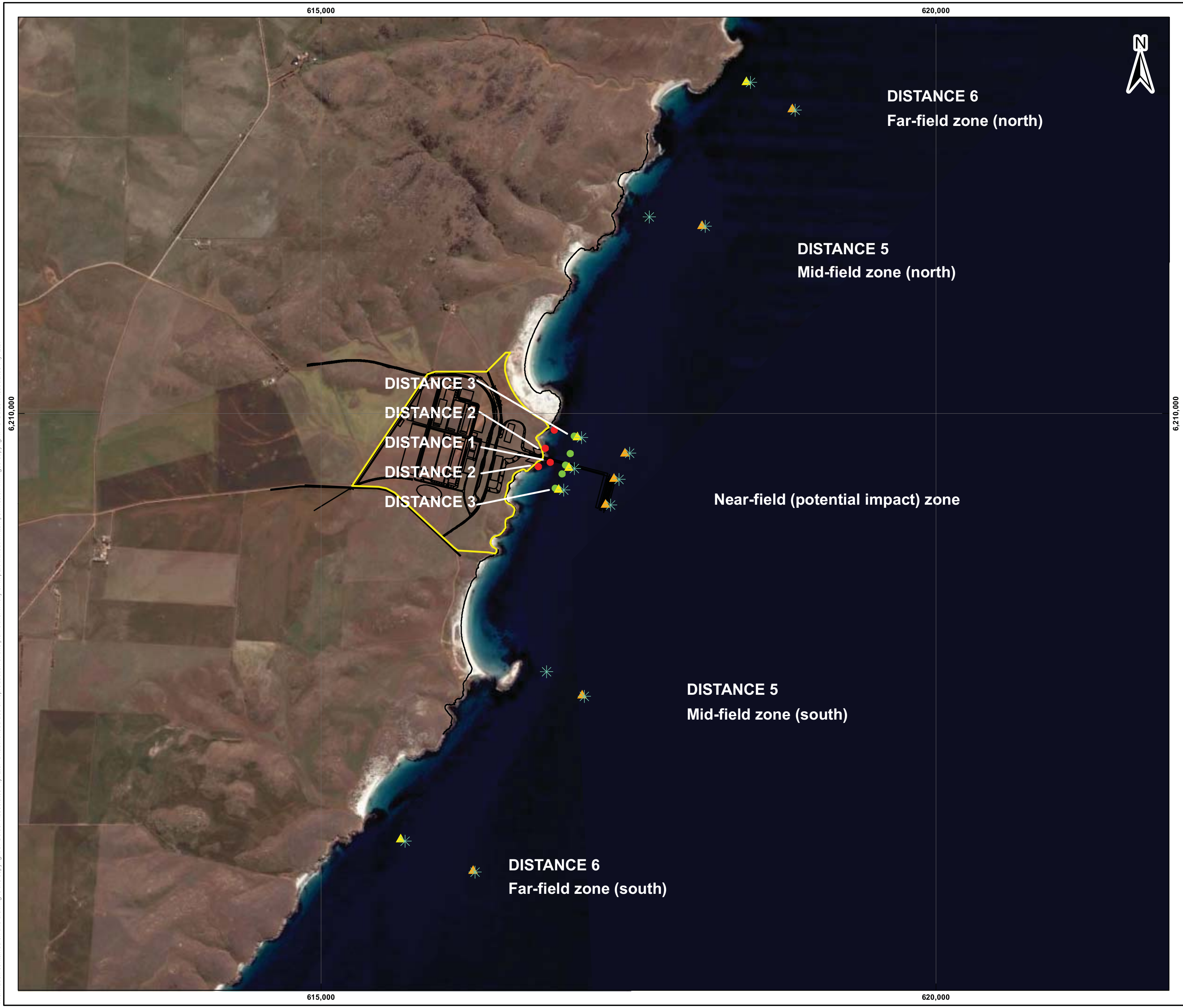

PORT SPENCER

CENTREX METALS LTD

SAMPLING ZONES

Legend

- Approximate Subtidal Rocky Reef Survey Location
- Approximate Seagrass Survey Location
- Approximate Seagrass Sediment Sampling (incl. Infauna)
- Approximate Mid Benthic Sediment Sampling (incl. Infauna)
- Approximate Water Quality Sampling Sampling Location

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Site data sourced from Parsons Brinckerhoff.

0 125 250 500 750 1,000 Meters

SCALE (at A3) **1:30,000**

DATUM GDA 94, PROJECTION MGA Zone 53

PROJECT: **107661001**
DATE: **07 OCT 2011**
DRAWN: **KB**
CHECKED: **EL**

FIGURE 6

Golder Associates

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APPENDIX B

Ecological Survey Results

Table 1: Summary of Species / Taxa Recorded During Intertidal Rocky Shore Surveys

Group	Phylum / subphylum	Description	Species
Algae	Cyanobacteria	Blue green algae	*Rivularia firma*
			Blue green film
	Chlorophyta	Green algae	Green turfing algae
			Ulva lactuca
	Heterokontophyta	Brown algae	Brown filamentous algae
			Hildenbrandia rubra
			Colpomenia sinuosa
			Sargassum sp.
	Rhodophyta	Red algae	Red turfing algae
			Red encrusting algae
			Pink enc. coralline algae
			Coralline algae
			Gelidium pusillum
			Gracilaria sp.
			Laurencia sp.
Sessile Invertebrates	Bivalvia	Mussel	*Xenostrobus pulex*
	Crustacea	Barnacles	*Tetraclitella purpurascens*
			Chthamalus antennatus
			Chamaesipho tasmanica
			Catomerus polymerus
	Anthozoa	Anemones	*Actinia tenebrosa*
	Polychaeta	Tube worm	*Galeolaria caespitosa*
Mobile invertebrates	Gastropoda	Snails	*Austrocochlea porcata*
			Austrocochlea constricta
			Austrocochlea concamerata
			Austrolittorina unifasciata
			Bembicium spp.
			Nerita atramentosa
			Cantharidus sp.
		Whelk	*Lepsiella* sp.
		True limpets	*Cellana tramoserica*
			Patelloida latistrigata
			Patelloida alticostata
			Patella chapmani
			Notoacmea spp.
		False limpets	*Siphonaria diemenensis*
			Siphonaria zelandica
	Polyplacophora	Chitons	*Plaxiphora albida*

Table 2: Port Spencer Intertidal Line Intercept Transect (LIT) Data

Golder Associates

Location: Potential Impact Zone

Site	**Distance 1 (Centre) (15/08/2011)**									
Transect	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Substrate										
Rock	180	490	500	205	470	500	470	500	500	315
Boulders	320	10	0	126	30	0	30	0	0	185
Pebbles	0	0	0	107	0	0	0	0	0	0
Sand	0	0	0	62	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**
Organisms										
Bare	290	303	41	500	207	185	96	159	336	500
Turfing alage	5	126	62	0	208	108	202	104	88	0
Encrusting algae	33	0	5	0	15	0	0	0	20	0
Foliose algae	0	10	0	0	0	0	52	0	0	0
Barnacles	0	0	382	0	35	199	124	237	56	0
Galeolaria	22	6	0	0	35	8	26	0	0	0
Mussels	0	0	0	0	0	0	0	0	0	0
Pink encrusting	150	55	10	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**

Site	**Distance 2 North (18/08/11)**									
Transect	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Substrate										
Rock	379	448	442	189	26	500	113	320	120	210
Boulders	121	52	58	311	474	0	387	180	380	290
Pebbles	0	0	0	0	0	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**
Organisms										
Bare	500	336	407	457	500	447	470	475	500	500
Turfing alage	0	52	0	17	0	0	0	0	0	0
Encrusting algae	0	0	0	0	0	0	0	0	0	0
Foliose algae	0	0	0	0	0	0	0	0	0	0
Barnacles	0	112	93	19	0	53	30	25	0	0
Galeolaria	0	0	0	7	0	0	0	0	0	0
Mussels	0	0	0	0	0	0	0	0	0	0
Pink encrusting	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**

Site	**Distance 2 South (15/08/2011)**									
Transect	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Substrate										
Rock	260	493	475	0	103	189	500	452	500	500
Boulders	225	0	25	500	397	258	0	38	0	0
Pebbles	15	7	0	0	0	53	0	10	0	0
Sand	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**
Organisms										
Bare	488	500	341	291	460	355	90	475	441	360
Turfing alage	0	0	69	0	0	17	85	25	36	0
Encrusting algae	0	0	0	105	0	40	0	0	0	0
Foliose algae	0	0	0	0	0	0	0	0	0	0
Barnacles	12	0	90	47	40	0	300	0	0	140
Galeolaria	0	0	0	57	0	88	25	0	23	0
Mussels	0	0	0	0	0	0	0	0	0	0
Pink encrusting	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**

August 2011 sampling period
Entered by RB and CB.
Checked by EKL.

Table 2: Port Spencer Intertidal Line Intercept Transect (LIT) Data

Golder Associates

Location	Control North																				Control South									
Site	**Site 1 (16/08/2011)**										**Site 2 (16/08/2011)**										**Site 1 (18/08/2011)**									
Transect	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Substrate																														
Rock	22	215	365	25	115	130	312	140	460	25	205	500	380	500	400	431	330	500	313	63	0	399	210	186	332	95	251	500	319	477
Boulders	379	226	120	340	315	353	171	309	40	321	295	0	120	0	100	69	170	0	187	391	500	89	290	314	168	405	249	0	123	23
Pebbles	99	59	15	135	70	17	17	51	0	154	0	0	0	0	0	0	0	0	0	46	0	12	0	0	0	0	0	0	58	0
Sand	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**
Organisms																														
Bare	442	500	358	500	395	450	500	380	294	500	317	223	305	310	211	500	482	425	500	201	495	392	486	480	433	500	458	465	500	420
Turfing alage	0	0	0	0	0	0	0	0	0	0	16	0	0	148	25	0	18	0	0	0	0	0	0	0	5	0	42	0	0	0
Encrusting algae	53	0	142	0	40	25	0	10	60	0	9	0	5	0	124	0	0	10	0	0	0	0	0	20	0	0	0	0	0	0
Foliose algae	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Barnacles	5	0	0	0	0	0	0	75	21	0	77	17	55	0	0	0	0	65	0	0	0	108	0	0	52	0	0	35	0	80
Galeolaria	0	0	0	0	0	0	0	25	115	0	81	260	135	42	140	0	0	0	0	299	5	0	14	0	10	0	0	0	0	0
Mussels	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink encrusting	0	0	0	0	65	25	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**

August 2011 sampling period
Entered by RB and CB.
Checked by EKL.

Table 2: Port Spencer Intertidal Line Intercept Transect (LIT) Data

Location	Control South									
Site	Site 2 (18/08/2011)									
Transect	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Substrate										
Rock	500	475	422	500	0	410	500	352	0	500
Boulders	0	0	78	0	500	75	0	148	500	0
Pebbles	0	25	0	0	0	15	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**
Organisms										
Bare	437	475	443	475	495	440	342	477	470	420
Turfing alage	0	0	0	0	0	15	0	0	0	0
Encrusting algae	0	0	0	0	0	0	0	0	10	0
Foliose algae	0	0	0	0	0	0	0	0	0	0
Barnacles	63	25	12	15	0	45	150	18	0	80
Galeolaria	0	0	45	0	5	0	0	5	20	0
Mussels	0	0	0	0	0	0	0	0	0	0
Pink encrusting	0	0	0	0	0	0	8	0	0	0
TOTAL	**500**	**500**	**500**	**490**	**500**	**500**	**500**	**500**	**500**	**500**

Location	Lipson Island									
Site	Site 2 (17/08/2011)									
Transect	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Substrate										
Rock	332	163	250	245	151	257	210	0	161	170
Boulders	168	244	188	255	239	243	191	391	313	173
Pebbles	0	93	62	0	110	0	99	109	26	157
Sand	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**
Organisms										
Bare	500	500	500	500	500	500	500	500	360	500
Turfing alage	0	0	0	0	0	0	0	0	50	0
Encrusting algae	0	0	0	0	0	0	0	0	0	0
Foliose algae	0	0	0	0	0	0	0	0	0	0
Barnacles	0	0	0	0	0	0	0	0	0	0
Galeolaria	0	0	0	0	0	0	0	0	90	0
Mussels	0	0	0	0	0	0	0	0	0	0
Pink encrusting	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**

Location	Lipson Island									
Site	Site 1 North									
Transect	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Substrate										
Rock	500	190	0	385	303	238	247	425	27	500
Boulders	0	310	500	115	180	262	253	75	473	0
Pebbles	0	0	0	0	17	0	0	0	0	0
Sand	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**
Organisms										
Bare	378	495	442	500	484	427	500	500	500	430
Turfing alage	0	0	0	0	0	0	0	0	0	0
Encrusting algae	112	0	58	0	16	73	0	0	0	16
Foliose algae	0	0	0	0	0	0	0	0	0	0
Barnacles	10	5	0	0	0	0	0	0	0	54
Galeolaria	0	0	0	0	0	0	0	0	0	0
Mussels	0	0	0	0	0	0	0	0	0	0
Pink encrusting	0	0	0	0	0	0	0	0	0	0
TOTAL	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**	**500**

August 2011 sampling period
Entered by RB and CB.
Checked by EKL.

Table 3: Port Spencer Intertidal Rugosty Measures

Golder Associates

Location	Potential Impact Zone																			
Site	Distance 1 (Centre)										Distance 2 South									
Rep	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Rugosity	0.73	0.87	0.97	0.92	0.75	0.99	0.99	0.98	0.87	0.88	0.86	0.99	0.87	0.85	0.68	0.81	0.96	0.88	0.97	0.94

Location	Potential Impact Zone continued...									
Site	Distance 2 North									
Rep	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Rugosity	0.97	0.68	0.75	0.47	0.78	0.59	0.65	0.45	0.69	0.61

Location	Control North																			
Site	Site 1										Site 2									
Rep	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Rugosity	0.67	0.65	0.7	0.85	0.6	0.66	0.78	0.88	0.91	0.95	0.89	0.73	0.78	0.78	0.84	0.64	0.73	0.66	0.87	0.62

Location	Control South																			
Site	Site 1										Site 2									
Rep	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Rugosity	0.72	0.86	0.78	0.44	0.64	0.47	0.71	0.9	0.75	0.59	0.76	0.9	0.96	0.98	0.65	0.73	0.78	0.59	0.66	0.56

Location	Lipson Island																			
Site	Site 1										Site 2									
Rep	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Rugosity	0.96	0.68	0.71	0.65	0.62	0.62	0.7	0.51	0.62	0.41	0.74	0.92	0.8	0.76	0.83	0.72	0.71	0.5	0.97	0.83

August 2011 sampling period
Entered by RB and CB.
Checked by EKL.

Table 4: Port Spencer Intertidal Quadrat Data

Location	Potential Impact Zone																													
Site	Site 1 (Centre)										Distance 2 North										Distance 2 South									
Replicate	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
% cover																														
Rivularia firma	0	0	0	0	0.5	0	0.5	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.5	0
Blue green film	0	0	0	0	0	0	0	0	0	0	0	0	0	0	14	0.5	0.5	0	0.5	0	0	0	0	0	0	0.5	0	0	2	0.5
Green turfing algae	0	2	0	4	0.5	0	0.5	0	2	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	5	0.5	2	0
Ulva lactuca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Brown filamentous algae	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0.5	0
Hildenbrandia rubra	5	0	0	3	0	0	11	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	2	0	0	0	0	0	0	0	0	0
Colpomenia sinuosa	0	0	4	12	0.5	0	8	0	0	0	0	0	0	0	0	0	0.5	0	0	0	2	0	0	0	0	0	0	0	0	0
Sargassum sp.	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red turfing algae	0	1	0	0	0	0	0	0	5	0	7	7	0	0	0	0	0	0.5	0	0	0	0	0	0	1	0	5	0	0.5	0
Red encrusting algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink enc. coralline algae	0.5	2	0	14	0	0	14	0	0.5	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0	0	0	0	0	0	0	2	0
Coralline algae	86	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0.5	0
Gelidium pusillum	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0.5	0	0
Gracilaria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Laurencia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Xenostrobus pulex	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Tetraclitella purpurascens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0
Chthamalus antennatus	0	0	0	0	0	0.5	0	0	0.5	0	28	0	0	0	0	0.5	0	0	0.5	0	1	0.5	0	0	0	0.5	0	0	9	0.5
Chamaesipho tasmanica	0	0	0	12	0.5	2	0	15	1	0	0	3	0.5	0	0	0.5	0	94	0.5	9	34	3	36	12	13	5	9	4	4	0.5
Catomerus polymerus	0	0	0.5	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0.5	0	1	0	0.5
Actinia tenebrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galeolaria caespitosa	4	38	4	15	0.5	0	21	5	2	0	0	0	0.5	8	0	0	0	0.5	3	6	0	0	0	0	0	0.5	6	0	4	0
Mobile animals	0	1	0	0	0	0	0	2	2	0	0	0	0	0	0	0	0	0	0	0	5	0	0	0	2	0	0	0	0	1
Counts																														
Austrocochlea porcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Austrocochlea constricta	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrocochlea concamerata	0	0	0	0	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrolittorina unifasciata	0	0	0	0	0	0	0	0	0	0	10	1	0	0	0	0	13	122	0	0	0	0	323	29	0	51	273	290	68	24
Bembicium spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellana tramoserica	0	14	13	0	6	0	0	0	11	0	0	1	1	0	0	10	3	0	0	9	6	22	10	3	4	1	0	0	3	0
Nerita atramentosa	0	0	0	0	1	7	0	0	0	3	0	7	0	0	3	6	98	0	1	0	0	2	0	0	0	0	0	0	0	0
Cantharidus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patelloida latistrigata	0	0	46	0	68	0	0	21	27	0	4	2	0	0	0	0	9	0	3	12	36	7	26	0	15	50	4	54	4	23
Patelloida alticostata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0
Patella chapmani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siphonaria diemenensis	0	0	38	34	22	3	0	2	32	0	7	1	0	0	1	5	4	17	5	26	56	54	24	11	74	82	24	3	12	9
Siphonaria zelandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	0	4	0	0	0
Notoacmea spp.	0	6	21	26	32	0	0	11	14	0	0	1	2	0	0	9	2	0	0	13	0	9	52	15	4	21	9	53	29	36
Plaxiphora albida	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0
Lepsiella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

August 2011 sampling period
Entered by RB and CB.
Checked by EKL.

Table 4: Port Spencer Intertidal Quadrat Data

Location	Control North																			
Site	Site 1										Site 2									
Replicate	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
% cover																				
Rivularia firma	3	0	0	2	0	0.5	0	0.5	0	0.5	0.5	1	1	0	3	0	0	0.5	0.5	0.5
Blue green film	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Green turfing algae	0	0	1	0	0	1	1	0	0	0	0.5	0	0	0	4	0	0	0	0.5	0
Ulva lactuca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brown filamentous algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hildenbrandia rubra	0	13	0	1	6	22	0	22	2	45	0	0	0	0	0	0	0	0	19	3
Colpomenia sinuosa	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0.5	0
Sargassum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red turfing algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red encrusting algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink enc. coralline algae	0	0	0	0	0	0	0	6	0	0.5	0	0	0	0	0	0	0	0	0	0
Coralline algae	0	0	0	0	0	4	0	4	0	0	0	0	0	0	0.5	0	0	0	0	0
Gelidium pusillum	0	0	0	1	0	0	0	0	0.5	0.5	0	0	0	0	3	0	0	0	0.5	1
Gracilaria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Laurencia sp.	0	0	0	0	0	6	0	10	0	0	0	0	0	0	0	0	0	0	0.5	0.5
Xenostrobus pulex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tetraclitella purpurascens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0
Chthamalus antennatus	0	0.5	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0.5
Chamaesipho tasmanica	0	4	0	0	0	0.5	0	0.5	0.5	0	0	0	0	8	0	0	0	0	11	0.5
Catomerus polymerus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Actinia tenebrosa	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Galeolaria caespitosa	0	21	0	0	1	3	0	0	0.5	0.5	0	0	2	4	1	0.5	0	0.5	11	3
Mobile animals	0	0	0	0	0	0	4	0	1	0	0	0	0	0	0	0	0	0	1	1
Counts																				
Austrocochlea porcata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrocochlea constricta	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0
Austrocochlea concamerata	4	0	2	1	1	0	9	0	0	0	4	1	1	2	0	1	0	3	0	0
Austrolittorina unifasciata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Bembicium spp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cellana tramoserica	0	0	0	0	0	4	1	0	0	0	0	0	0	0	1	0	0	0	3	6
Nerita atramentosa	2	0	2	4	13	0	34	0	0	1	15	4	9	18	10	7	11	13	0	6
Cantharidus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patelloida latistrigata	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	1	11
Patelloida alticostata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patella chapmani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siphonaria diemenensis	0	39	2	4	1	178	0	43	0	0	0	0	0	4	8	0	0	0	98	55
Siphonaria zelandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notoacmea spp.	0	0	1	0	0	42	0	11	0	0	0	0	0	0	0	0	0	0	12	12
Plaxiphora albida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
Lepsiella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

August 2011 sampling period
Entered by RB and CB.
Checked by EKL.

Table 4: Port Spencer Intertidal Quadrat Data

Golder Associates

Location	South																			
Site	**Control Site 1**										**Control Site 2**									
Replicate	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
% cover																				
Rivularia firma	0	0	0	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0	0	0	0
Blue green film	0	0	96	90	0	4	0	0	0.5	0.5	1	0	0	14	0	0	0.5	0.5	0.5	0.5
Green turfing algae	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0
Ulva lactuca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brown filamentous algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0	0.5	0	0
Hildenbrandia rubra	0	0	0	0	13	0	0	2	0	0	0	0	6	0	0	0	0	0	0	0
Colpomenia sinuosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red turfing algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Red encrusting algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Pink enc. coralline algae	0	0	0	0	0	0	0	0	0	0	0	15	0	0	0	3	0	3	0.5	0
Coralline algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Gelidium pusillum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0.5	0
Gracilaria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Laurencia sp.	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0.5	0.5	0
Xenostrobus pulex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0.5	1	0
Tetraclitella purpurascens	0	0	0	0	0	0	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0
Chthamalus antennatus	0	0	0	0	0.5	0	0.5	0	0	4	0	11	0.5	0	0	0.5	0.5	0	0	0.5
Chamaesipho tasmanica	0	0	0	0	0	0	0	0	0	19	0	10	0.5	0	2	0.5	0.5	3	16	0.5
Catomerus polymerus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Actinia tenebrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galeolaria caespitosa	0	3	0	0	0	0	0	3	0	0	0	0.5	1	0	15	0	9	0.5	0.5	0
Mobile animals	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Counts																				
Austrocochlea porcata	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	1	3
Austrocochlea constricta	0	3	0	0	4	0	0	4	3	0	0	0	0	1	0	0	0	0	0	0
Austrocochlea concamerata	1	0	0	1	0	0	2	0	0	0	2	0	0	2	1	0	0	0	0	0
Austrolittorina unifasciata	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	23	0	111
Bembicium spp.	0	0	0	0	0	0	0	0	1	1	1	1	0	0	0	0	0	0	0	0
Cellana tramoserica	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	12	7	6
Nerita atramentosa	22	121	0	0	0	6	6	3	80	144	7	12	0	0	2	0	24	10	0	66
Cantharidus sp.	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patelloida latistrigata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Patelloida alticostata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patella chapmani	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	1	6	1	4
Siphonaria diemenensis	0	1	13	5	5	0	0	0	0	3	5	2	7	0	5	8	4	8	2	19
Siphonaria zelandica	0	0	3	0	1	3	0	0	0	0	0	0	1	1	0	6	3	0	0	0
Notoacmea spp.	0	0	1	0	0	0	4	2	0	0	0	0	1	0	6	3	4	0	1	6
Plaxiphora albida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepsiella sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0

August 2011 sampling period
Entered by RB and CB.
Checked by EKL.

Golder Associates

Location	Lipson Island																			
Site	Site 1										Site 2									
Replicate	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
% cover																				
Rivularia firma	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Blue green film	0	0	0	3	0	0.5	0	0	0	0	0	6	11	3	0	6	0.5	0.5	0	0.5
Green turfing algae	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ulva lactuca	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Brown filamentous algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Hildenbrandia rubra	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Colpomenia sinuosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Sargassum sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red turfing algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Red encrusting algae	5	2	0	0	3	2	7	0	8	4	0	0	0	0	0	0	0	0	0	0.5
Pink enc. coralline algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Coralline algae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gelidium pusillum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Gracilaria sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Laurencia sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Xenostrobus pulex	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Tetraclitella purpurascens	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Chthamalus antennatus	0.5	0.5	0.5	0	0	0	0	0	0.5	0.5	0	0	0	0	0	0	0.5	0	0	0
Chamaesipho tasmanica	0	0	0	2	0	0	0	0.5	0	0	0	0	0	0	0	0	0	0	0	0
Catomerus polymerus	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Actinia tenebrosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Galeolaria caespitosa	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Mobile animals	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0
Counts																				
Austrocochlea porcata	0	0	0	2	0	5	0	1	0	7	1	1	0	0	0	1	3	0	3	0
Austrocochlea constricta	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrocochlea concamerata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Austrolittorina unifasciata	11	19	51	116	3	18	0	4	22	23	14	0	0	0	0	15	18	0	9	0
Bembicium spp.	0	0	0	0	4	0	2	0	0	0	0	0	0	0	0	2	0	0	0	0
Cellana tramoserica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Nerita atramentosa	0	0	5	5	3	13	9	3	23	5	17	3	10	0	0	5	7	0	16	12
Cantharidus sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patelloida latistrigata	0	0	0	0	0	0	0	0	5	0	0	0	0	0	0	0	0	0	0	0
Patelloida alticostata	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Patella chapmani	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Siphonaria diemenensis	0	0	1	0	0	0	0	2	3	0	0	0	0	0	0	1	0	0	0	0
Siphonaria zelandica	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Notoacmea spp.	0	0	0	0	0	3	0	0	0	0	0	0	0	0	0	1	0	0	0	0
Plaxiphora albida	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lepsiella sp.	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0

August 2011 sampling period
Entered by RB and CB.
Checked by EKL.

Table 5: Summary of Species / Taxa Recorded During Subtidal Rocky Reef Surveys

Summary of total number of taxa recorded	
Algae	22
Seagrasses	1
Fish	22
Invertebrates	32

Species List

Algae and Seagrasses	***Invertebrates***	***Invertebrates continued...***
Amphiroa anceps	*Amblypneustes* spp.	Sponge
Caulocystis cephalornithos	*Anthaster valvulatus*	Ascidians
Crustose coralline algae	*Australostichopus mollis*	Bryozoans
Cystophora brownii	*Thyone okeni*	
Cystophora expansa	*Comanthus tasmaniae*	***Demersal Fish***
Cystophora monilifera	*Comanthus trichoptera*	*Cheilodactylus nigripes*
Cystophora moniliformis	*Comanthus* spp.	*Chelmonops curiosus*
Cystophora subfarcinata	*Dicathais orbita*	*Dactylophora nigricans*
Dictyota sp.	*Phasianella ventricosa*	*Girella zebra*
Ecklonia radiata	*Pinna bicolor*	*Meuschenia galii*
Haliptilon roseum	*Turbo undulatus*	*Meuschenia hippocrepis*
Jania sp.	*Turbo torquatus*	*Notolabrus parilus*
Lobophora variegata	*Pleuroploca australasia*	*Notolabrus tetricus*
Metagoniolithon spp.	*Goniocidaris tubaria*	*Parma victoriae*
Red turfing algae	*Haliotis laevigata*	*Pempheris multiradiata*
Sargassum decipiens	*Haliotis* spp.	*Pictilabrus laticlavius*
Sargassum spp. subgenus Arthrophycus	*Heliocidaris erythrogramma*	*Scorpis aequipinnis*
Sargassum spp. subgenus *Sargassum*	*Herdmania grandis*	*Sepia apama*
Scaberia agardhii	*Leptomithrax gaimardii*	*Siphonognathus beddomei*
Turfing algae	*Nectocarcinus tuberculatus*	*Tilodon sexfasciatus*
Zonaria spiralis	*Paguristes frontalis*	
Articulated corallines	*Plagusia chabrus*	***Cryptic Fish***
Heterozostera nigricaulis	*Schizophrys aspera*	*Heteroclinus* spp.
	Petricia vernicina	*Heteroclinus tristis*
	Meridiastra gunnii	*Omegaphora armilla*
	Tosia australis	*Pempheris multiradiata*
	Coscinasterias muricata	*Trinorfolkia clarkei*
	Unidentified hermit crab	*Trinorfolkia cristata*
	Uniophora granifera	Unidentified small fish

Golder Associates

Location	Potential Impact Zone																													
Site	Distance 1										Distance 2 North										Distance 3 North									
Transect	1					2					1					2					1					2				
Quadrat	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Species / sum of count																														
Bare rock	0	0	0	0	0	0	0	0	0	0	0	0	0	0	10	0	0	0	8	0	9	0	0	0	0	8	0	0	0	0
Gravel/sand	0	0	0	0	0	0	0	0	0	0	0	8	3	0	16	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Amphiroa anceps	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	6	0	6	3	0	5	0	7
Caulocystis cephalornithos	0	0	0	0	0	0	0	0	0	0	0	19	0	0	22	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Crustose coralline algae	40	4	6	0	3	2	6	10	1	7	0	0	4	0	0	0	3	0	0	0	1	0	3	2	2	0	20	8	25	15
Cystophora brownii	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	0	0	0
Cystophora expansa	0	0	0	0	6	0	17	0	0	0	4	0	7	4	0	42	23	42	0	22	0	0	0	7	14	0	0	0	0	0
Cystophora monilifera	0	11	0	0	45	0	0	0	0	0	34	1	38	0	0	8	0	0	0	0	0	1	0	2	2	0	0	0	0	0
Cystophora moniliformis	0	0	0	0	5	0	0	0	0	0	8	0	0	0	0	5	0	8	0	12	0	24	0	0	0	0	0	0	0	0
Cystophora subfarcinata	2	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	12	0	14	40	0	12	0	0	0	0	0	0	0	2
Dictyota sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Ecklonia radiata	37	0	22	1	0	0	16	10	6	5	0	0	0	0	0	0	25	0	0	0	20	0	0	4	0	16	38	14	50	4
Haliptilon roseum	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	8	7	4	2	0	0	0	0	0	1	0	2	0	0
Heterozostera nigricaulis	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0
Jania sp.	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Lobophora variegata	0	4	6	5	3	0	0	5	10	26	19	2	7	4	0	10	2	6	0	2	2	4	7	7	17	1	4	16	0	12
Metagoniolithon spp.	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	8	32	3	0	0	0	0	0	0	0	0	0	0	0	0
Red turfing algae	0	0	0	0	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	12	0	0	0	0	0	0	0	0	0	0
Sargassum decipiens	0	0	0	0	0	0	2	7	0	0	0	0	0	12	0	0	12	4	17	18	0	1	0	0	0	0	0	0	0	0
Sargassum spp. subgenus Arthrophycus	15	0	12	0	7	0	4	6	5	9	1	0	1	0	0	0	2	2	0	0	30	3	0	2	3	0	1	33	0	9
Sargassum spp. subgenus Sargassum	0	45	16	45	4	50	9	19	39	30	0	0	0	37	2	2	0	2	0	0	15	23	49	41	38	0	0	0	0	44
Scaberia agardhii	0	0	0	0	0	0	0	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Turfing algae	0	0	0	0	0	0	0	0	0	0	0	20	0	0	0	0	0	0	10	0	0	3	0	0	0	0	0	0	0	0
Zonaria spiralis	5	0	2	0	0	0	6	17	0	0	0	0	0	0	0	0	2	1	0	0	1	0	0	5	4	24	0	6	0	5
Articulated corallines	0	0	0	0	0	0	0	0	1	0	2	0	0	0	0	8	40	10	4	2	4	0	6	0	6	4	0	7	0	7
Sponge	1	0	3	0	0	2	3	0	2	2	0	0	0	0	0	0	2	0	0	0	0	0	6	0	0	0	2	5	0	0
Ascidians	0	0	5	0	0	0	0	0	1	2	0	0	0	0	0	2	0	2	0	0	0	0	1	0	0	0	0	0	0	0
Bryozoans	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	0
Sessile invertebrates	1	0	8	0	0	2	3	0	3	4	0	0	0	0	0	2	2	2	0	0	0	0	11	0	0	0	2	5	0	0

July August 2011 sampling period
Entered by JB. Checked by JB SB.
Checked by EKL

Golder Associates

Location	Potential Impact Zone									
Site	Distance 2 South									
Transect	1					2				
Quadrat	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Species / sum of count										
Bare rock	0	0	0	0	0	0	0	0	0	0
Gravel/sand	0	0	0	0	0	0	0	0	0	0
Amphiroa anceps	2	0	0	0	0	0	2	4	0	3
Caulocystis cephalornithos	0	0	0	0	0	0	0	0	0	0
Crustose coralline algae	0	2	0	0	0	0	6	3	0	14
Cystophora brownii	0	0	0	0	12	0	0	0	0	2
Cystophora expansa	0	0	0	0	0	50	0	0	0	3
Cystophora monilifera	0	0	0	0	0	0	0	0	0	0
Cystophora moniliformis	0	0	0	0	0	0	0	0	0	0
Cystophora subfarcinata	0	0	0	0	0	0	7	18	0	0
Dictyota sp.	0	0	0	3	0	0	0	0	0	0
Ecklonia radiata	7	38	0	0	0	2	20	20	50	19
Haliptilon roseum	0	0	0	0	0	0	15	7	19	7
Heterozostera nigricaulis	0	0	0	0	0	0	0	0	0	0
Jania sp.	0	0	0	0	0	0	0	1	0	1
Lobophora variegata	2	2	4	2	0	1	1	0	0	0
Metagoniolithon spp.	1	0	0	0	0	0	0	2	3	0
Red turfing algae	0	0	0	0	0	0	0	0	0	0
Sargassum decipiens	0	0	0	12	16	0	0	0	0	0
Sargassum spp. subgenus Arthrophycus	20	12	0	2	12	1	1	0	0	3
Sargassum spp. subgenus Sargassum	14	0	20	32	42	3	0	0	4	4
Scaberia agardhii	0	0	8	3	0	0	0	0	0	0
Turfing algae	0	0	0	0	0	0	0	0	0	0
Zonaria spiralis	19	14	0	8	0	22	10	10	11	6
Articulated corallines	3	0	0	0	0	0	17	14	22	11
Sponge	2	0	2	0	0	0	1	0	0	2
Ascidians	0	0	0	0	0	0	0	2	0	0
Bryozoans	0	0	0	0	0	0	0	0	0	0
Sessile invertebrates	2	0	2	0	0	0	1	2	0	2

July August 2011 sampling period
Entered by JB. Checked by JB SB.
Checked by EKL

Table 7: Port Spencer Subtidal Rocky Reef - Demersal Fish, Intertebrates and Cryptic Fish Surveys

Location	Potential Impact Location							
Site	Distance 1		Distance 2 North		Distance 3 North		Distance 2 South	
Transect	1	2	1	2	1	2	1	2
Fish								
Cheilodactylus nigripes	0	1	0	0	0	2	0	1
Chelmonops curiosus	0	0	0	0	0	0	1	0
Dactylophora nigricans	0	0	0	0	0	1	0	0
Girella zebra	10	0	2	1	0	1	0	3
Meuschenia galii	0	0	0	0	1	0	0	0
Meuschenia hippocrepis	0	0	0	0	1	12	0	3
Notolabrus parilus	0	1	2	1	0	0	1	1
Notolabrus tetricus	4	17	11	1	15	32	11	29
Parma victoriae	1	0	0	0	0	1	0	2
Pempheris multiradiata	0	0	0	0	0	10	0	0
Pictilabrus laticlavius	0	1	0	0	0	0	0	0
Scorpis aequipinnis	15	12	0	0	16	9	1	12
Sepia apama	0	0	0	0	0	0	1	0
Siphonognathus beddomei	1	3	10	2	20	1	1	2
Tilodon sexfasciatus	0	0	1	0	0	0	0	0
Invertebrates and Cryptic Fish								
Amblypneustes spp.	0	0	0	0	3	0	0	0
Anthaster valvulatus	0	1	0	0	0	0	0	0
Australostichopus mollis	0	1	0	0	2	0	1	0
Comanthus tasmaniae	5	5	0	0	28	11	3	1
Comanthus trichoptera	11	14	4	14	23	49	5	13
Coscinasterias muricata	0	0	1	0	0	0	0	0
Dicathais orbita	0	8	0	2	1	12	10	8
Goniocidaris tubaria	1	2	0	0	1	0	0	0
Haliotis laevigata (sub-legal)	0	0	3	0	0	0	0	0
Haliotis spp.	0	0	0	0	1	0	0	0
Heliocidaris erythrogramma	27	3	1	8	1	36	3	8
Herdmania grandis	0	3	0	0	1	1	0	1
Heteroclinus spp.	1	0	0	0	0	0	0	0
Heteroclinus tristis	0	1	0	0	0	0	0	0
Leptomithrax gaimardii	0	0	0	0	0	0	1	0
Meridiastra gunnii	7	2	6	8	50	25	91	42
Nectocarcinus tuberculatus	0	0	0	1	0	0	0	0
Omegaphora armilla	0	0	0	0	0	2	0	0
Paguristes frontalis	6	9	0	0	4	12	1	4
Pempheris multiradiata	0	0	0	0	0	10	0	0
Petricia vernicina	1	1	0	0	1	1	0	0
Phasianella ventricosa	0	3	0	0	2	0	1	0
Pinna bicolor	0	0	1	0	0	0	0	0
Plagusia chabrus	2	2	0	0	0	2	2	2
Pleuroploca australasia	1	4	1	2	4	3	8	5
Schizophrys aspera	0	0	0	0	0	0	0	1
Thyone okeni	0	0	0	0	0	0	0	1
Tosia australis	1	4	0	0	4	3	4	2
Trinorfolkia clarkei	1	5	0	0	0	4	3	4
Trinorfolkia cristata	0	0	0	0	0	1	0	0
Turbo torquatus	2	3	1	0	1	0	0	0
Turbo undulatus	4	41	0	0	69	71	57	44
Unidentified hermit crab	0	0	0	0	2	3	0	1
Unidientified small fish	0	0	0	0	0	0	1	0
Uniophora granifera	2	1	0	0	4	1	0	0
Comanthus spp.	16	19	4	14	51	60	8	14

July August 2011 sampling period
Entered by JB. Checked by JB SB.
Checked by EKL

Table 8: Summary of Species / Taxa Recorded During Subtidal Seagrass Surveys

Summary of number of taxa recorded	
Seagrasses	3
Fish	7
Invertebrates	30

Species List

Seagrasses:	
Posidonia spp.	
Amphibolis spp.	
Zosteraceae	
Fish:	
Siphonognathus beddomei	
Haletta semifasciata	
Omegaphora armilla	
Aracana aurita	
Notolabrus parilus	
Neoodax balteatus	
Gobiid spp.	
Invertebrates:	
Phallusia obesa	*Naxia aurita*
Herdmania grandis	*Nectocarcinus integrifrons*
Pyura gibbosa	*Ovalipes australiensis*
Pyura sp.	*Malleus meridianus*
Unidentified ascidian	*Mimachlamys asperrima*
Pinna bicolor	*Sepia apama*
Astropecten vappa	*Cabestana tabulata*
Coscinasterias muricata	*Fusinus australis*
Meridiastra gunnii	*Haliotis cyclobates*
Tosia australis	*Haliotis laevigata*
Amblypneustes ovum	*Phasianella australis*
Goniocidaris tubaria	*Phlyctenactus tuberculosa*
Australostichopus mollis	*Pleuroploca australasia*
Thyone okeni	*Pterynotus triformis*
Paguristes frontalis	*Uniophora granifera*

Table 9: Port Spencer Seagrass Quadrat Data

Site	**Distance 1 11/08/2011**																			
Depth	**7-9 / Shallower**																			
Transect	**1**										**2**									
Transect side	**A**					**B**					**A**					**B**				
Quadrat	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Posidonia		60	10	40	60		10		50		90	20			80	20			5	70
Amphibolis	90		20	50		80	40	80	20	60				30		80				
Sand	10	40	70	10	40	20	50	20	30	40	10	80	100	70	20		100	100	95	30
Zosteraceae																				

Site	**Distance 2 North 11/08/2011**																			
Depth	**7-9 / Shallower**																			
Transect	**1**										**2**									
Transect side	**A**					**B**					**A**					**B**				
Quadrat	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Posidonia								80					95	30					40	
Amphibolis	100					80					90	95		60		95	90	95	40	
Sand		100	95	100	80	20	100	20	100	100	10		5	10	80	5	10	5	20	90
Zosteraceae			5		20							5			20					10

Site	**Distance 3 North 11/08/2011**																			
Depth	**7-9 / Shallower**																			
Transect	**1**										**2**									
Transect side	**A**					**B**					**A**					**B**				
Quadrat	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Posidonia		90			87		70	70	30		10	65		10	10		60		60	10
Amphibolis	100		89	81	3	100		10	40	70	60		90	60	60	70	30	100	10	70
Sand		10	11	19	10		30	20	30	30	30	35	10	30	30	30	10		30	20
Zosteraceae																				

Site	**Distance 2 South 12/08/2011**																			
Depth	**8.6 / Shallower**										**8.8 / Shallower**									
Transect	**1**										**2**									
Transect side	**A**					**B**					**A**					**B**				
Quadrat	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Posidonia	80	95	60	70	60	90	70	75	60	60	90	80	70	70	60	90	70	60	70	60
Amphibolis																				
Sand	20	5	40	30	40	10	30	25	40	40	10	20	30	30	40	10	30	40	30	40
Zosteraceae																				

Site	**Distance 3 South 12/08/2011**																			
Depth	**7-9 / Shallower**																			
Transect	**1**										**2**									
Transect side	**A**					**B**					**A**					**B**				
Quadrat	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**	**R1**	**R2**	**R3**	**R4**	**R5**	**R6**	**R7**	**R8**	**R9**	**R10**
Posidonia	70	95	75	75	80	55	85	80	95	80	75	55	80	70	95	90	60	70	80	85
Amphibolis																				
Sand	30	5	25	25	20	45	15	20	5	20	25	45	20	30	5	10	40	30	20	15
Zosteraceae																				

August 2011 sampling period
Entered by SB. Checked by JB SB.
Checked by EKL

Table 9: Port Spencer Seagrass Quadrat Data

Site	Distance 2 North 11/08/2011																			
Depth	11.5 / Deeper										11 / Deeper									
Transect	1										2									
Transect side	A					B					A					B				
Quadrat	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10	R1	R2	R3	R4	R5	R6	R7	R8	R9	R10
Posidonia	70	90	65	91	78	85	68	85	80	90	76	78	82	90	92	80	80	88	90	91
Amphibolis																				
Sand	30	10	35	9	22	15	32	15	20	10	24	22	18	10	8	20	20	12	10	9
Zosteraceae																				

Site	Distance 1 11/08/2011																			
Depth	11.5 / Deeper										11 / Deeper									
Transect	1										2									
Transect side	A					B					A					B				
Quadrat	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Posidonia	85	88	89	73	87	90	92	92	91	85	88	81	82	84	92	82	85	81	90	93
Amphibolis																				
Sand	15	12	11	27	13	10	8	8	9	15	12	19	18	16	8	18	15	19	10	7
Zosteraceae																				

Site	Distance 3 North 11/08/2011																			
Depth	11.5 / Deeper										11 / Deeper									
Transect	1										2									
Transect side	A					B					A					B				
Quadrat	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Posidonia	95	95	85	85	65	98	90	93	78	70	100	95	92	95	96	98	90	100	100	98
Amphibolis																				
Sand	5	5	15	15	35	2	10	7	22	30		5	8	5	4	2	10			2
Zosteraceae																				

Site	Distance 3 South 12/08/2011																			
Depth	11.5 / Deeper										11 / Deeper									
Transect	1										2									
Transect side	A					B					A					B				
Quadrat	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Posidonia	65	62	81	71	78	70	83	62	75	69	55	82	91	90	94	74	80	65	67	92
Amphibolis																				
Sand	35	38	19	29	22	30	17	38	25	31	45	18	9	10	6	26	20	35	33	8
Zosteraceae																				

Site	Distance 2 South 12/08/2011																			
Depth	11.5 / Deeper										11 / Deeper									
Transect	1										2									
Transect side	A					B					A					B				
Quadrat	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5	R1	R2	R3	R4	R5
Posidonia	96	91	97	97	97	89	92	98	98	96	50	91	90	96	98	72	92	92	96	98
Amphibolis																				
Sand	4	9	3	3	3	11	8	2	2	4	50	9	10	4	2	28	8	8	4	2
Zosteraceae																				

Table 10: Seagrass Surveys Invertebrate Counts

Golder Associates

Seagrass Invertebrates

Notes	11/08/2011, Diver SB						12/08/2011, Diver SB			
Location	Distance 2 North		Distance 1		Distance 3 North		Distance 2 South		Distance 3 South	
Depth	7.9		7.9		7.9		7.9		7.9	
Transect	1	2	1	2	1	2	1	2	1	2
Species / Count										
Meridiastra gunnii	10	43	35	24	25	73	104	45	75	64
Goniocidaris tubaria	1	4	1	0	0	1	10	8	1	2
Haliotis laevigata	1	0	3	0	0	0	0	0	0	0
Pinna bicolor	0	37	82	93	7	2	0	0	0	1
Nectocarcinus integrifrons	0	1	0	0	0	0	0	0	0	0
Haliotis laevigata	0	4	0	2	2	0	0	0	0	0
Phasianella australis	0	3	0	0	0	2	2	2	3	1
Tosia australis	0	2	3	2	1	0	0	0	0	0
Paguristes frontalis	0	1	0	1	1	0	0	0	0	0
Australostichopus mollis	0	1	0	1	0	0	0	0	0	0
Malleus meridianus	0	0	1	1	0	0	0	0	0	0
Pleuroploca australasia	0	0	1	1	0	1	2	2	2	2
Unidentified ascidian	0	0	1	0	0	0	0	0	0	0
Haliotis cyclobates	0	0	2	0	0	0	0	0	0	0
Pterynotus triformis	0	0	0	1	0	0	0	0	0	0
Cabestana tabulata	0	0	0	1	0	0	0	0	0	0
Amblypneustes ovum	0	0	0	0	1	1	0	0	0	0
Pyura gibbosa	0	0	0	0	0	1	0	0	0	0
Mimachlamys asperrimus	0	0	0	0	0	1	0	0	0	0
Uniophora granifera	0	0	0	0	0	1	1	1	2	0
Sepia apama	0	0	0	0	0	0	1	0	0	0
Phlyctenactus tuberculosa	0	0	0	0	0	0	0	1	1	1
Ovalipes australiensis	0	0	0	0	0	0	0	0	0	1
Naxia aurita	0	0	0	0	0	0	0	0	0	0
Thyone okeni	0	0	0	0	0	0	0	0	0	0
Gobiid spp.	0	0	0	0	0	0	0	0	0	0
Neoodax balteatus	0	0	0	0	0	0	0	0	0	0
Phallusia obesa	0	0	0	0	0	0	0	0	0	0
Pyura sp.	0	0	0	0	0	0	0	0	0	0
Coscinasterias muricata	0	0	0	0	0	0	0	0	0	0
Herdmania grandis	0	0	0	0	0	0	0	0	0	0
Astropecten vappa	0	0	0	0	0	0	0	0	0	0
Fusinus australis	0	0	0	0	0	0	0	0	0	0

Notes:

+ - Unidentified ID

All data are cross checked by SB anf JB on 25/08/2011

Table 10: Seagrass Surveys Invertebrate Counts

Seagrass Invertebrates

Notes	11/08/2011, Diver JB								12/08, Diver JB	
Location	Distance 3 North		Distance 1		Distance 2 North		Distance 3 South		Distance 2 South	
Depth	11.5	11.0	11.5	11.0	11.5	11.0	11.5	11.0	11.5	11.0
Transect	1	2	1	2	1	2	1	2	1	2
`										
Meridiastra gunnii	0	7	6	20	15	43	34	44	0	1
Goniocidaris tubaria	8	0	4	10	15	3	19	13	23	14
Haliotis laevigata	0	0	0	0	0	0	0	0	0	0
Pinna bicolor	10	114	67	196	17	119	0	0	0	0
Nectocarcinus integrifrons	1	0	2	0	2	5	1	3	7	0
Haliotis laevigata	0	0	0	0	0	0	0	0	0	0
Phasianella australis	1	0	3	2	3	1	1	1	1	0
Tosia australis	1	4	1	0	1	2	1	0	2	3
Paguristes frontalis	1	1	1	4	0	0	0	1	0	0
Australostichopus mollis	7	0	1	1	2	0	0	0	3	0
Malleus meridianus	4	4	0	0	2	3	0	0	0	0
Pleuroploca australasia	0	0	1	0	0	1	0	0	0	0
Unidentified ascidian	0	0	0	0	0	0	0	0	0	0
Haliotis cyclobates	0	0	0	0	0	0	0	0	0	0
Pterynotus triformis	0	0	0	0	0	0	0	0	0	0
Cabestana tabulata	0	0	0	0	0	0	0	0	0	0
Amblypneustes ovum	0	0	0	1	0	0	0	1	0	0
Pyura gibbosa	2	1	0	0	0	0	1	0	0	0
Mimachlamys asperrimus	0	0	0	0	0	0	0	0	0	0
Uniophora granifera	1	0	0	0	0	0	1	1	1	2
Sepia apama	0	0	0	0	0	0	0	0	0	0
Phlyctenactus tuberculosa	1	0	0	0	0	0	0	0	0	0
Ovalipes australiensis	0	0	0	0	0	0	0	0	0	0
Naxia aurita	1	0	0	0	1	0	0	0	0	0
Thyone okeni	1	0	0	0	0	0	0	1	0	0
Gobiid spp.	3	0	6	4	3	1	1	0	5	2
Neoodax balteatus	0	1	0	0	0	0	0	0	1+	0
Phallusia obesa	0	2	0	0	0	0	0	0	0	0
Pyura sp.	0	0	3	1	2	2	1	0	4	1
Coscinasterias muricata	0	0	0	1	0	0	0	0	0	0
Herdmania grandis	0	0	0	0	1	0	0	1	0	0
Astropecten vappa	0	0	0	0	0	0	0	1	0	0
Fusinus australis	0	0	0	0	0	0	0	1	0	0

Notes:

All data are cross checked by SB anf JB on 25/08/2011

+ - Unidentified ID

August 2011 sampling period
Entered by SB. Checked by JB SB.
Checked by EKL

Golder Associates

Seagrass Fish

Site	Distance 2 North	Distance 1					Distance 3 North	
Depth	**7-9**	**7-9**		**11**			**7-9**	
Diver	**SB**	**SB**		**JB**			**SB**	
Transect	**1**	**1**	**2**	**not on transect**			**1**	**2**
Species Count / Size cm								
Siphonognathus beddomei	2 / 10	2 / 10	0	0	0	0	6 / 10	10 / 10
Haletta semifasciata	0	0	1 / 30	0	0	0	0	0
Omegaphora armilla	0	0	0	1	0	0	0	0
Aracana aurita	0	0	0	0	2	0	0	0
Notolabrus parilus	0	0	0	0	0	1	0	0

Notes:
Date 11/08/2011
All data are cross checked by SB and JB on 25/08/2011

Table 12: Taxonomic Resolution for Macro-Infauna Samples

Phylum	Class	Order	Taxonomic resolution
Annelida	Polychaeta		Family
Annelida	Oligochaeta		Class
Sipuncula			Phylum
Crustacea	Malacostraca	Amphipoda	Family
Crustacea	Malacostraca	Isopoda	Family
Crustacea	Malacostraca	Tanaidacea	Order
Crustacea	Malacostraca	Mysidacea	Order
Crustacea	Malacostraca	Decapoda	Family
Crustacea	Malacostraca	Cumacea	Family
Crustacea	Ostracoda	Podocopida	Family
Crustacea	Maxillopoda	Calanoida	Order
Mollusca	Gastropoda		Family
Mollusca	Opisthobranchia		Family
Mollusca	Bivalvia		Family
Mollusca	Polyplacophora		Class
Echinodermata	Asteroidea		Family
Echinodermata	Holothuroidea		Class
Echinodermata	Echinoidea		Class
Cnidaria	Anthozoa		Class
Arthropoda	Pycnogonida		Class
Nemertea			Phylum
Nemotoda			Phylum
Platyhelminthes			Phylum
Phoronida			Phylum

Table 13: Port Spencer Benthic Macro Infauna Data

Golder Associates

Seagrass

Location				Distance 1 (SG)				Distance 3 North (SG)				Distance 3 South (				Distance 6 North, s				Distance 6 South,				Sum
Replicate				R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	
Phylum	***Class***	***Order***	***Family/rep***																					
Annelida	***Polychaeta***		Ampharetidae	0	0	0	1	0	0	1	5	0	1	0	0	0	0	0	0	0	0	0	0	8
			Amphinomidae	0	0	0	0	2	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	3
			Capitellidae	0	0	1	0	1	0	2	0	0	3	1	0	0	0	0	0	2	0	0	0	10
			Chaetopteridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Chrysopetalidae	0	0	1	0	1	1	4	4	0	0	1	0	0	0	0	0	0	0	0	0	12
			Dorvilleidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	2
			Eunicidae	1	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Flabelligeridae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Goniadidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
			Hesionidae	0	0	0	0	0	0	3	0	0	1	2	0	0	0	0	0	0	0	0	0	6
			Lumbrineridae	2	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	6
			Maldanidae	1	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	2
			Magalionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
			Nephtyidae	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	1	0	0	3
			Nereididae	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
			Opheliidae	1	0	0	1	4	1	4	10	0	0	4	0	0	0	0	0	0	0	0	0	25
			Orbiniidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
			Oweniidae	0	1	0	0	0	0	1	2	0	1	0	1	0	0	0	0	0	0	0	0	6
			Paraonidae	5	0	0	4	0	1	0	0	1	0	1	1	0	0	0	0	1	0	0	1	15
			Pectinariidae	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
			Phyllodocidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
			Sabellidae	0	0	1	0	0	0	4	1	0	0	0	0	0	0	0	0	0	0	0	0	6
			Serpulidae	0	0	0	1	1	1	2	3	11	0	3	0	0	0	0	0	1	0	0	0	23
			Spionidae	0	0	1	0	0	0	1	0	0	1	0	0	0	0	0	0	1	0	0	0	4
			Syllidae	0	1	0	1	3	1	5	1	0	0	0	0	1	0	0	0	2	0	0	1	16
			Terebellidae	1	0	1	1	2	0	0	2	3	0	0	0	0	0	1	0	0	0	0	2	13
	Sipuncle		Sipuncle spp	1	2	1	0	1	0	1	0	0	2	2	0	0	0	0	0	1	0	0	1	12
	Oligocheata		Oligocheata spp	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Crustacea	***Malscostraca***	***Amphipoda***	Amaryllididae	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	0	0	0	0	0	2
			Amphithoidae	0	2	0	0	2	0	1	0	0	0	0	1	0	0	0	0	0	0	0	1	7
			Ampeliscidae	2	2	1	0	0	1	2	0	0	0	0	1	0	0	0	0	0	1	0	0	10
			Corophiidae	30	16	14	14	85	39	72	13	7	8	51	23	1	2	1	0	5	0	0	9	390
			Cyproideidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Dexaminidae	4	0	0	0	7	4	3	2	0	0	3	0	3	1	0	0	0	2	1	2	32
			Eusiridae	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	2
			Hyalidae	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	2
			Lysianassidae	0	0	0	1	2	1	8	5	0	0	2	1	0	0	0	0	0	0	0	0	20
			Melitidae	0	0	0	1	6	1	2	7	0	0	0	0	0	0	0	0	0	0	0	0	17
			Phoxocephalidae	14	4	3	7	7	0	9	1	2	0	5	1	1	0	1	0	0	0	0	0	55
			Podoceridae	0	0	0	0	0	0	2	0	0	0	0	2	0	0	0	0	0	0	0	0	4
			Urohaustoridae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Amphipoda damaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
		Isopoda	Anthuridae	0	0	1	0	0	0	1	2	0	0	1	0	0	0	0	0	0	0	0	0	5
			Paranthuridae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1	2
			Cirolanidae	0	1	0	0	0	0	0	0	1	0	1	2	0	0	0	0	0	0	0	0	5
			Jaeropsidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Serolidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Sphaeromatidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Stenetriidae	0	2	2	1	0	4	4	1	0	0	0	0	0	0	0	0	0	0	0	0	14
		Tanacidacea	Tanacidacea	0	0	0	0	3	8	2	5	2	2	2	7	0	0	0	0	1	1	0	0	33
		Mysidacea	Mysidacea	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
		Decapoda	Anamura damaged	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Hymenosomatidae	0	1	1	1	1	1	0	0	0	0	1	0	0	0	0	0	0	0	0	0	6
			Leucosidae[1]	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Majidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
		Cumacea	Bodotriidae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
			Gynodiastylidae	0	0	0	0	1	0	2	1	0	0	1	0	0	0	0	0	0	0	0	0	5
	Ostrocoda	***Podocopida***	Bairdiidae	0	0	0	0	0	3	2	1	0	0	0	0	0	0	0	0	0	0	0	0	6
		Myodocopida	Cylinderoleberidae	2	0	0	1	0	0	2	1	0	0	0	0	0	0	1	0	0	0	1	0	8
			Cypridinidae	0	0	0	0	0	0	2	2	1	2	1	0	0	0	0	0	0	0	0	0	8
			Philomedidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Unknown ostrocoda	1	0	0	0	1	2	0	1	0	1	0	0	0	0	0	0	0	0	0	0	6
	Maxillopoda	***Calanoida***	Calanoida spp	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Mollusca	***Gastropoda***		Cylichnidae	0	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	3
			Eulimoidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Fissurellidae	0	0	1	0	4	3	3	0	0	0	1	0	0	0	0	0	0	0	0	0	12
			Phasianellidae	1	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
			Trocidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Turtellidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Opisthobranchia		Nudibrachia	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
	Bivalve		Galeommatidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
			Glycymeridae	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
			Limidae	0	0	0	0	4	0	1	1	0	0	3	0	0	0	0	0	0	0	0	0	9
			Mactridae	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
			Mesodesmatidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
			Mytilidae[2]	5	1	2	5	11	2	2	1	0	3	4	0	1	0	0	0	0	0	0	1	38
			Mytilidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1
			Nuculanidae	0	0	0	0	0	1	1	0	2	1	0	0	0	0	0	0	0	0	0	0	5
			Psammobiidae	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	4
			Solemyidae	2	0	1	0	0	0	2	0	0	0	0	1	1	0	0	0	0	0	0	0	7
			Vereridae	2	1	0	2	8	6	9	0	1	1	2	6	0	0	0	0	0	0	0	0	38
			Unknown bivalve	1	0	1	0	1	0	1	2	0	0	0	0	0	0	0	0	0	0	0	0	6
			Bivalve juvenile	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	Polyplacophora		Polyplacophora sp	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3

Notes: 1 = C*ryptocnemus vincentianus*
2 = *Musculista senhousia*

Entered and Checked by LA or Infauna Data
Checked by EKL

Golder Associates

Seagrass Continued...

Location				Distance 1 (SG)				Distance 3 North (SG)				Distance 3 South (				Distance 6 North, s				Distance 6 South,				Sum
Replicate				R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	
Phylum	*Class*	*Order*	*Family/rep*																					
Echinodermata	***Asteroidea***		Asteriidae	0	0	0	0	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	0	4
			Asterinidae	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
			Goniasteridae	1	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
	Ophiuroidea		Ophiuroidea spp	2	1	1	0	5	1	1	1	0	1	2	0	0	1	0	0	0	0	0	0	16
	Holothuroidea		Holothuroidea spp	0	0	2	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
Cnidaria	***Anthozoa***		Anthozoa spp	1	0	0	0	3	1	0	2	2	0	0	1	0	0	0	0	0	0	0	0	10
Pycogonia			Pycogonia	0	0	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
Nemertean			Nemertean	0	0	1	0	0	0	1	3	0	1	1	1	0	0	0	0	0	0	1	1	10
Nemotoda			Nemotoda	0	0	0	0	2	1	3	0	0	1	1	0	0	0	0	1	1	0	0	3	13
Platyhelminthes			Platyhelminthes	0	0	0	0	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0	0	3
Phoronida			Phoronida	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1

Table 13: Port Spencer Benthic Macro Infauna Data

Golder Associates

Mid Benthic

Location				Dist. 1 (MB)				Dist3 Nth (MB)				Dist3 Sth (MB)				Dist5 Nth (MB)				Dist5 Sth (MB)				Dist6 Nth (MB)				Dist6 Sth (MB)				Sum
Replicate				R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	R1	R2	R3	R4	
Phylum	***Class***	***Order***	***Family/rep***																													
Annelida	***Polychaeta***		Ampharetidae	0	0	0	0	0	0	0	0	0	0	0	0	2	0	2	0	1	0	0	2	2	2	0	1	0	0	1	1	14
			Amphinomidae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Capitellidae	1	0	0	1	3	0	2	2	0	0	1	0	0	0	2	0	1	1	1	0	0	0	0	1	2	0	0	1	19
			Cirratulidae	0	0	0	0	3	0	0	0	0	1	2	0	0	1	1	4	0	0	0	0	0	0	0	0	0	0	3	1	16
			Eunicidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
			Goniadidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1
			Hesionidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
			Lumbrineridae	0	1	0	0	0	0	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4
			Magalionidae	1	0	0	1	1	0	1	0	0	0	0	0	1	2	0	0	1	0	0	0	0	4	1	0	0	1	3	0	17
			Nephtyidae	1	0	0	2	3	0	1	0	0	1	0	3	2	1	2	5	1	0	2	1	3	1	0	0	1	2	1	1	34
			Nereididae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1
			Opheliidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	2
			Paraonidae	3	14	10	0	2	1	7	4	4	3	3	7	2	3	7	14	11	0	5	0	0	2	0	0	1	0	3	1	107
			Phyllodocidae	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2
			Poelcilochaetidae	0	1	0	0	0	0	0	0	0	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Polynoidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
			Sabellidae	0	0	1	0	1	0	0	0	0	0	0	0	1	2	1	0	0	0	1	2	0	7	0	5	1	0	0	0	22
			Sigalionidae	0	0	0	0	2	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	5
			Spionidae	2	0	4	5	3	4	2	1	3	1	0	2	2	1	3	1	0	8	0	0	0	4	2	6	2	1	3	3	63
			Syllidae	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2	0	0	0	0	0	0	0	1	0	4
			Terebellidae	0	1	1	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
	Sipuncle		Sipuncle spp	1	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	4
	Oligocheata		Oligocheata spp	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	1	0	0	0	0	4
Crustacea	***Malscostraca***	***Amphipoda***	Corophiidae	0	2	0	0	0	0	0	0	1	0	0	1	0	0	1	0	1	1	0	1	2	0	1	3	2	1	0	0	17
			Eusiridae	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Liljeborgiidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Oedicerodidae	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	2
			Phoxocephalidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	2
		Tanacidacea	Tanacidacea	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	2	0	0	0	0	0	0	1	1	4	3	0	13
		Decapoda	Callanassidae	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	3
		Cumacea	Gynodiastylidae	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1	3	0	0	0	0	0	1	0	0	0	0	0	0	6
			Cumacea damaged	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	2
	Ostrocoda	***Myodocopida***	Cylinderoleberidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2
	Maxillopoda	***Calanoida***	Calanoida spp	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	4	0	0	0	0	0	0	5
Mollusca	***Gastropoda***		Fissurellidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
			Mitridae	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
			Naticidae	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
	Bivalve		Laternulidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	7	0	0	0	0	0	0	0	0	0	0	7
			Mesodesmatidae	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2	2	0	2	0	0	0	0	6
			Nuculanidae	1	2	2	2	1	1	0	1	0	1	0	1	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0	14
			Psammobiidae	0	0	0	0	0	2	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3
			Thraciidae	0	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Echinodermata	***Holothuroidea***		Holothuroidea spp	2	1	2	1	0	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	9
	Echinoidea		Echinoidea damaged	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1
Nemertean			Nemertean	0	0	1	0	1	0	0	2	0	1	1	0	1	1	1	0	1	2	2	0	0	0	0	1	0	0	0	2	17
Nemotoda			Nemotoda	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	0	0	1

APPENDIX C

Underwater Noise Modelling Report

September 14, 2011

APPENDIX C: UNDERWATER NOISE MODELLING REPORT – PORT SPENCER FACILITY

1.0 INTRODUCTION

Acoustic modelling was performed to delineate underwater noise fields expected to result from construction and operational activities required to develop an offloading marine port (Port Spencer) in Spencer Gulf, South Australia (the Project). The receptors of concern assessed in the noise model included marine mammals and fish occurring in the Spencer Gulf region. Underwater noise sources considered in the model included impact pile driving, vibrational pile driving, underwater drilling, and vessel traffic. These sound sources can be categorised generally as pulsed (pile driving) or continuous (drilling and vessel traffic). Sounds from moving sources (ships) are considered to be transient relative to the receivers. The standard sound measurement for determining potential effects on marine organisms is root mean square (RMS) pressure, though peak pressure is often used to determine threshold values.

2.0 NOISE MODEL PARAMETERS

Noise modelling was conducted using a two-dimensional noise model designed by National Marine Fisheries Service (NMFS) specifically for pile driving/drilling activities (WSDOT 2009). Underwater noise levels were calculated on the basis of data and methods described in WSDOT's Advanced Training Manual, Biological Assessment Preparation for Transportation Projects Version 10-08 (WSDOT, 2008). In accordance with guidance from the NMFS, this analysis used the Practical Spreading Loss Model.

The Practical Spreading Loss Model is based on the following formula for geometric spreading:

$$\mathbf{TL = 15 \times Log (R1/R2) + \alpha R}$$

Where:

TL: is the transmission loss in dB.

R1: is range in metres of the sound pressure level.

R2: is the distance from the source of the initial measurement.

αR: linear absorption and scattering loss

Solving for TL will provide the underwater sound pressure level at a given distance. To determine at what distance or range a known sound pressure level will occur, the equation must be solved for R1:

$$R1= (10(TL/15)) \bullet R2$$

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The NMFS model was used to calculate the noise attenuation in the project area to determine at what distance from the source the sound level would be expected to reach injury and behavioural threshold values for fishes and marine mammals.

3.0 ACOUSTIC THRESHOLD CRITERIA

There are presently no underwater noise impact criteria established under Australian legislation for the protection of marine fauna from injury or behavioural disturbance due to construction noise. The National Marine Fisheries Service (NMFS) in the United States has developed impact criteria based upon RMS sound pressure levels for fish and marine mammals. In the absence of regional impact criteria for underwater sound, the present modeling exercise has adopted NMFS criteria for assessing impacts to fish and marine mammals in the Spencer Gulf region. The current NMFS interim thresholds protective of injury and behavioural disturbance to fish and marine mammals are as follows:

- The underwater noise pressure threshold (RMS) for potential injury to cetaceans is 180 dB (Southall et al. 2007)
- The underwater noise pressure threshold (RMS) for potential injury to pinnipeds is 190 dB (Southall et al. 2007)
- The underwater noise pressure threshold (RMS) for behavioral disturbance to cetaceans and pinnipeds is 160 dB for pulsed sounds (Southall et al. 2007) and 140 db for continuous sounds (Richardson et al. 1995)
- The underwater noise cumulative sound pressure threshold (SEL) for potential injury to fish ≥ 2 g is 187 dB (Stadler and Woodbury 2009)
- The underwater noise cumulative sound pressure threshold (SEL) for potential injury to fish < 2 g is 183 dB (Stadler and Woodbury 2009)
- The underwater noise peak sound pressure threshold (SEL) for potential injury to fish is 206 dB (Stadler and Woodbury 2009)
- The underwater noise pressure threshold (RMS) for behavioral disturbance to fish is 150 dB (Stadler and Woodbury 2009)
- All sound pressure levels are referenced to 1 micro Pascal (uPa) at 1 m.

The most stringent of the behavioural thresholds for each of cetacean, pinniped and fish were adopted in the model for determining the spatial limits of noise effects.

3.1 Pile Driving (Impact and Vibrational)

Certain piling activities are known to generate high intensity underwater noise that can adversely affect marine animals, particularly dolphins, whales and seals which rely on underwater sound as a primary method of navigation, orientation, communication and foraging. Pile-driving sounds result from a rapid release of energy when two objects hit one another. The characteristics of impact sounds depend primarily on the physical properties of the impacting objects. When a pile-driving hammer strikes a pile, sound from the impact radiates into the air and a transient stress wave, or pulse, propagates down the length of the pile. The impact will also create flexural (or transverse) stress waves in the wall of the pile which couple with the surrounding fluids (air and water) to radiate sound into the water and additional sound into the air. Moreover, the pulse propagating down the length of the pile may couple to the substrate at the water bottom and cause waves to propagate outward through the bottom sediment. These transient waves in the substrate can be transmitted from the bottom into the water at some distance away from the pile to create localised areas of very low and/or very high sound pressure and acoustic particle motion because of interference with the sound pulse directly from the pile that is traveling outward through the water. Typically, pile-driving sounds underwater are characterised by multiple rapid increases and decreases in sound pressure over a very short period of time. The peak pressure is the highest absolute value of the measured waveform, and can be a negative or positive pressure peak.

Typically, noise generated by pile driving consists of pulsed sounds that occur at intervals of approximately 1 to 3 seconds depending upon the equipment used. The repetitive nature of the pile driving sounds does not allow for receivers to fully recover from one pulse before the next pulse is produced. In order to assess this type of sound source, the NMFS noise model and impact criteria are based upon the peak sound pressure (RMS) and the sound exposure level (SEL) which take into account the number of pulses generated per day. Generally, the preferred method of initial pile placement into the substrate prior to drilling is to use a vibratory hammer. This technology uses rapidly pulsing vibrations to drive the piles until they encounter bedrock, or at least refusal. For the purpose of this modelling exercise, pile installation by vibratory hammer was analysed as a continuous noise source by entering a value of one as the number of strikes in the NMFS model.

Predicted noise levels were obtained for standard pile sizes and driving techniques compiled by the California Department of Transportation (2009). Three pile driving scenarios were considered in the model involving two different pile sizes and two potential driving techniques:

- Driving a 48-inch steel or cast-in-steel shell (CISS) pile with an impact hammer produces noise at a peak pressure of 200 dB (20 m), RMS of 190 dB, and SEL of 175 dB
- Driving a 40-inch steel or CISS pile with an impact hammer produces noise at a peak pressure of 205 dB (10 m), RMS of 190 dB, and SEL of 175 dB
- Driving a 48-inch steel or CISS pile with a vibratory hammer produces noise at a peak pressure of 185 dB (10 m), RMS of 170 dB, and SEL of 170 dB.

All sound pressure levels are referenced to 1 micro Pascal (uPa) at 1 m.

3.2 Pile Drilling

The anticipated method of pile setting involves drilling after the use of a piling hammer to drive the steel piles to the point of refusal. The pile will then be held in place and a drill rig will be used to bore a socket into the bedrock. Drilling was analysed as a continuous noise source by entering a value of one as the number of strikes in the NMFS model.

Predicted noise levels from drilling were obtained using measured sound levels from drilling techniques reported in Nedwell and Brooker (2008). For the purpose of this model, it was assumed that underwater noise produced from drilling into the substrate within a steel pile will have a maximum RMS pressure of 146 dB at 10 m (re 1 uPa at 1 m).

3.3 Marine Vessel Noise

The construction and operation of the marine facilities will include the operation of cargo vessels, barges, and/or tug boats. Underwater noise from these vessels will be generated primarily from propeller cavitation. Vessel noise was analysed as a continuous noise source in the NMFS model.

There are no data available for noise levels from the specific vessels anticipated for the project. Predicted noise levels were obtained using measured sound levels from similar vessels reported in JASCO (2006). It was assumed that vessels approaching or leaving the marine facilities will have a maximum RMS pressure of 175 dB (re uPa at 1 m).

4.0 RESULTS

The results of the assessment of the effect on underwater noise levels are presented in the following section in comparison to established underwater noise threshold levels for effects to marine biota. The predicted noise and sound level thresholds are summarised in Table 1.

4.1 Pile Driving (Impact and Vibrational)

Pile installation using a vibratory hammer is predicted to produce a sound pressure level of 170 dB (RMS) at 10 m. This level is below the injury threshold for both marine fish and marine mammals. The model predicts that the noise level from this activity will attenuate to the behavioral threshold for mammals (160 dB) at a distance of 46 m from each pile, and it will attenuate to the behavioral threshold for fish (150 dB) at a distance of 215 m from each pile (Table 1). Modelling assumes that the vibratory hammer will seat a given pile into position in 30 minutes or less, and a maximum of three piles will be driven on a given day.

If an impact hammer is required for pile driving, the model predicts that the noise level from this activity will attenuate to the behavioral threshold for mammals (160 dB) at a distance of 928 m from each pile, and it will attenuate to the behavioral threshold for fish (150 dB) at a distance of 4.3 km from each pile. The model also predicts that the noise level from this activity will attenuate to the lowest injury threshold for mammals (180 dB) at a distance of 431 m from each pile, and it will attenuate to the injury threshold for fish ≥ 2g (187dB) at a distance of 469 m from each pile.

4.2 Pile Drilling

Once the piles are seated in position, a drilling rig will bore a socket into the bedrock. This method of drilling is predicted to produce a maximum sound pressure level of 146 dB (RMS) at 10 m. This drilling will occur inside the steel pile, and the drilling operation also includes the use of and air/water injection to lift suspended material out of the pile casing. These two factors likely result in an actual attenuated sound level that is greatly reduced from the 146 dB, which was used as a conservative proxy. This level is below the injury threshold for both fish and marine mammals. If the sound pressure level during drilling reached 146 dB, the model predicts that the noise level will attenuate to the behavioral threshold for mammals (140 dB) at a distance of 25 m from each pile, and it will attenuate to the behavioral threshold for fish (150 dB) at a distance of 5 m from each pile.

4.3 Marine Vessel Traffic

Container vessels and tug boats are predicted to produce a maximum sound pressure level of 175 dB (RMS) at 1 m. This level is below the injury threshold for both fish and marine mammals. The model predicts that the noise level from these vessels will attenuate to the continuous sound behavioral threshold for mammals (140 dB) at a distance of 115 m from the vessel, and it will attenuate to the behavioral threshold for fish (150 dB) at a distance of 30 m from the vessel.

Table 1: Summary of Predicted Noise and Distances to Thresholds.

Project Activity	Predicted Noise (dB)	Injury Threshold (dB)		Distance to Injury Threshold (m)		Behavioral Threshold (dB)		Distance to Behavioral Threshold (m)	
		Mammals	Fish	Mammals	Fish	Mammals	Fish	Mammals	Fish
Impact Pile Driving	205 Peak/ 190 RMS @ 10 m	190/180	187	93/431	469*	160	150	928	4642
Vibration Pile Driving	170 (RMS @ 10 m)	190/180	187	1	1	160	150	46	215
Drilling	146 (RMS @ 10 m)	190/180	187	NA	NA	140	150	25	5
Vessel Traffic	175 (RMS @ 1m)	190/180	187	93/431	469	140	150	115	30

* Distance to cumulative SEL based up on an estimated 1800 pile strikes per day.

5.0 PREDICTION CONFIDENCE

Prediction confidence in the noise model is considered to be moderate based on the following factors:

- The activities associated with construction and operations of the marine facilities were modelled using conservative values and measured values from similar materials, equipment, and operations.
- The NMFS model is designed specifically for pile driving activities.
- There are no other significant noise sources in the project area that would need to be modelled with the anticipated project noise sources.
- The short duration of all noise sources minimises potential effects.
- Quality assurance was accomplished by implementing quality control checks on all model runs to ensure that model input parameters were correct, model output was plotted correctly and any calculations were checked.
- There are limitations of using a two-dimensional model with respect to sound attenuation in a three-dimensional environment. However, these limitations were assumed to be minor given that the zone of greatest influence corresponded with shallow water.
- The present model assumes that sound travels in a homogeneous environment. In reality, variability in the physical environment (salinity, water depth, currents, substrate type) likely exists within the area of interest. This variability could potentially influence underwater sound transmission as well as actual threshold distances, when compared to the predicted model (which assumes a constant sound velocity). It has been noted that in-field gradients in temperature, bottom topography, and current cause sound levels to attenuate more rapidly than predicted by this geometric spreading-based model.

6.0 LITERATURE CITED

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APPENDIX D

Sediment Quality Results

a) Particle Size Distribution Data and Graphs

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199 Franklin Street, Adelaide SA 5000

Particle Size Distribution & Consistency Limits Test Report

Client:	Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000		
Project:	Additional Marine Studies	**Date:**	11-Aug-11
Location:	Sheep Hill Port **Job No.** 107661001	**Report No.**	107661001 / R21
Lab Reference No.	11641311	**Sample Identification:**	D1 Seagrass / NS
Laboratory Specimen Description:	(SP) SAND, fine to coarse grained, grey, with fines, organics present.		

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	98	
1.18 mm	97	
600 um	95	
300 um	65	
150 um	22	
75 um	8	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

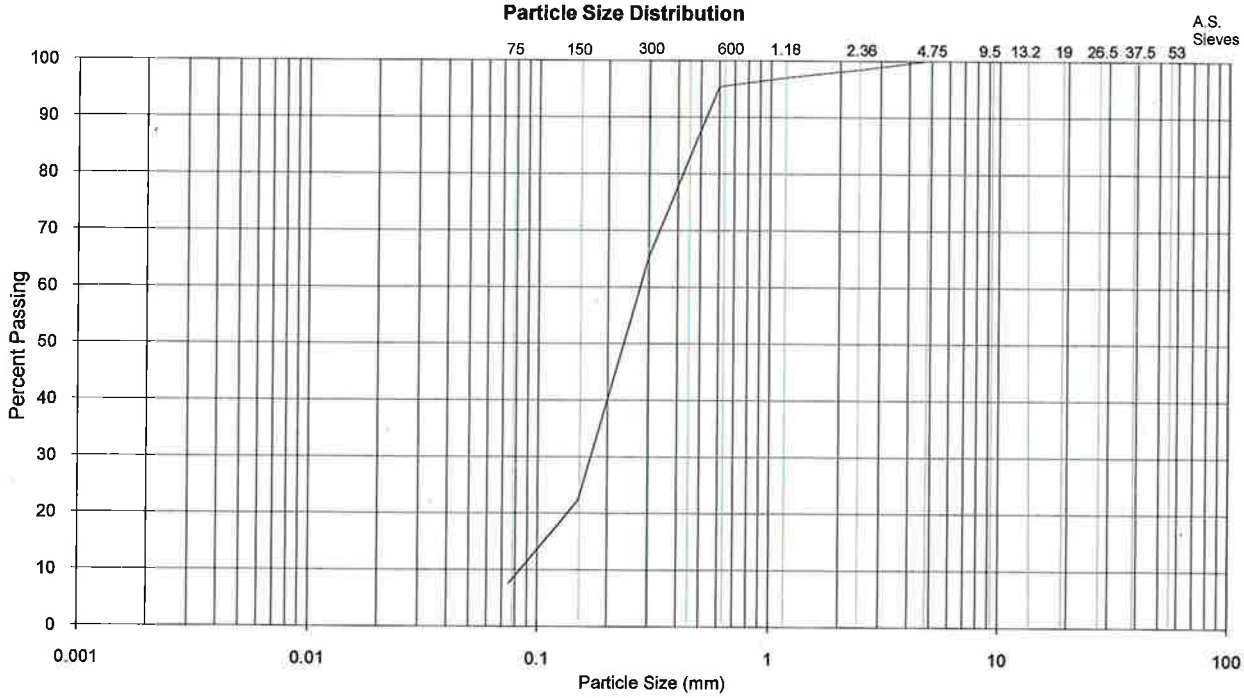
Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density:	t/m3
Optimum Moisture Content:	%

Notes



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Golder Associates Pty Ltd

199 Franklin Street, Adelaide SA 5000

Particle Size Distribution & Consistency Limits Test Report

Client:	Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000				
Project:	Additional Marine Studies			**Date:**	11-Aug-11
Location:	Sheep Hill Port	**Job No.**	107661001	**Report No.**	107661001 / R22
Lab Reference No.	11641312	**Sample Identification:**	D1 MB		

Laboratory Specimen Description: (SP) SAND, fine to coarse grained, grey, with fines.

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	100	
1.18 mm	100	
600 um	96	
300 um	87	
150 um	66	
75 um	7	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

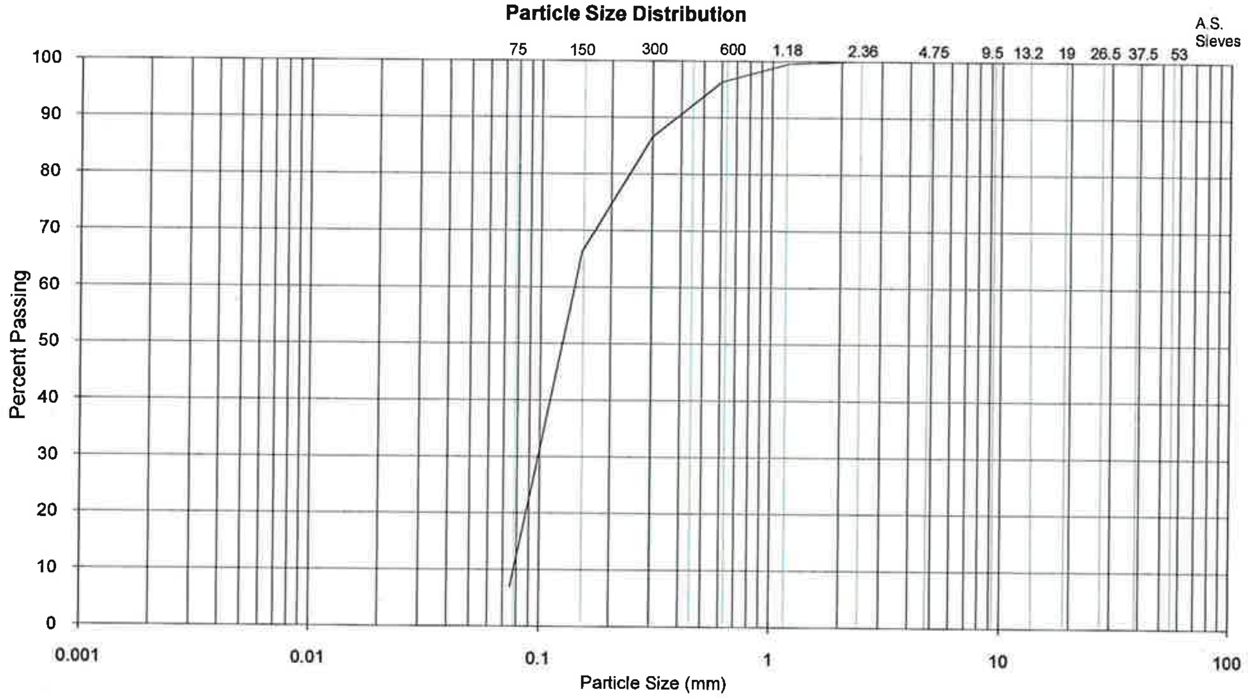
Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density:	t/m3
Optimum Moisture Content:	%

Notes



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199 Franklin Street, Adelaide SA 5000

Particle Size Distribution & Consistency Limits Test Report

Client:	Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000		
Project:	Additional Marine Studies	**Date:**	11-Aug-11
Location:	Sheep Hill Port **Job No.** 107661001	**Report No.**	107661001 / R23
Lab Reference No.	11641313	**Sample Identification:**	D3 NTH MB
Laboratory Specimen Description:		(SP) SAND, fine to coarse grained, grey, with fines.	

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	99	
1.18 mm	97	
600 um	92	
300 um	81	
150 um	40	
75 um	11	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

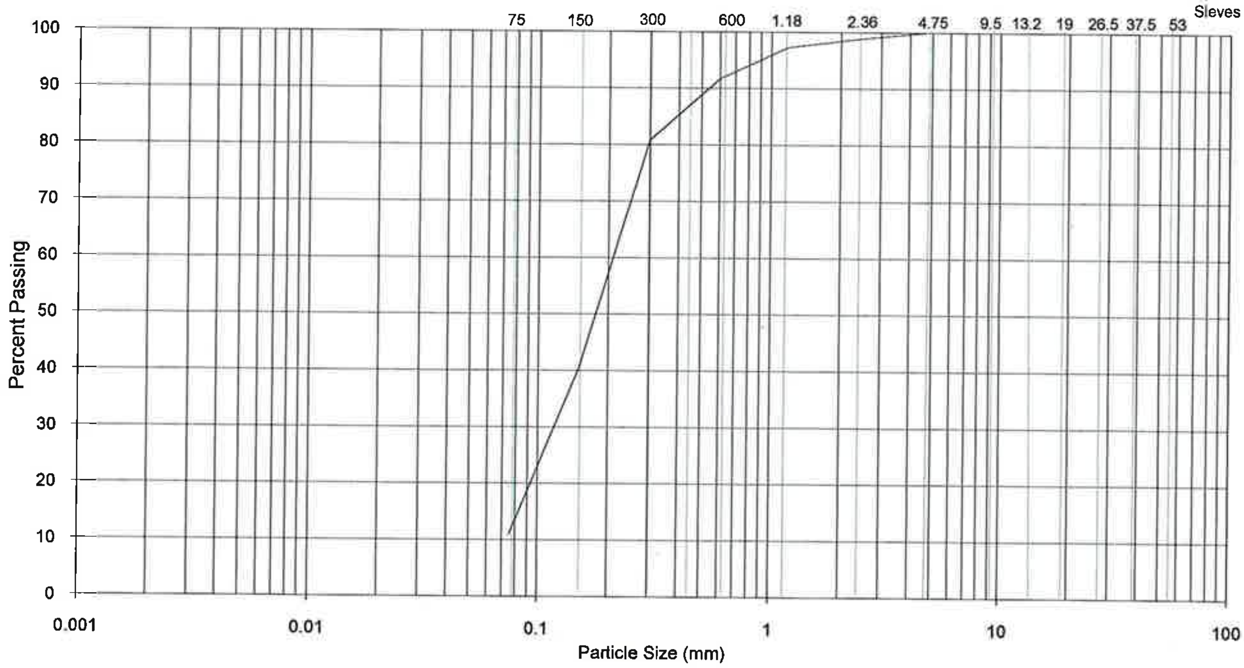
Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density:	t/m3
Optimum Moisture Content:	%

Notes



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199 Franklin Street, Adelaide SA 5000

Particle Size Distribution & Consistency Limits Test Report

Client:	Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000		
Project:	Additional Marine Studies	**Date:**	11-Aug-11
Location:	Sheep Hill Port **Job No.** 107661001	**Report No.**	107661001 / R24
Lab Reference No.	11641314	**Sample Identification:**	D3 STH MB
Laboratory Specimen Description:	(SP) SAND, fine to coarse grained, grey, with fines.		

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	100	
1.18 mm	100	
600 um	94	
300 um	83	
150 um	49	
75 um	12	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

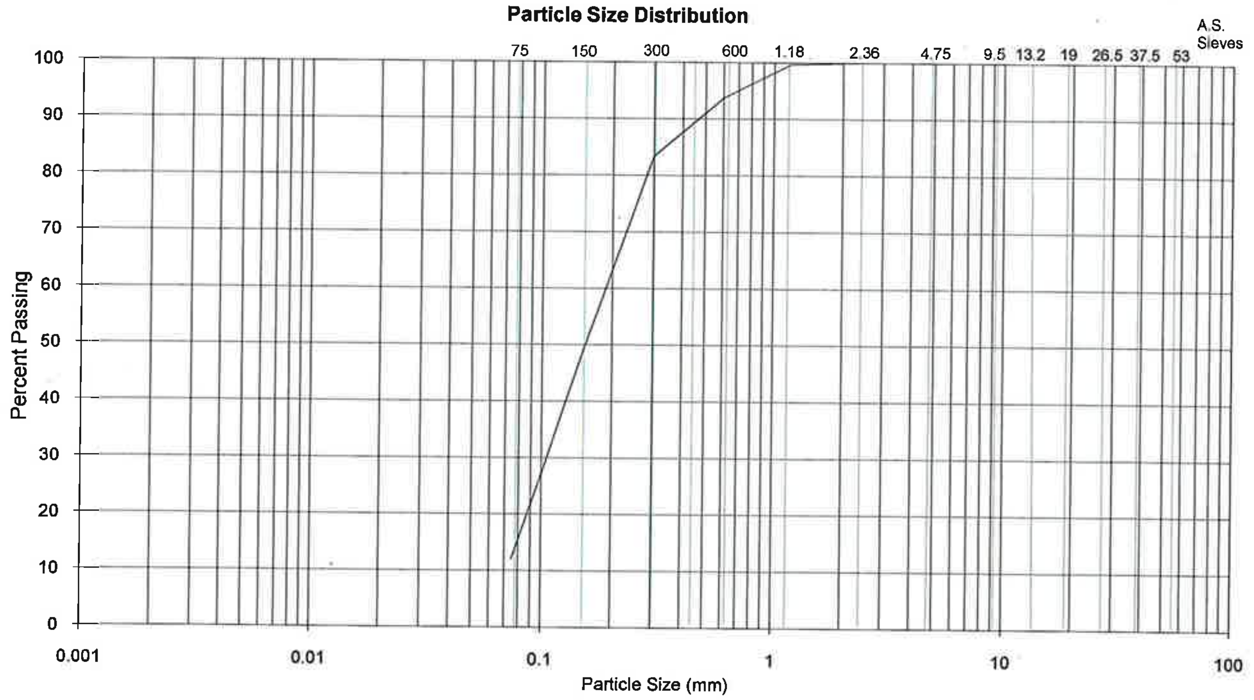
Sample History: Air Dried
Preparation Method: Dry sieved
Crumbling / Curling of linear shrinkage: No
Linear shrinkage mould length: 250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density: t/m3
Optimum Moisture Content: %

Notes



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Particle Size Distribution & Consistency Limits Test Report

Client:	Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000		
Project:	Additional Marine Studies	**Date:**	11-Aug-11
Location:	Sheep Hill Port **Job No.** 107661001	**Report No.**	107661001 / R25
Lab Reference No.	11641315	**Sample Identification:**	D6 NTH MB

Laboratory Specimen Description: (SP) SAND, fine to coarse grained, grey, with fines.

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	99	
1.18 mm	93	
600 um	76	
300 um	53	
150 um	31	
75 um	10	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

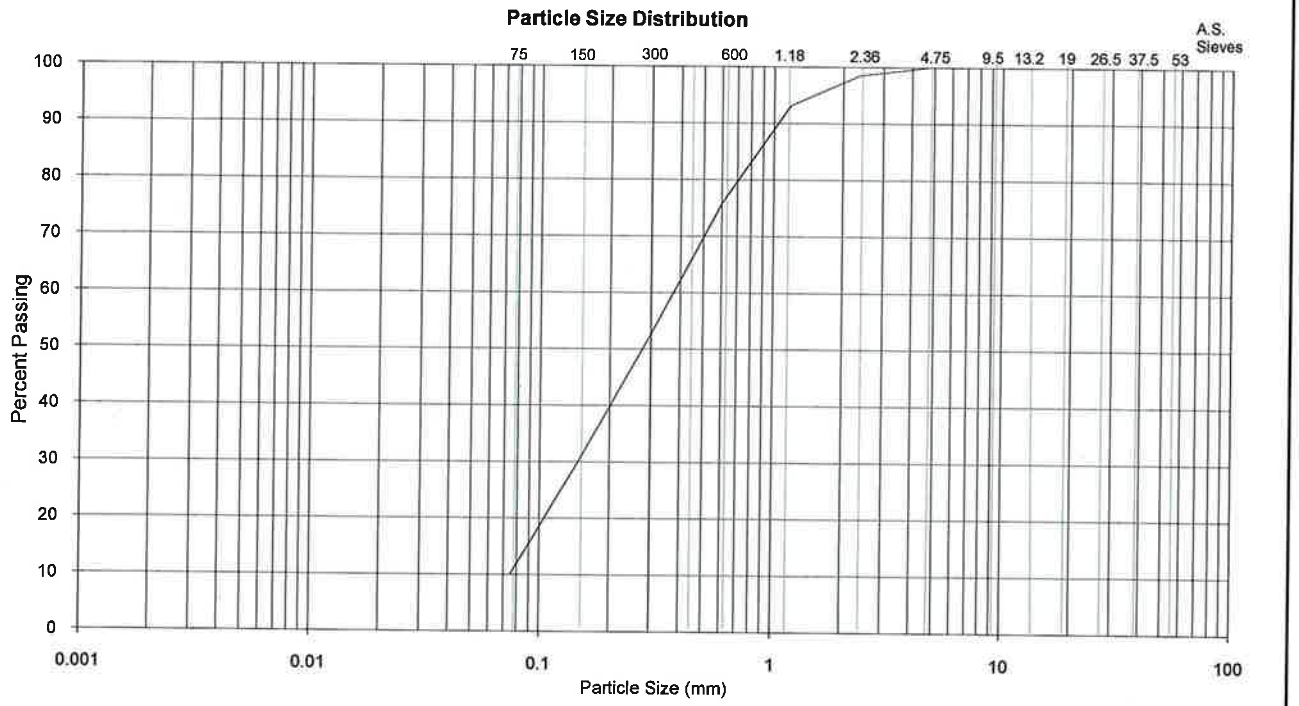
Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density:	t/m3
Optimum Moisture Content:	%

Notes



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Particle Size Distribution & Consistency Limits Test Report

Client: Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000

Project: Additional Marine Studies

Date: 11-Aug-11

Location: Sheep Hill Port

Job No. 107661001

Report No. 107661001 / R26

Lab Reference No. 11641316

Sample Identification: D6 STH MB

Laboratory Specimen Description: (SP) SAND, fine to coarse grained, grey, with fines.

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	99	
1.18 mm	96	
600 um	85	
300 um	67	
150 um	32	
75 um	11	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

Sample History: Air Dried

Preparation Method: Dry sieved

Crumbling / Curling of linear shrinkage: No

Linear shrinkage mould length: 250 mm

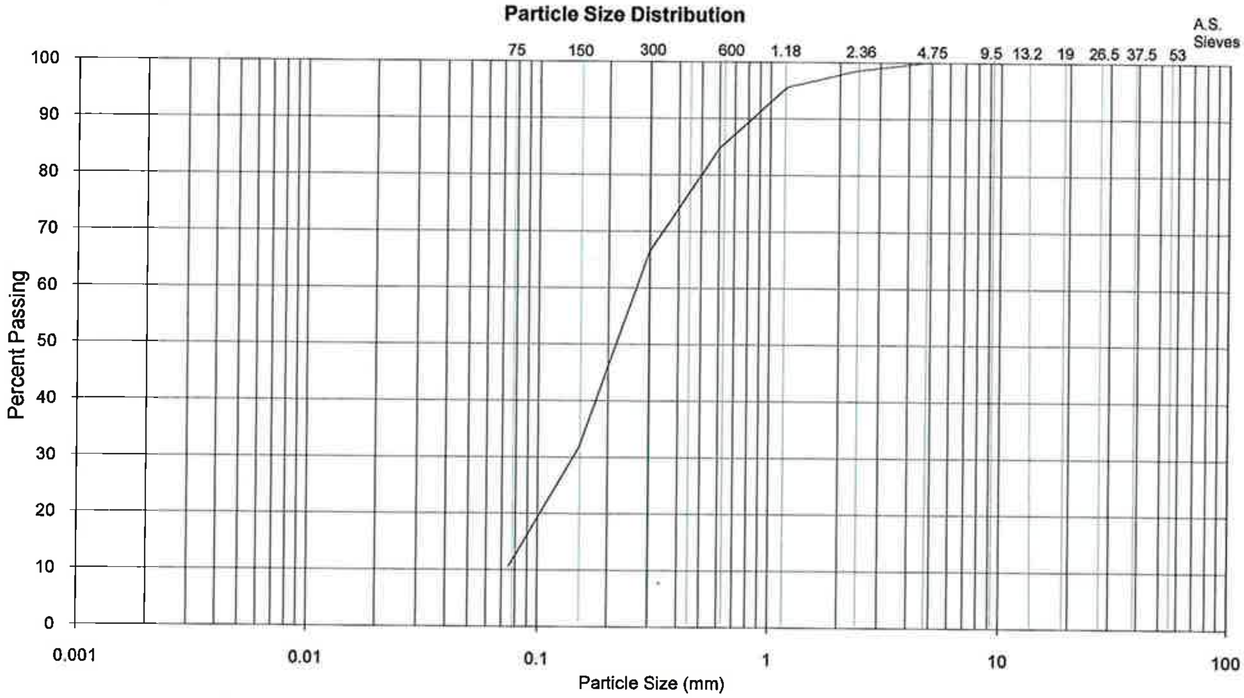
ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density: t/m3

Optimum Moisture Content: %

Notes



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Approved Signatory, Ben Wessling - Senior Technical Officer

Golder Associates Pty Ltd

199 Franklin Street, Adelaide SA 5000

Particle Size Distribution & Consistency Limits Test Report

Client:	Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000
Project:	Additional Marine Studies
Date:	11-Aug-11
Location:	Sheep Hill Port
Job No.	107661001
Report No.	107661001 / R27
Lab Reference No.	11641317
Sample Identification:	Distance 6 (D6) NTH Seagrass / NS
Laboratory Specimen Description:	(SP) SAND, fine to coarse grained, grey, trace of fines, organics present.

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	92	
1.18 mm	89	
600 um	87	
300 um	77	
150 um	16	
75 um	5	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

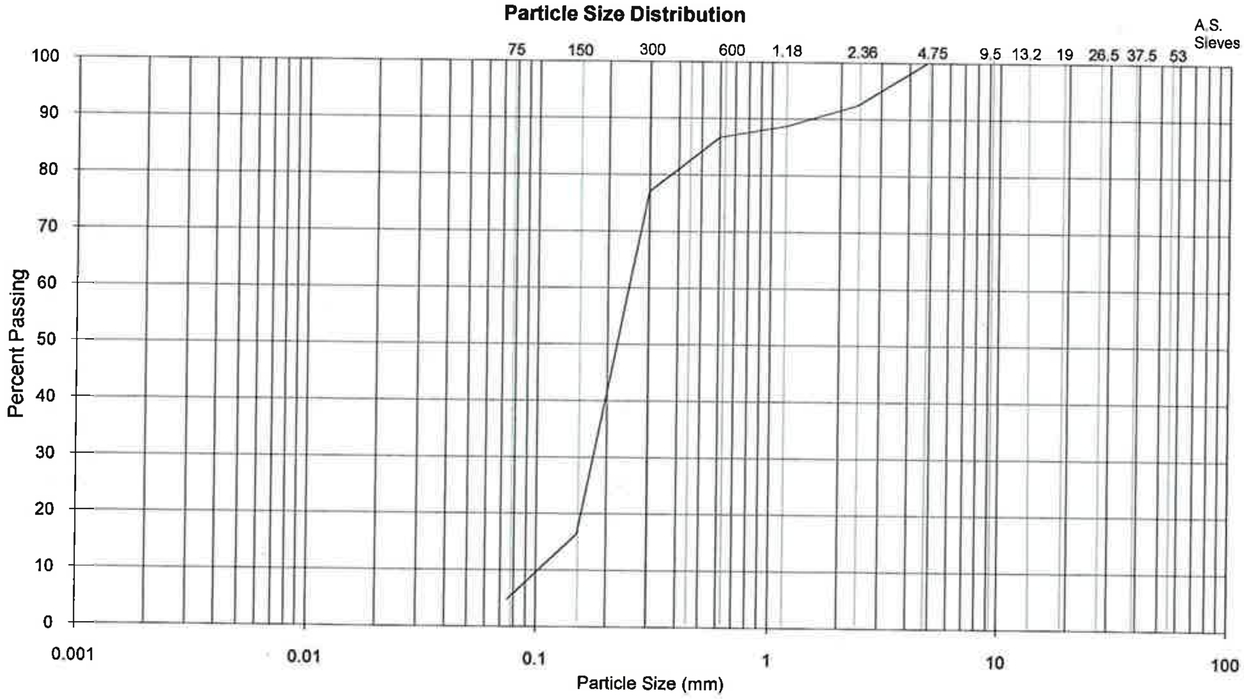
Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density:	t/m3
Optimum Moisture Content:	%

Notes



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Golder Associates Pty Ltd
199 Franklin Street, Adelaide SA 5000

Particle Size Distribution & Consistency Limits Test Report

Client:	Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000		
Project:	Additional Marine Studies	**Date:**	11-Aug-11
Location:	Sheep Hill Port	**Job No.** 107661001	**Report No.** 107661001 / R28
Lab Reference No.	11641318	**Sample Identification:**	Distance 6 (D6) STH Seagrass / NS
Laboratory Specimen Description:		(SP) SAND, fine to coarse grained, grey, with fines, organics present.	

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	99	
1.18 mm	97	
600 um	71	
300 um	25	
150 um	18	
75 um	6	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

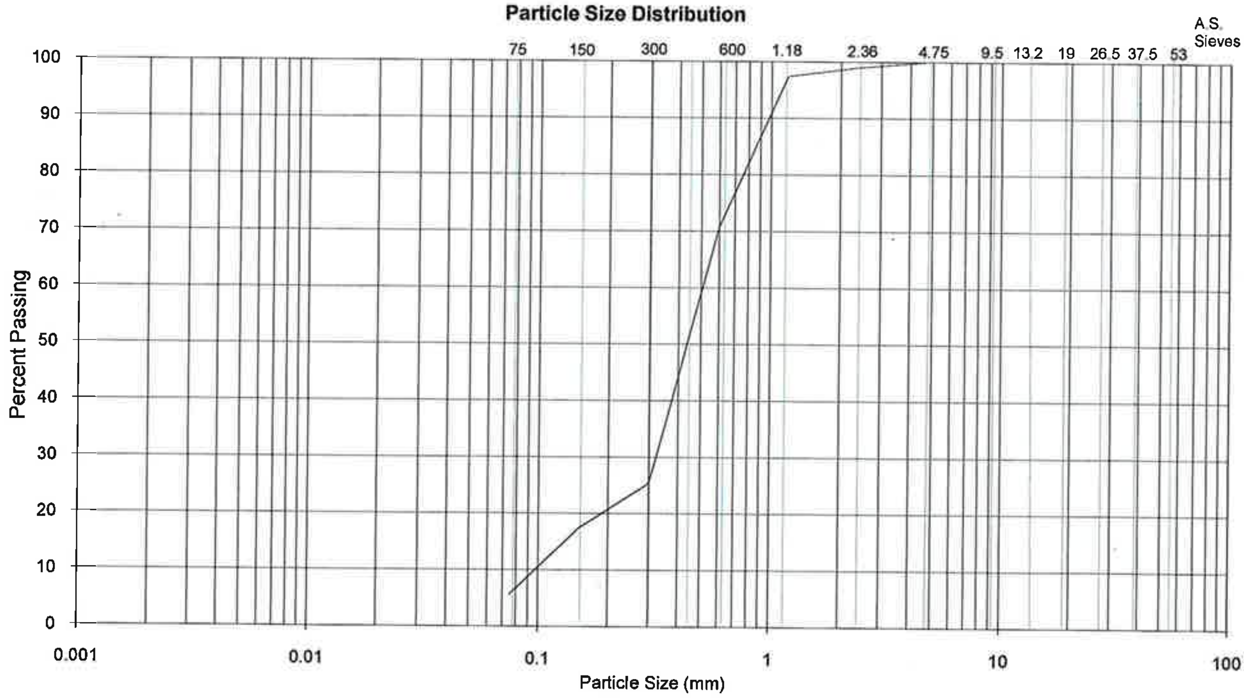
Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density:	t/m3
Optimum Moisture Content:	%

Notes



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Golder Associates Pty Ltd
199 Franklin Street, Adelaide SA 5000

Particle Size Distribution & Consistency Limits Test Report

Client:	Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000		
Project:	Additional Marine Studies	**Date:**	11-Aug-11
Location:	Sheep Hill Port **Job No.** 107661001	**Report No.**	107661001 / R29
Lab Reference No.	11641319	**Sample Identification:**	Distance 3 (D3) STH Seagrass / NS
Laboratory Specimen Description:		(SP) SAND, fine to coarse grained, grey, with fines, organics present.	

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	93	
1.18 mm	90	
600 um	86	
300 um	32	
150 um	11	
75 um	5	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

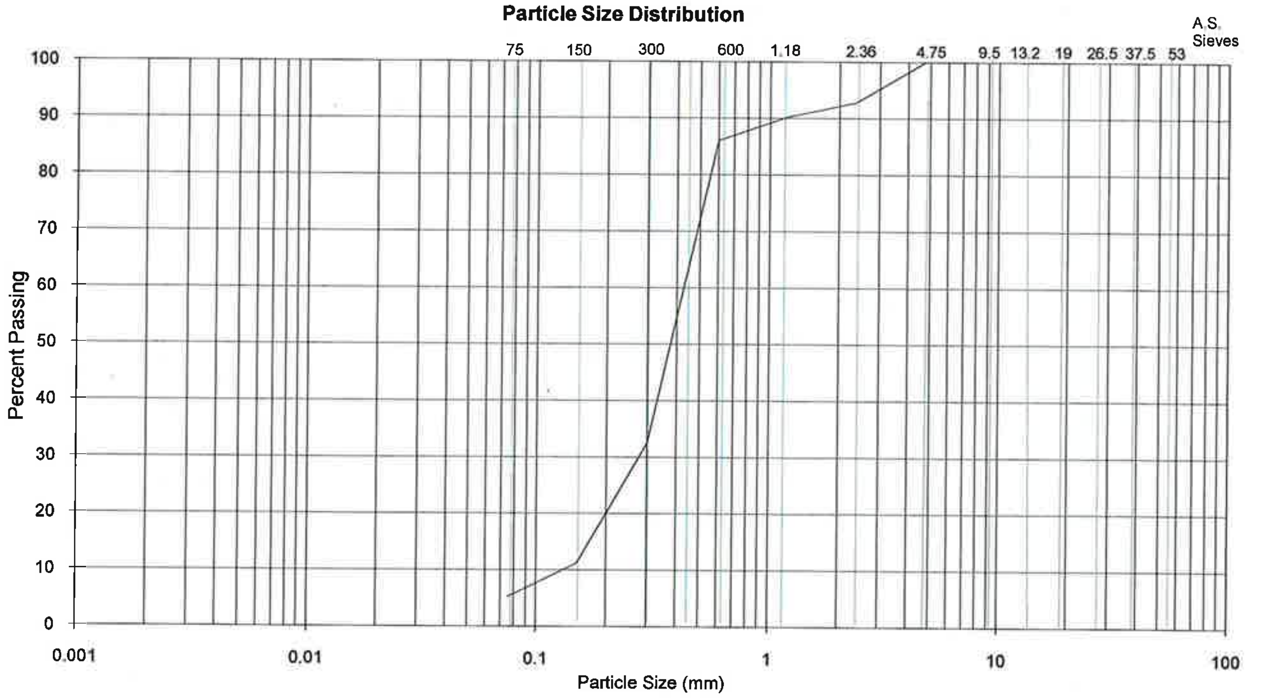
Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density:	t/m3
Optimum Moisture Content:	%

Notes



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Approved Signatory, Ben Wessling - Senior Technical Officer

Golder Associates Pty Ltd

199 Franklin Street, Adelaide SA 5000

Particle Size Distribution & Consistency Limits Test Report

Client: Centrex Metals Ltd, Level 3, 100 Pirie Street, Adelaide, SA, 5000

Project: Additional Marine Studies **Date:** 11-Aug-11

Location: Sheep Hill Port **Job No.** 107661001 **Report No.** 107661001 / R30

Lab Reference No. 11641320 **Sample Identification:** Distance 3 (D3) NTH Seagrass / NS

Laboratory Specimen Description: (SP) SAND, fine to coarse grained, grey, trace of fines, organics present.

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing	Specification
150 mm	100	
75 mm	100	
53 mm	100	
37.5 mm	100	
26.5 mm	100	
19.0 mm	100	
13.2 mm	100	
9.5 mm	100	
6.7 mm	100	
4.75 mm	100	
2.36 mm	100	
1.18 mm	100	
600 um	98	
300 um	40	
150 um	8	
75 um	5	

Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

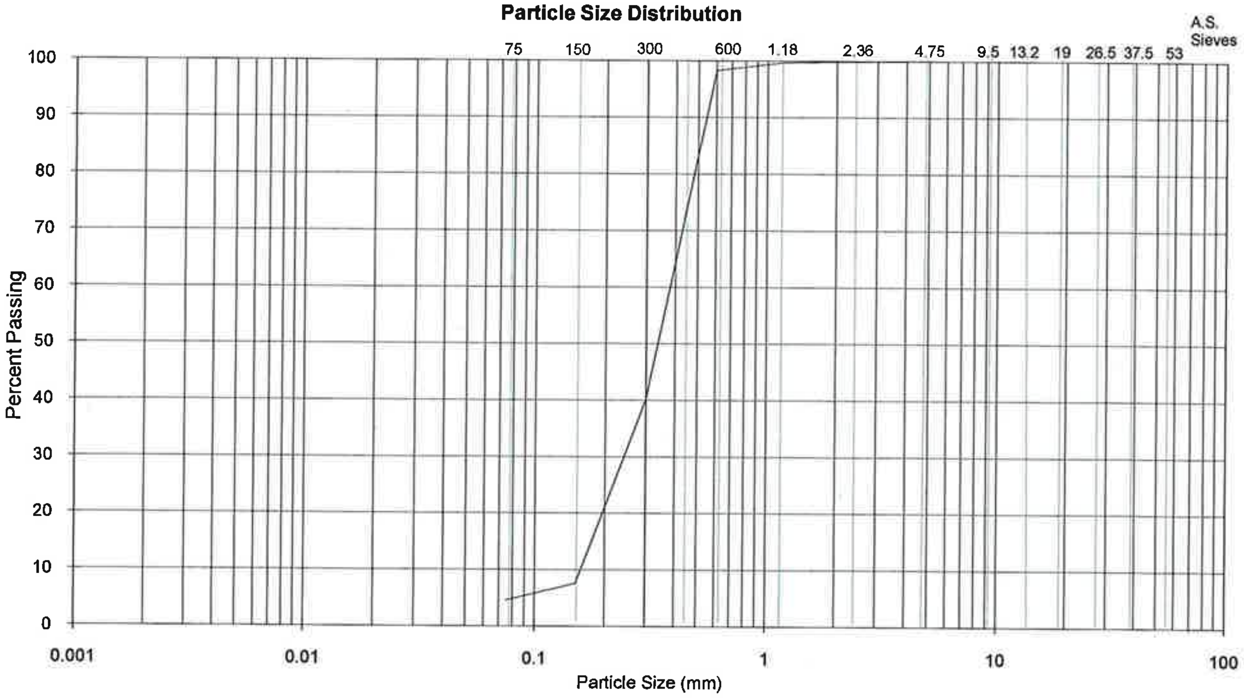
Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.2.1

Maximum Dry Density:	t/m3
Optimum Moisture Content:	%

Notes



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Approved Signatory, Ben Wessling - Senior Technical Officer

Golder Associates Pty Ltd
84 Guthrie Street, Osborne Park, WA, 6017

Particle Size Distribution, Hydrometer & Consistency Limits Test Report

Client:	Centrex	Date:	19-Aug-11
Project:	Port EIA Approvals	Report No:	11-218
Location:	Lipson Job No. 107661001	Sheet No:	1 of 8
Lab Reference No.	11441498	Sample Identification:	D3 STH MB. 11641314

Laboratory Specimen Description: Grey SAND
AS1726 - Soil Classification:

Particle Size Distribution AS1289 3.6.1

Sieve Size	% Passing
150 mm	100
75 mm	100
53 mm	100
37.5 mm	100
26.5 mm	100
19.0 mm	100
13.2 mm	100
9.5 mm	100
6.7 mm	100
4.75 mm	100
2.36 mm	100
1.18 mm	100
0.6 mm	94
0.425 mm	90
0.3 mm	83
0.15 mm	49
0.075 mm	12

Hydrometer Analysis AS1289.3.6.3

Sieve Size	% Passing
0.073 mm	10
0.052 mm	8
0.037 mm	7
0.027 mm	5
0.019 mm	4
0.014 mm	4
0.010 mm	4
0.007 mm	4
0.005 mm	4
0.003 mm	3
0.001 mm	2

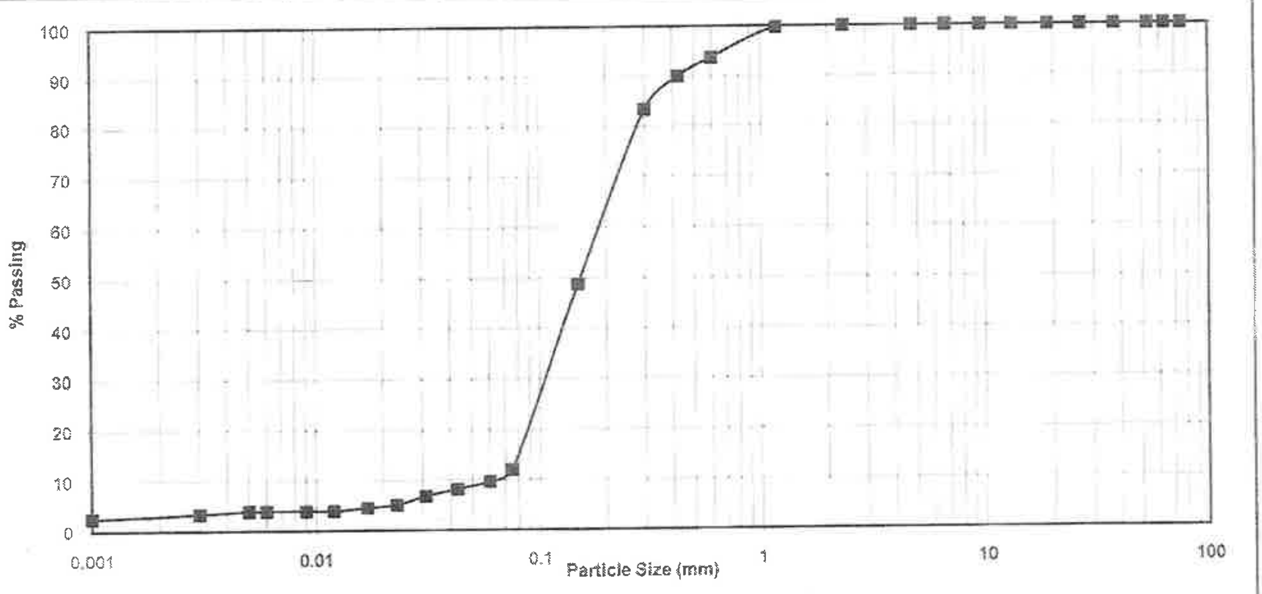
Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

Sample History: Air Dried
Preparation Method: Dry sieved
Crumbling / Curling of linear shrinkage: No
Linear shrinkage mould length: 250 mm
ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.1.1
Maximum Dry Density: t/m^3
Optimum Moisture Content: %

Notes on Hydrometer Test
Pretreated for salt — Measured Particle Density - 2.70 g/cm^3
Type of hydrometer - ASTM — Type of dispersion - Mechanical



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Paul Hamilton, Laboratory Manager

Golder Associates Pty Ltd

84 Guthrie St OBSORNE PARK WA 6017

Soil Particle Density Report

Client:	Centrex	**Date:**	19/8/11
		Report No:	11-218
Project:	Port EIA Approvals	**Job No:**	107661001
Location:	Lipson	**Sheet No:**	2 of 8

Test Procedure: AS 1289 - 3.5.1

Laboratory Sample No.	11441498
Sample Identification	D3 STH MB, 11641314
Material Description	Grey SAND
The Average Apparent Particle Density of The Fraction Passing 2.36mm Fraction (g/cm^3)	2.70
The Average Apparent Particle Density of The Fraction Retaine 2.36mm Fraction (g/cm^3)	NA
The Soil Particle Density of The Total Sample (g/cm^3)	2.70

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Approved Signatory:
Paul Hamilton, Laboratory Manager

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Golder Associates Pty Ltd
84 Guthrie Street, Osborne Park, WA, 6017

Particle Size Distribution, Hydrometer & Consistency Limits Test Report

Client:	Centrex	Date:	19-Aug-11
Project:	Port EIA Approvals	Report No:	11-218
Location:	Lipson Job No. 107661001	Sheet No:	3 of 8
Lab Reference No.	11441499	Sample Identification:	D6 NTH MB, 11641315

Laboratory Specimen Description: Grey SAND
AS1726 - Soil Classification:

Particle Size Distribution AS1289 3.6.1		Hydrometer Analysis AS1289.3.6.3	
Sieve Size	% Passing	Sieve Size	% Passing
150 mm	100	0.073 mm	8
75 mm	100	0.052 mm	7
53 mm	100	0.037 mm	7
37.5 mm	100	0.026 mm	6
26.5 mm	100	0.019 mm	5
19.0 mm	100	0.014 mm	5
13.2 mm	100	0.010 mm	5
9.5 mm	100	0.007 mm	4
6.7 mm	100	0.005 mm	4
4.75 mm	100	0.003 mm	4
2.36 mm	99	0.001 mm	3
1.18 mm	93		
0.6 mm	76		
0.425 mm	65		
0.3 mm	53		
0.15 mm	31		
0.075 mm	10		

Consistency Limits and Moisture Content

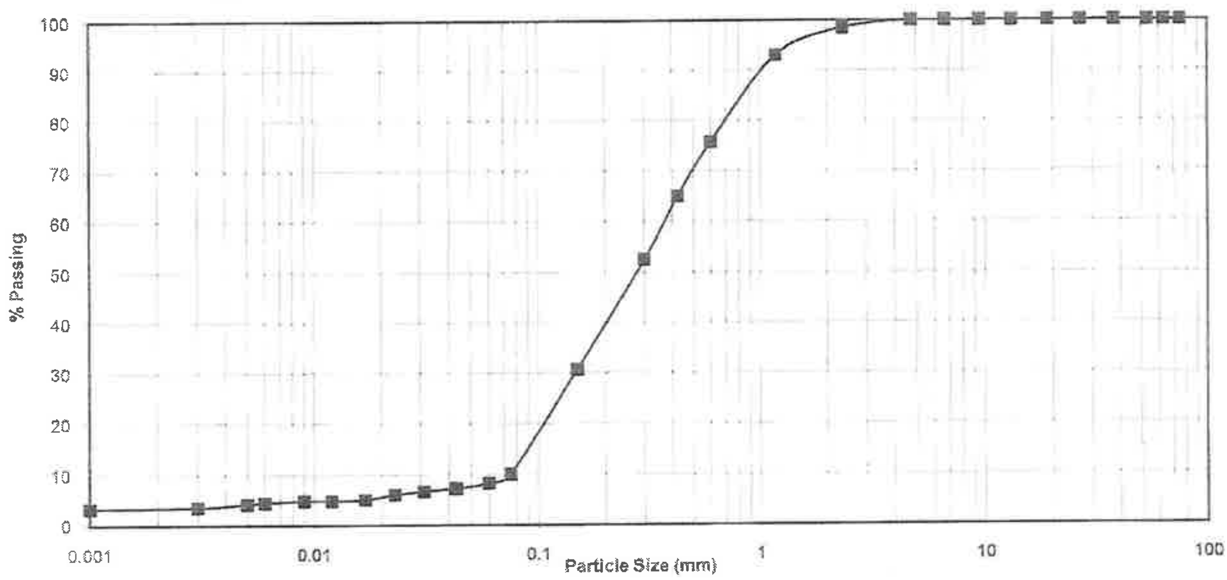
Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

Sample History: Air Dried
Preparation Method: Dry sieved
Crumbling / Curling of linear shrinkage: No
Linear shrinkage mould length: 250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.1.1
Maximum Dry Density: t/m³
Optimum Moisture Content: %

Notes on Hydrometer Test
Pretreated for salt — Measured Particle Density - 2.76 g/cm³
Type of hydrometer - ASTM — Type of dispersion - Mechanical



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84 Guthrie St OBSORNE PARK WA 6017

Soil Particle Density Report

Client:	Centrex	Date:	19/8/11
		Report No:	11-218
Project:	Port EIA Approvals	Job No:	107661001
Location:	Lipson	Sheet No:	4 of 8

Test Procedure: AS 1289 - 3.5.1

Laboratory Sample No.	11441499
Sample Identification	D6 NTH MB, 11641315
Material Description	Grey SAND
The Average Apparent Particle Density of The Fraction Passing 2.36mm Fraction (g/cm^3)	2.76
The Average Apparent Particle Density of The Fraction Retaine 2.36mm Fraction (g/cm^3)	NA
The Soil Particle Density of The Total Sample (g/cm^3)	2.76

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Approved Signatory: Paul Hamilton, Laboratory Manager

Golder Associates Pty Ltd
84 Guthrie Street, Osborne Park, WA, 6017

Particle Size Distribution, Hydrometer & Consistency Limits Test Report

Client:	Centrex			**Date:**	19-Aug-11
Project:	Port EIA Approvals			**Report No:**	11-218
Location:	Lipson	**Job No.**	107661001	**Sheet No:**	5 of 8
Lab Reference No.	11441500	**Sample Identification:**	D6 STH MB, 11641316		

Laboratory Specimen Description: Grey SAND
AS1726 - Soil Classification:

Particle Size Distribution AS1289 3.6.1		Hydrometer Analysis AS1289.3.6.3	
Sieve Size	% Passing	Sieve Size	% Passing
150 mm	100	0.072 mm	12
75 mm	100	0.052 mm	8
53 mm	100	0.037 mm	6
37.5 mm	100	0.027 mm	5
26.5 mm	100	0.019 mm	4
19.0 mm	100	0.014 mm	4
13.2 mm	100	0.010 mm	4
9.5 mm	100	0.007 mm	3
6.7 mm	100	0.005 mm	3
4.75 mm	100	0.003 mm	3
2.36 mm	99	0.001 mm	3
1.18 mm	96		
0.6 mm	86		
0.425 mm	80		
0.3 mm	70		
0.15 mm	38		
0.075 mm	19		

Consistency Limits and Moisture Content

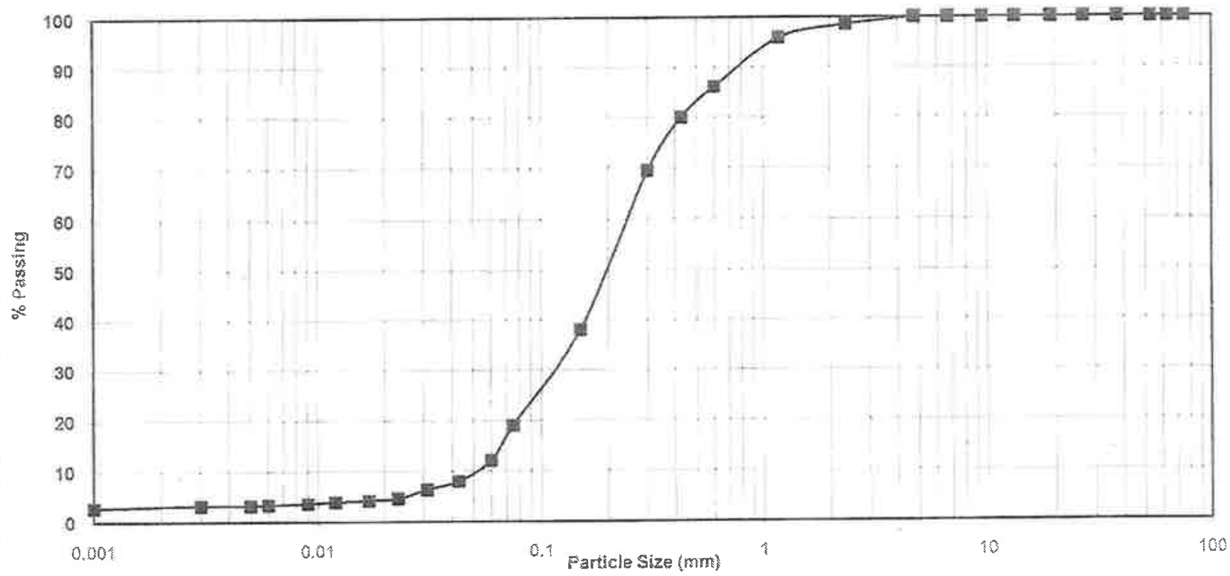
Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

Sample History:	Air Dried
Preparation Method:	Dry sieved
Crumbling / Curling of linear shrinkage:	No
Linear shrinkage mould length:	250 mm

ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.1.1
Maximum Dry Density: t/m^3
Optimum Moisture Content: %

Notes on Hydrometer Test
Pretreated for salt Measured Particle Density - 2.73 g/cm^3
Type of hydrometer - ASTM Type of dispersion - Mechanical



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Paul Hamilton, Laboratory Manager

Golder Associates Pty Ltd
84 Guthrie St OBSORNE PARK WA 6017

Soil Particle Density Report

Client:	Centrex	Date:	19/8/11
		Report No:	11-218
Project:	Port EIA Approvals	Job No:	107661001
Location:	Lipson	Sheet No:	6 of 8

Test Procedure: AS 1289 - 3.5.1

Laboratory Sample No.	11441500
Sample Identification	D6 STH MB, 11641316
Material Description	Grey SAND
The Average Apparent Particle Density of The Fraction Passing 2.36mm Fraction (g/cm^3)	2.73
The Average Apparent Particle Density of The Fraction Retaine 2.36mm Fraction (g/cm^3)	NA
The Soil Particle Density of The Total Sample (g/cm^3)	2.73

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Approved Signatory: ____________________
Paul Hamilton, Laboratory Manager

Golder Associates Pty Ltd
84 Guthrie Street, Osborne Park, WA, 6017

Particle Size Distribution, Hydrometer & Consistency Limits Test Report

Client: Centrex		**Date:**	19-Aug-11
Project: Port EIA Approvals		**Report No:**	11-218
Location: Lipson	**Job No.** 107661001	**Sheet No:**	7 of 8
Lab Reference No. 11441501	**Sample Identification:**	D3 NTH MB, 11641313	

Laboratory Specimen Description: Grey SAND
AS1726 - Soil Classification:

Particle Size Distribution AS1289 3.6.1		Hydrometer Analysis AS1289.3.6.3	
Sieve Size	% Passing	Sieve Size	% Passing
150 mm	100	0.074 mm	10
75 mm	100	0.052 mm	9
53 mm	100	0.037 mm	7
37.5 mm	100	0.026 mm	7
26.5 mm	100	0.019 mm	6
19.0 mm	100	0.014 mm	5
13.2 mm	100	0.010 mm	5
9.5 mm	100	0.007 mm	4
6.7 mm	100	0.005 mm	4
4.75 mm	100	0.003 mm	3
2.36 mm	99	0.002 mm	3
1.18 mm	97		
0.6 mm	92		
0.425 mm	88		
0.3 mm	81		
0.15 mm	41		
0.075 mm	11		

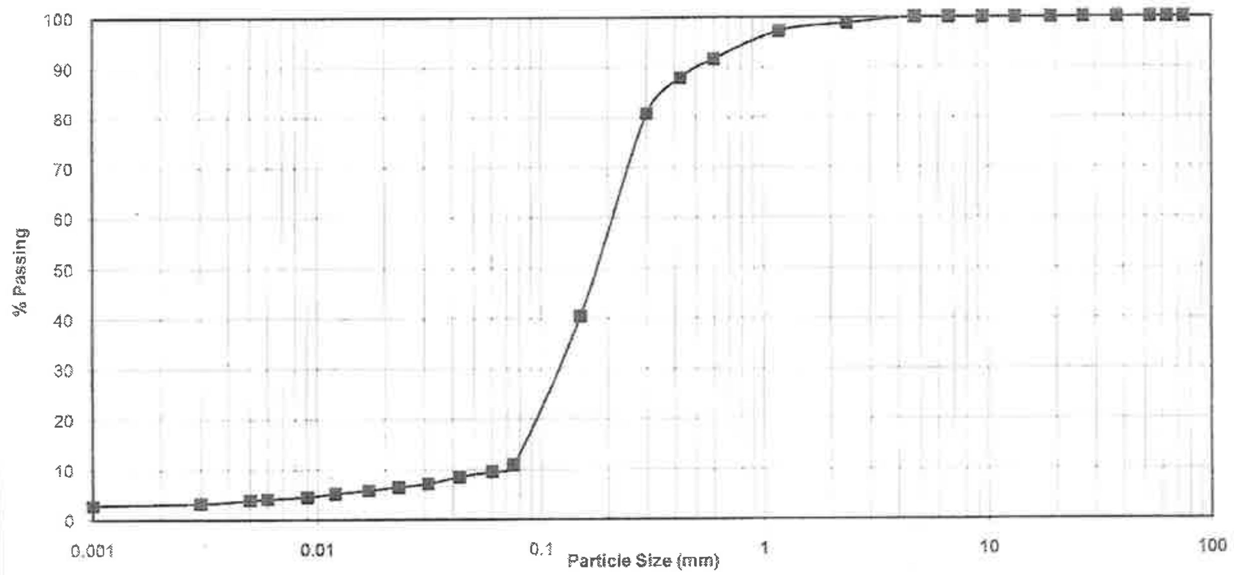
Consistency Limits and Moisture Content

Test		Method	Result	Spec.
Liquid Limit	%	AS1289 3.1.2	ND	
Plastic Limit	%	AS1289 3.2.1	ND	
Plasticity Index	%	AS1289 3.3.1	ND	
Linear Shrinkage	%	AS1289 3.4.1	ND	
Moisture Content	%	AS1289 2.1.1	ND	

Sample History: Air Dried
Preparation Method: Dry sieved
Crumbling / Curling of linear shrinkage: No
Linear shrinkage mould length: 250 mm
ND = not determined NO = not obtainable NP = non plastic

Moisture / Dry Density Relationship AS 1289 5.1.1
Maximum Dry Density: t/m^3
Optimum Moisture Content: %

Notes on Hydrometer Test
Pretreated for salt — Measured Particle Density - 2.70 g/cm^3
Type of hydrometer - ASTM — Type of dispersion - Mechanical



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Golder Associates Pty Ltd
84 Guthrie St OBSORNE PARK WA 6017

Soil Particle Density Report

Client:	Centrex	Date:	19/8/11
		Report No:	11-218
Project:	Port EIA Approvals	Job No:	107661001
Location:	Lipson	Sheet No:	8 of 8

Test Procedure: AS 1289 - 3.5.1

Laboratory Sample No.	11441501
Sample Identification	D3 NTH MB, 11641313
Material Description	Grey SAND
The Average Apparent Particle Density of The Fraction Passing 2.36mm Fraction (g/cm^3)	2.70
The Average Apparent Particle Density of The Fraction Retaine 2.36mm Fraction (g/cm^3)	NA
The Soil Particle Density of The Total Sample (g/cm^3)	2.70

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Approved Signatory:
Paul Hamilton, Laboratory Manager

b) Sediment Chemistry Data

Golder Associates

Centrex Marine Sediment Characteristics

Location_Code	Field_ID	Sampled_Date_Time	SDG	SampleCode	Heavy Metals											Heavy Metals (Organo)
					Aluminium	**Arsenic**	**Cadmium**	**Chromium**	**Copper**	**Iron**	**Lead**	**Manganese**	**Mercury**	**Nickel**	**Zinc**	**Tributyltin**
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
LOR					50	1	0.1	1	1	50	1	10	0.01	1	1	0.0005
ANZECC Table 3.5.1 ISQG High						**70**	**10**	**370**	**270**		**220**		**1**	**52**	**410**	**0.07**
ANZECC Table 3.5.1 ISQG Low (Trigger Value)						**20**	**1.5**	**80**	**65**		**50**		**0.15**	**21**	**200**	**0.005**
NAGD 2009 Table 2						**20**	**1.5**	**80**	**65**		**50**		**0.15**	**21**	**200**	**0.009**
D1 MB 1	D1 MB 1	8/07/2011	ES1114945	ES1114945002	850	1.05	<0.1	5.9	<1	1,330	<1	12	<0.01	9	1.6	<0.0005
D1 MB2	D1 MB2	8/07/2011	ES1114945	ES1114945003	1660	1.88	<0.1	6.7	<1	1830	<1	15	<0.01	<1	1.7	
D1 NS 1	D1 NS 1	9/07/2011	ES1114945	ES1114945001	260	<1	<0.1	1.2	<1	300	<1	<10	<0.01	<1	1	<0.0005
D3 Nth MB	D3 Nth MB	9/07/2011	ES1114945	ES1114945004	1140	2.53	<0.1	7	<1	1990	1.1	13	<0.01	1	1.7	<0.0005
D3 NTH NS	D3 NTH NS	12/07/2011	ES1115404	ES1115404001	410	<1	<0.1	1.7	<1	460	<1	<10	<0.01	<1	1.1	<0.0005
D3 Sth Mb	D3 Sth Mb	9/07/2011	ES1114945	ES1114945005	850	1.66	<0.1	5.3	<1	1320	<1	<10	<0.01	<1	1.1	<0.0005
D3 STH NS	D3 STH NS	12/07/2011	ES1115404	ES1115404002	450	<1	<0.1	1.8	<1	470	<1	<10	<0.01	<1	<1	<0.0005
D5 Nth Mb	D5 Nth Mb	10/07/2011	ES1114945	ES1114945006	680	<1	<0.1	3.3	<1	860	<1	<10	<0.01	<1	1.2	
D5 Sth Mb	D5 Sth Mb	10/07/2011	ES1114945	ES1114945007	870	2.19	<0.1	5.4	<1	1720	1	<10	<0.01	<1	1.1	
D6 Nth Mb	D6 Nth Mb	8/07/2011	ES1114945	ES1114945008	840	3.39	<0.1	5.8	<1	2310	1.1	<10	<0.01	<1	1.1	<0.0005
D6 NTH NS	D6 NTH NS	11/07/2011	ES1115404	ES1115404003	1050	<1	<0.1	3.5	1.1	1770	<1	17	<0.01	1.5	2.8	<0.0005
D6 Sth Mb	D6 Sth Mb	10/07/2011	ES1114945	ES1114945009	930	2.8	<0.1	6.2	<1	1710	<1	13	<0.01	<1	1.3	<0.0005
D6 STH NS	D6 STH NS	12/07/2011	ES1115404	ES1115404004	500	<1	<0.1	2.1	<1	540	<1	<10	<0.01	<1	<1	<0.0005

Location_Code	MAH						
	Benzene	**Ethylbenzene**	**Toluene**	**Total BTEX (QLD EPA 1999 Draft)**	**Xylenes (m & p)**	**Xylene (o)**	**Total MAHs**
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
LOR	0.2	0.2	0.2		0.2	0.2	
ANZECC Table 3.5.1 ISQG High							
ANZECC Table 3.5.1 ISQG Low (Trigger Value)							
NAGD 2009 Table 2							
D1 MB 1							
D1 MB2							
D1 NS 1							
D3 Nth MB							
D3 NTH NS	<0.2	<0.2	<0.2	<1[#1]	<0.2	<0.2	<1[#1]
D3 Sth Mb							
D3 STH NS	<0.2	<0.2	<0.2	<1[#1]	<0.2	<0.2	<1[#1]
D5 Nth Mb							
D5 Sth Mb							
D6 Nth Mb							
D6 NTH NS	<0.2	<0.2	<0.2	<1[#1]	<0.2	<0.2	<1[#1]
D6 Sth Mb							
D6 STH NS	<0.2	<0.2	<0.2	<1[#1]	<0.2	<0.2	<1[#1]

Location_Code	PAH															
	Acenaphthene	**Acenaphthylene**	**Anthracene**	**Benz(a)anthracene**	**Benzo(a)pyrene**	**Benzo(b)fluoranthene**	**Benzo(g,h,i)perylene**	**Benzo(k)fluoranthene**	**Chrysene**	**Dibenz(a,h)anthracene**	**Fluoranthene**	**Fluorene**	**Indeno(1,2,3-c,d)pyrene**	**Naphthalene**	**Phenanthrene**	**Perylene**
	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
LOR	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.004	0.005	0.004	0.004
ANZECC Table 3.5.1 ISQG High	**0.5**	**0.64**	**1.1**	**1.6**	**1.6**				**2.8**	**0.26**	**5.1**	**0.54**		**2.1**	**1.5**	
ANZECC Table 3.5.1 ISQG Low (Trigger Value)	**0.016**	**0.044**	**0.085**	**0.261**	**0.43**				**0.384**	**0.063**	**0.6**	**0.019**		**0.16**	**0.24**	
NAGD 2009 Table 2																
D1 MB 1	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D1 MB2	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D1 NS 1	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D3 Nth MB	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D3 NTH NS	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D3 Sth Mb	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D3 STH NS	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D5 Nth Mb	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D5 Sth Mb	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D6 Nth Mb	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D6 NTH NS	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D6 Sth Mb	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
D6 STH NS	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004

Statistical Summary

	Aluminium	Arsenic	Cadmium	Chromium	Copper	Iron	Lead	Manganese	Mercury	Nickel	Zinc	Tributyltin
Number of Results	13	13	13	13	13	13	13	13	13	13	13	10
Number of Detects	13	7	0	13	1	13	3	5	0	3	11	0
Minimum Concentration	260	<1	<0.1	1.2	<1	300	<1	<10	<0.01	<1	<1	<0.0005
Minimum Detect	260	1.05	ND	1.2	1.1	300	1	12	ND	1	1	ND
Maximum Concentration	1,660	3.39	<0.1	7	1.1	2,310	1.1	17	<0.01	9	2.8	<0.0005
Maximum Detect	1,660	3.39	ND	7	1.1	2,310	1.1	17	ND	9	2.8	ND
Average Concentration	807	1.4	0.05	4.3	0.55	1,278	0.63	8.5	0.005	1.3	1.3	0.00025
Median Concentration	850	1.05	0.05	5.3	0.5	1,330	0.5	5	0.005	0.5	1.1	0.00025
Standard Deviation	367	1	0	2.1	0.17	677	0.25	4.7	0	2.3	0.59	0
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0

	Benzene	Ethylbenzene	Toluene	Total BTEX (QLD EPA 1999 Draft)	Xylenes (m & p)	Xylene (o)	Total MAHs
Number of Results	4	4	4	4	4	4	4
Number of Detects	0	0	0	0	0	0	0
Minimum Concentration	<0.2	<0.2	<0.2	<1	<0.2	<0.2	<1
Minimum Detect	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<0.2	<0.2	<0.2	<1	<0.2	<0.2	<1
Maximum Detect	ND	ND	ND	ND	ND	ND	ND
Average Concentration	0.1	0.1	0.1	0.5	0.1	0.1	0.5
Median Concentration	0.1	0.1	0.1	0.5	0.1	0.1	0.5
Standard Deviation	0	0	0	0	0	0	0
Number of Guideline Exceedances	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0

	Acenaphthene	Acenaphthylene	Anthracene	Benz(a)anthracene	Benzo(a)pyrene	Benzo(b)fluoranthene	Benzo(g,h,i)perylene	Benzo(k)fluoranthene	Chrysene	Dibenz(a,h)anthracene	Fluoranthene	Fluorene	Indeno(1,2,3-c,d)pyrene	Naphthalene	Phenanthrene	Perylene
Number of Results	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	13
Number of Detects	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Minimum Concentration	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
Minimum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Maximum Concentration	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.004	<0.005	<0.004	<0.004
Maximum Detect	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Average Concentration	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.0025	0.002	0.002
Median Concentration	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.002	0.0025	0.002	0.002
Standard Deviation	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Comments

#1 ESDAT Combined. Some Analytes are missing from this Combined Compound.

#2 ESDAT Combined with Non-Detect Multiplier of 0.5.

#3 ESDAT Combined.

							PAH-Others					Sample Quality Parameters			Total Petroleum Hydrocarbons						
					Pyrene	PAH (Sum of Common 16 PAHs - Lab Reported)	High Molecular Weight PAHs (ANZECC 3.5.1)	Low Molecular Weight PAHs (ANZECC 3.5.1)	2-Methylnaphthalene	Benzo(e)pyrene	Coronene	Moisture	pH (Lab)	Magnesium	TPH C 6 - C 9 Fraction	TPH C10 - C14 Fraction	TPH C15 - C28 Fraction	TPH C29-C36 Fraction	TPH+C10 - C36 (Sum of total) (Calculated)	TPH+C10 - C36 (Sum of total) (Lab Reported)	C6 - C10 Fraction
					mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	%	pH	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg	mg/kg
LOR					0.004	0.004			0.005	0.004	0.005	1	0.1	10	3	3	3	5		3	3
ANZECC Table 3.5.1 ISQG High					2.6	45	9.6	3.16													
ANZECC Table 3.5.1 ISQG Low (Trigger Value)					0.665	4	1.7	0.552													
NAGD 2009 Table 2						10														550	
Location_Code	**Field_ID**	**Sampled_Date_Time**	**SDG**	**SampleCode**																	
D1 MB 1	D1 MB 1	8/07/2011	ES1114945	ES1114945002	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	29.7	8.8	480	<3	<3	14	5	20.5[#2]		<3
D1 MB2	D1 MB2	8/07/2011	ES1114945	ES1114945003	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	36.2	8.8	480	<3	<3	7	<5	11[#2]		<3
D1 NS 1	D1 NS 1	9/07/2011	ES1114945	ES1114945001	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	19.1	8.9	300	<3	<3	7	<5	11[#2]		<3
D3 Nth MB	D3 Nth MB	9/07/2011	ES1114945	ES1114945004	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	29	8.8	460	<3	<3	14	8	23.5[#2]		<3
D3 NTH NS	D3 NTH NS	12/07/2011	ES1115404	ES1115404001	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	20.1	8.8	310	<3	<3	4	<5	8[#2]	4	
D3 Sth Mb	D3 Sth Mb	9/07/2011	ES1114945	ES1114945005	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	28	8.8	500	<3	<3	13	<5	17[#2]		<3
D3 STH NS	D3 STH NS	12/07/2011	ES1115404	ES1115404002	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	19.8	8.9	300	<3	<3	<3	<5	<11[#3]	<3	
D5 Nth Mb	D5 Nth Mb	10/07/2011	ES1114945	ES1114945006	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	24	8.8	450	<3	<3	17	<5	21[#2]		<3
D5 Sth Mb	D5 Sth Mb	10/07/2011	ES1114945	ES1114945007	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	30.1	8.6	510	<3	<3	19	8	28.5[#2]		<3
D6 Nth Mb	D6 Nth Mb	8/07/2011	ES1114945	ES1114945008	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	27.6	8.8	450	<3	<3	16	6	23.5[#2]		<3
D6 NTH NS	D6 NTH NS	11/07/2011	ES1115404	ES1115404003	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	22	8.8	320	<3	<3	6	<5	10[#2]	6	
D6 Sth Mb	D6 Sth Mb	10/07/2011	ES1114945	ES1114945009	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	28.5	8.8	480	<3	<3	23	9	33.5[#2]		<3
D6 STH NS	D6 STH NS	12/07/2011	ES1115404	ES1115404004	<0.004	<0.004	<0.024[#3]	<0.03[#3]	<0.005	<0.004	<0.005	26.2	8.8	390	<3	<3	3	<5	7[#2]	3	
Statistical Summary																					
Number of Results					13	13	13	13	13	13	13	13	13	13	13	13	13	13	13	4	9
Number of Detects					0	0	0	0	0	0	0	13	13	13	0	0	12	5	12	3	0
Minimum Concentration					<0.004	<0.004	<0.024	<0.03	<0.005	<0.004	<0.005	19.1	8.6	300	<3	<3	<3	<5	7	<3	<3
Minimum Detect					ND	ND	ND	ND	ND	ND	ND	19.1	8.6	300	ND	ND	3	5	7	3	ND
Maximum Concentration					<0.004	<0.004	<0.024	<0.03	<0.005	<0.004	<0.005	36.2	8.9	510	<3	<3	23	9	33.5	6	<3
Maximum Detect					ND	ND	ND	ND	ND	ND	ND	36.2	8.9	510	ND	ND	23	9	33.5	6	ND
Average Concentration					0.002	0.002	0.012	0.015	0.0025	0.002	0.0025	26	8.8	418	1.5	1.5	11	4.3	17	3.6	1.5
Median Concentration					0.002	0.002	0.012	0.015	0.0025	0.002	0.0025	27.6	8.8	450	1.5	1.5	13	2.5	17	3.5	1.5
Standard Deviation					0	0	0	0	0	0	0	5	0.071	82	0	0	6.8	2.6	8.9	1.9	0
Number of Guideline Exceedances					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Number of Guideline Exceedances(Detects Only)					0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Comments

#1 ESDAT Combined. Some Analytes are missing from this Combined Compound.
#2 ESDAT Combined with Non-Detect Multiplier of 0.5.
#3 ESDAT Combined.

APPENDIX E

Water Quality Results

a) Water Quality Meter Results

In-situ water quality readings

Location		Water Quality Meter Aquaread Temp (°C)	Salinity (‰)	DO (mg/l)	pH (no units)	Turbidity (NTU)	Secchi Disc Distance (m)
South Australian EPP (2003)		**-**	**-**	**> 6**	**-**	**10**	
ANZECC (2000) Table 3.3.8 -3.3.9		**-**	**-**	**-**	**8 - 8.5**	**0.5-10***	
Distance 6 North Near Shore	Rep 1	13.1	30.00	10.16	7.98	0	11
	Rep 2	13.1	30.00	10.15	7.98	0	11
	Rep 3	13.1	30.00	10.16	7.98	0	11
Distance 6 North Mid Benthic	Rep 1	13.1	30.6	10.07	8.11	0	11
	Rep 2	13.1	30.6	10.07	8.11	0	11
	Rep 3	13.1	30.6	10.07	8.11	0	11
Distance 5 North Near Shore	Rep 1	13.2	35.8	9.65	8.07	0	10
	Rep 2	13.2	35.8	9.65	8.07	0	10
	Rep 3	13.2	35.8	9.65	8.07	0	10
Distance 5 North Mid Benthic	Rep 1	13.2	35.5	9.70	8.24	0	10
	Rep 2	13.2	35.5	9.70	8.24	0	10
	Rep 3	13.2	35.5	9.70	8.24	0	10
Distance 3 North Near Shore	Rep 1	13.3	35.9	9.6	8.16	0	11
	Rep 2	13.3	35.9	9.6	8.16	0	11
	Rep 3	13.3	35.9	9.6	8.16	0	11
Distance 3 North Mid Benthic	Rep 1	13.2	35.8	9.8	8.26	0	11
	Rep 2	13.2	35.8	9.8	8.26	0	11
	Rep 3	13.2	35.8	9.8	8.26	0	11
Distance 1 Near Shore	Rep 1	13.2	36.84	9.52	7.90	0	11
	Rep 2	13.2	36.84	9.52	7.90	0	11
	Rep 3	13.2	36.84	9.52	7.90	0	11
Distance 1 Mid Benthic	Rep 1	13.2	37.11	9.70	8.10	0	11
	Rep 2	13.2	37.11	9.70	8.10	0	11
	Rep 3	13.2	37.11	9.70	8.10	0	11

Golder Associates

In-situ water quality readings

		Water Quality Meter Aquaread					Secchi Disc
Location		**Temp (^{o}C)**	**Salinity (‰)**	**DO (mg/l)**	**pH (no units)**	**Turbidity (NTU)**	**Distance (m)**
South Australian EPP (2003)		**-**	**-**	**> 6**	**-**	**10**	
ANZECC (2000) Table 3.3.8 -3.3.9		**-**	**-**	**-**	**8 - 8.5**	**0.5-10***	
Distance 3 South Near Shore	Rep 1	13.2	36.84	9.60	8.00	0	11
	Rep 2	13.2	36.84	9.60	8.00	0	11
	Rep 3	13.2	36.84	9.60	8.00	0	11
Distance 3 South Mid Benthic	Rep 1	13.2	37.01	9.81	8.00	0	11
	Rep 2	13.2	37.01	9.81	8.00	0	11
	Rep 3	13.2	37.01	9.81	8.00	0	11
Distance 5 South Near Shore	Rep 1	13.2	37.60	9.91	8.25	0	11
	Rep 2	13.2	37.60	9.91	8.25	0	11
	Rep 3	13.2	37.60	9.91	8.25	0	11
Distance 5 South Mid Benthic	Rep 1	13.2	38.00	9.78	7.98	0	11
	Rep 2	13.2	38.00	9.78	7.98	0	11
	Rep 3	13.2	38.00	9.78	7.98	0	11
Distance 6 South Near Shore	Rep 1	13.3	37.65	9.71	8.26	0	11
	Rep 2	13.3	37.65	9.71	8.26	0	11
	Rep 3	13.3	37.65	9.71	8.26	0	11
Distance 6 South Mid Benthic	Rep 1	13.3	38.10	9.95	8.11	0	11
	Rep 2	13.3	38.10	9.95	8.11	0	11
	Rep 3	13.3	38.10	9.95	8.11	0	11

Note : * - Higher values are representative of estuarine waters

b) Water Chemistry Data

Laboratory Results and Screening levels

	pH			EC (µS/cm)			Nitrite (mg/l)		Nitrate (mg/l)		Iron (mg/l)		Phosphorus (mg/l)		Chlorophyll-a (µg/l)	
	ALS M	ALS S	mgt	ALS M	ALS S	mgt	ALS S	mgt	ALS S	mgt	ALS M	mgt	ALS M	mgt	ALS M	mgt
Limit Of Reporting (LOR)	0.01	0.01	0.1	1	1	10	0.002	0.02	0.002	0.02	0.50	0.05	0.01	0.05	1	5
South Australian EPP (2003)		-			-		-		-		-		0.5		-	
ANZECC (2000) Table 3.4.1		-			-		-		-		-		-		-	
ANZECC (2000) Table 3.3.8 -3.3.9		8.0 - 8.5			-		50		50		-		0.1		1	
Distance 1 Near Shore 1	8.06	7.83		60300	55200		<0.002		0.021		<0.50		0.34		<1	
Distance 1 Near Shore 2	8.08	7.90		63400	55200		<0.002		0.018		<0.50		0.26		4	
Distance 1 Near Shore 3			8.2			56000		<0.02		<0.02		< 0.05		<0.05		<5
Distance 3 North Near Shore	8.09	8.04		63000	55100		<0.002		0.018		<0.50		0.34		<1	
Distance 3 South Near Shore	8.11	8.06		60800	55200		<0.002		0.018		<0.50		0.16		6	
Distance 5 North Near Shore	8.12	8.07		60600	55300		<0.002		0.026		<0.50		0.26		<1	
Distance 5 South Near Shore	8.12	8.08		61200	55200		<0.002		0.024		<0.50		0.10		6	
Distance 6 North Near Shore	8.10	8.15		62000	54800		<0.002		0.030		<0.50		0.15		<1	
Distance 6 South Near Shore	8.12	8.08		60800	55200		<0.002		0.017		<0.50		0.20		4	
Distance 1 Mid Benthic	8.09	8.07		60400	55100		<0.002		0.021		<0.50		0.25		<1	
Distance 3 North Mid Benthic	8.08	8.07		61100	55100		<0.002		0.023		<0.50		0.26		2	
Distance 3 South Mid Benthic	8.12	7.88		63000	55300		<0.002		0.028		<0.50		0.25		<1	
Distance 5 North Mid Benthic	8.12	8.04		60200	55000		<0.002		0.016		<0.50		0.34		3	
Distance 5 South Mid Benthic	8.13	8.06		57100	55100		<0.002		0.034		<0.50		0.16		<1	
Distance 6 North Mid Benthic	8.12	8.07		61800	55000		<0.002		0.017		<0.50		0.15		2	
Distance 6 South Mid Benthic	8.11	7.99		60600	55300		<0.002		0.028		<0.50		0.09		<1	

APPENDIX F

Limitations

LIMITATIONS

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